Legionella eliminated with no 'side-effects'

Stuart Watkin BEng (Hons) MSc CEng MIHEEM, head of Engineering Compliance & Energy at North Tees & Hartlepool NHS Foundation Trust, reports on a recent six-month trial, at the Trust's University Hospital of North Tees, of a new saline-based disinfection system for combating *Legionella*. The system, from Danish company, DCW, has reportedly proven highly effective in keeping the water system at the test site, the hospital's North Wing, *Legionella*-free, impressing both estates and facilities/engineering personnel, and an independent consultant, with both its efficacy and lack of "side-effects".

Stuart Watkin.

Legionella control relies on a series of measures that are well established in HSE guidance L8 and NHS HTM-04. Risk assessments of our sites and buildings direct the level of measures and corrective actions that we are required to take, but can you be sure that you are doing enough? There are many companies who will say "no", and push products and scaremonger. It is well established that *Legionella* is a naturally-occurring bacteria, and if you test you will undoubtedly find some level of contamination at some point; the big risk is the potential fall-out if a patient, visitor, or member of staff, becomes infected. There are many highly publicised failures; hence good independent advice is vital.

At North Tees & Hartlepool NHS Foundation Trust we tendered for a company to provide boiler water treatment and professional water hygiene support. Alan Edwards and Partners (see also panel page 43) was selected in 2008, and, since that time, has completed risk assessments across the Trust, and arranged independent testing of water samples. It was pleasing to note that our control measures and monitoring regime have had a positive effect, with most areas being rated as "Low Risk", albeit with a few corrective actions following alteration works.

One key area of concern

However, in spite of an overall good report, there was one particular area of concern – the hospital's North Wing had originally been a six-storey maternity block with a high water demand; however the building subsequently became vacant, and at one point was earmarked for demolition. After a period when it stood empty, various services gradually moved in, and the building is once again fully occupied. However, the water demand is now only a fraction of the building's design load, and the infrastructure is extensive, with approximately 50 risers – the consequence being that some areas had poor flow regimes. Following the initial risk assessment, work had been started to try to improve circulation and physically remove unwanted risers and "deadlegs", but, despite some successes, the problem had not been completely resolved.

Key issues discussed

Following further approaches from several companies offering a range of products for water treatment and *Legionella* control, associate director of Estates & Facilities, Peter Mitchell (as a freshly trained

The DWC generator is located in the cold water boost room of the hospital's main boiler house.

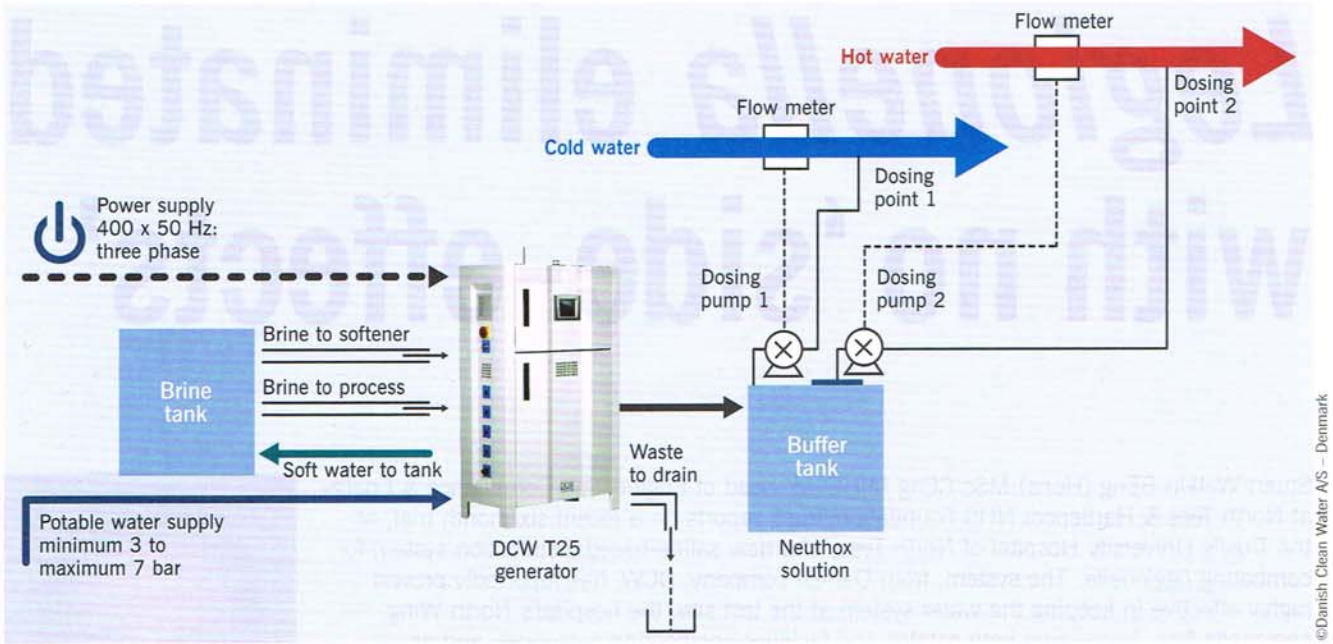

Figure 1. The DCW disinfection system in use at the University Hospital of North Tees.

Responsible Person), called a meeting to discuss our *Legionella* controls with Alan Edwards. It was agreed that:

- The control measures in place were good, with regular flushing.
- The actions from risk assessments were being completed.
- Building energy management systems showed good temperature regimes in virtually all areas of the hospital.
- A CQC audit had established that domestic staff were aware of their *Legionella* responsibilities, and manual flushing of little-used outlets was taking place.
- Six-monthly testing of the water tanks gave excellent drinking water results.
- Random TVCs (total viable counts) and tests for *Pseudomonas* presented very good results.

It was agreed that the risk was being appropriately managed as per HTMs, and there was some scepticism as to whether any further control measures would enhance the status, especially as such measures would require both capital investment, and increased revenue expenditure. We had to ask ourselves whether we were undertaking all reasonable practicable means to reduce the risk?

The first step

As a first step to assess the situation, it was determined that we would undertake some level of testing to establish if there was a distinct problem within the building. The initial results indicated that there was a higher than expected level of biofilm that potentially presented a greater risk of *Legionella* colonisation. Subsequent *Legionella* tests showed action levels of *Legionella* sg2-14, and a few minor levels of *Legionella* sg1. It was thus conceded that some enhancements to the control measures might be appropriate, but what type of product should we choose? We had seen a variety of products at seminars, read publications and product literature, and been approached by sales teams. We had issues regarding the chemicals used, technical support, and possible quality issues regarding taste and discolouration of water supplied to patients. There was also the question of cost, with both capital investment and ongoing revenue expenditure under tight financial constraints.

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At about this time, DCW Technology was endeavouring to sound out potential NHS clients for its disinfection system. After meeting with the company, and reviewing data, it was decided to complete a six-month trial. The performance criteria formed a verification list as follows:

- Reliability and simplicity of dosing plant.
- Running costs to meet predicted levels.
- Reliability, precision, and consistency, of chlorine dosing into the system.
- The ability to achieve 0.3 ppm chlorine at draw-off points without overdosing at injection point.
- Consistent achievement of *Legionella*-free conditions at selected (from the previous positive findings and perceived potential across the diverse hospital site) strategic sampling points.
- The ability to maintain the quality of drinking water throughout the system, so that it remained potable and in specification, and that there were no complaints about taint, taste, colouration, or clarity.
- Any deviations must be addressed

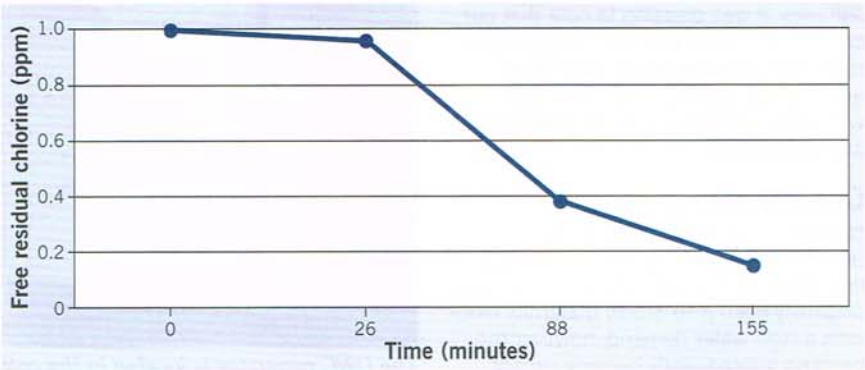

Figure 2: Free residual chlorine reserves (Neuthox) in relation to time (60°Celsius).

During the trial, it became apparent that the domestic cold water system 'cleaned up' very quickly

promptly, the reasons investigated, and their impact explained.

The DCW system

The DCW disinfection system produces a liquid through the process of electrolysis of brine (salt water). The cell contains a unique membrane which ensures separation of the fluids during the manufacturing process. The strength of the brine (salinity) is carefully controlled to ensure optimum production of disinfection agents, and to minimise any salt residue in the finished product. By carefully controlling the flow, the salinity, and the power, the generators can ensure a consistent product in terms of both pH value and free chlorine.

The disinfection liquid produced differs from typical brine electrolysis products because it is has enhanced biofilm removal properties compared to traditional Hypochlorous acid. The disinfection liquids show high redox potential, and a marked reduction in disinfection by-product production.

Independent laboratory analysis of disinfection shows electrolysed membrane saline solutions (Neuthox) to be an extremely effective legionellocide. The laboratory results indicate that Neuthox dosed at 0.5 ppm would be 22 times more efficient at destroying *Legionella pneumophila* than 0.67 ppm HOCL (Hypochlorous acid – chlorine derived from sodium hypochlorite).

Typical multi-occupancy building system

The water system at University Hospital of North Tees is typical of a large, multiple occupancy building. Mains water enters the site via a riser located in the booster plant room, and then feeds a cold water storage tank (holding approximate 200 m^3) housed above the calorifier room. The outlet from the cold water tank feeds a triplex booster set, which increases the water pressure to 4.5 Bar. The boosted water supply feeds the hospital cold water system, and tops up the domestic hot water system. Two large calorifiers were originally installed to supply hot water to the re-circulating domestic hot water system; subsequently this has been changed to reduce the amount of hot water storage, with one of the calorifiers replaced with a multiple plate heat exchanger system fed from boiler steam and CHP waste heat.

The DCW generator, brine tank, and buffer tank (see Fig. 1), were located in the plant room adjacent to the triplex booster set. Proportional dosage was achieved by installing a thermodynamic flow sensor in the distribution pipework from the triplex booster set.

The injection fitting was installed into the supply pipework to the booster set. The following factors determined the injection fitting location:

- Water supply fittings regulations.
- Placement to allow mixing of Neuthox and water prior to distribution to the rest of the system.
- Proximity to DCW generator.

Sampling point installed

In addition to the injection fitting and flow sensor, a sampling point was installed into the distribution side of the triplex booster set to allow continuous monitoring of the Free Residual Chlorine (FRC) levels achieved, which are then data logged (Fig. 2). The initial set-up allowed a low level dose of Neuthox into the cold water system to supplement the residual chlorine from the water authority.

In service

Following commissioning, as to be expected, there were a few teething problems for the plant, which was operating in a totally new environment, with specific needs, but DCW was quick to respond, making minor modifications and enhancing filtration as required.

During the trial, it became apparent that the domestic cold water system "cleaned up" very quickly. Checks of chlorination levels showed that we were achieving 75% of dosed level at terminal points within one month. TVC and *Legionella* tests at the end of the first month were negative. However, progress within the domestic hot water system was

Consultant's footnote:
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Legionella is a widespread, and naturally-occurring bacteria, so it was not altogether surprising to read that approximately 70% of hospitals which participated in a recent survey by the Health Protection Agency were found to have some level of *Legionella pneumophila* at points in their domestic hot water services.

Normally this can be controlled to the kind of minimal levels acceptable to the authors of the HSE's "L8" (Control of *Legionella*), and the NHS's HTM-04, by control of the hot and cold water temperatures, and by routine flushing, so as to avoid creating inadvertent "deadlegs". However, in this particular case, where the system was comprehensively oversized, and water flows were relatively low, the chlorine initially contained within the mains water supply dissipated, and cold water temperatures tended to rise to that in the building, leaving such sections vulnerable to the development of biofilms, notorious for harbouring bacteria, including *Legionella*, and thereby allowing them to proliferate in the film, eventually contaminating the water supply. Flushing of such areas reduced the problem, but did not completely solve it.

'Extreme care' required

When considering chemical systems of *Legionella* control for domestic water services, extreme care is necessary, particularly so if, as in this instance, the water is also for potable use, and is used by vulnerable patients. A study of the various chemical treatment options currently on the market convinced us that the most "natural" protective approach would be to "refresh the chlorine level", i.e. to replenish the chlorine already present in the mains supply entering the hospital. Perusal of the specification of the DCW equipment reassured us that the system was intrinsically safe, using harmless materials (salt), and operating at low electrical voltage.

I already had experience elsewhere that chlorine, in the form of hypochlorous acid (obtained via sodium hypochlorite), is an effective biofilm remover when dosed continuously, even at levels as low as 0.5 ppm. However, I was prepared to assess the claims of DCW that the "Neuthox" produced by its unit would be an even more effective biofilm remover (while not being too vigorous), and a bonus with Neuthox was that the water pH would not be altered (unlike hypochlorite solutions), thereby avoiding the risk of promoting calcium carbonate scale formation.

As an independent observer of what was initially just a trial, I became impressed by the effectiveness of the system coupled with the (DCW-predicted) lack of any side-effects, such as taste, odour, or alteration of the water chemistry. The previous persistent (albeit low) levels of *Legionella* are no longer present, as evidenced by the continued routine "verification" testing at strategic sampling points.

not as evident, and it was recognised that something extra would be required. This had been discussed as an option ahead of the trial, but had not been followed up, as it was thought that, when the calorifiers operate conventionally (at or above 60°C), there would be a tendency for oxidants within the make-up water to be lost by either gassing off, or by conversion back to basic elements. The calorifiers should act as a barrier to the dispersal of any pathogenic material in the hot water system.

Protected by biofilm

Testing on the cold water system ceased in August, following further satisfactory results, so that all efforts could be concentrated on the DHW system. Following a period of testing and analysis, it became apparent that the biocidal effect of the Neuthox was not being carried through the calorifiers and into the rest of the domestic hot water system, as expected. It was determined that the traces of *Legionella* were localised to specific areas in the hospital (notably North Wing), potentially protected in biofilm beyond the reach of the Neuthox residual. The FRC analysis of these outlets, coupled with bacterial tests, indicated that the Neuthox was not present in the domestic hot water systems. One outlet was actually deteriorating as the demand for DHW in that area dropped, and an engineered solution was required.

A study was conducted to check how much FRC was present following the calorifiers; the results indicated that negligible amounts were present post-calorifier.

Domestic hot water dosage

An injection fitting was identified beyond the calorifier with a secondary pump and dosage system installed. The initial set-up was to constantly dose the hot water system with a low level of Neuthox to try and remove the biofilm over a period of time, with the intention being to make the dosage proportional to the domestic hot water system make-up supply.

Slowly the chlorine levels within the domestic hot water system began to increase, indicating a removal of bacterial matter, until eventually consistent FRC reserves were established at the selected strategic outlets. *Legionella* analysis of the system indicated a reduction in bacterial levels until eventually all outlets recorded negative results.

Project evaluation

The Trust's verification criteria for the water treatment plant were expanded to form a tender specification document; the key elements identified are listed as follows:

The DCW generator incorporates a self-diagnostic system that identifies when performance is falling, and will stop production of Neuthox and perform a cleaning cycle.

The system and process must:

- Produce an effective Legionellocide.
- Provide thermal stability data.
- Be completely safe.
- Impart no odour or colour to the treated water.
- Gradually remove biofilm.
- Have minimal impact on the chemical composition of incoming water.
- The chemicals used to generate the sterilant should be intrinsically safe, and not present a chemical or manual handling risk.

The plant should be:

- Low maintenance and reliable.
- Automated dosing should be incorporated, to avoid under- or overdosing, with an independent monitoring system that can be interrogated by the Trust.
- Demonstrate reliable, precise, and consistent dosing into the system, and be affordable in terms of running costs.

DCW responded to the tender by referencing the three key elements of the proposed system:

- The characteristics of the liquid disinfectant.
- The DCW generator and the proportional dosage system.
- System reliability and running costs.

Neuthox – liquid disinfectant

In addition to the independent laboratory analysis of the electrolysed saline disinfectants, which has shown Neuthox to be an extremely effective legionellocide, the trial preceding the tender evaluation of the equipment ably demonstrated the ability of Neuthox to control and remediate *Legionella* in a large dynamic water distribution system.

The rapid increase in the reserves of Neuthox at the sentinel outlets relative to the dosage levels in the domestic cold water system gave clear indications that the bacterial loading potentially in biofilm in the cold water distribution system had been removed and controlled.

Following the installation of the supplementary dosage point in the hot water system, rapid reductions in the detectable levels of *Legionella* were observed; subsequently *Legionella* tests have indicated *Legionella*-free conditions. These on-site results are supported by research carried out at the University of Bonn, which demonstrated the ability of electrolysed (membrane) saline solutions to be effective at removing large concentrations (1.45 x 106 cfu/cm^2) of biofilm over a period of 37 days at dosage levels recommended for potable water disinfection. The results indicated that biofilm removal occurs in a gradual manner, thereby reducing the risk of large pieces blocking filters, valves, and other water service equipment.

Compliance with specifications

The effect on the wholesomeness and chemical composition of the water to be treated were of paramount importance to the Trust when selecting the continuous disinfectant system, especially with regard to odour and discolouration. In addition to being registered with the European biocide directive, the DCW disinfectant system shows full compliance with the European "DVGW W229" specification for treating potable water, and the treated water conforms to

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Prior to joining the NHS, he was an Aircraft Engineering Officer in the RAF for 12 years, before leaving to complete an MSc in Oil & Gas Engineering. After three years in the oil industry, in drilling operations, he returned to an engineering management role as hospital engineer in 2005.

Since then, he has project-managed numerous capital-funded schemes relating to compliance with HTMs and HSE guidance, while continually looking to enhance the quality of the infrastructure and save energy wherever possible.

the standards set out in the European council document EN98/83/EC – "Water intended for human consumption".

The installation complies with Water Supply (Water fittings regulations) 1999 and BS EN 15848:2010 – "Water conditioning equipment inside buildings".

The only changes to the chemical composition will obviously be an increase in the chlorine level, and a very small increase in sodium chloride <3.5 mg/L content of the mains water. Neuthox is essentially pH neutral, so will not alter the pH of the incoming water. The Hydro soft salt tablets currently used on site require no specialist PPE, and are classified as non-hazardous according to EC directive 67/548/EEC. The tablets are packaged in 10 kilogram bags, so pose no manual handling risk.

DCW generator and proportional dosage system

The dosage of Neuthox is fully automated and, as previously mentioned, a flow sensor is located in the discharge pipe work from the mains water booster set. This flow sensor sends a 4-20 mA signal to a Grundfos microprocessor-controlled pump to ensure accurate, reactive, and proportional dosage. An independent analysis both samples and records the free chlorine in the boosted mains water supply, and this information is then stored in a video graphic data logger to allow the Trust to monitor levels and follow trends.

The standalone monitoring panel.

Dose monitoring/data logging

Analysis of the data logger shows that consistent levels have been maintained in the mains cold water system, with the only interruptions since installation having been attributable to a level probe fault, and some debris blocking the chlorine sensor during the early stages of the trial.

Reliability/running costs

The generators are assembled by SERITRONIC, a leading defence contractor whose QA system meets the exacting requirements of the defence industry, ensuring that all the units are built to the highest standards. The maintenance of the DCW system requires only simple tasks which can be performed on a quarterly basis; otherwise the DCW generator has a self-diagnostic system that identifies when performance is falling, and will stop production of Neuthox and perform a cleaning cycle. If this proves unsuccessful, the diagnostic system will alarm and notify the user that the system requires attention.

An analysis of running costs for the system, as fitted, demonstrated that only 14 kg of salt and 40 kWh of electricity would be required weekly in addition to the annual maintenance package.

The trial and tendered installation have proved a great success. Admittedly, the project has taken a little longer to achieve than originally anticipated, but the plant has proven to be reliable, and has performed consistently, and all interested parties have jointly achieved so much: we have renewed confidence in our water system, having learnt more about it and its peculiarities; DCW has had a stern test of its plant, and is now progressing successfully with further NHS work; and a further product can now be presented as a solution to *Legionella* control. The capital installation costs are similar to those of other products on the market, but the low operating costs and competitive maintenance charges certainly help when revenue budgets are so tight. +

DCW
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For Further Information and a Brochure please contact

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