Six thousand lessons 'learned the hard way'

Tom Makin BSc Hons, MWMSoc, CEO and chief consultant of Envirocloud, an independent water hygiene consultant and Authorising Engineer (Water) for NHS Trusts across the UK, reports on the results and lessons learned from his recent work collecting *Pseudomonas aeruginosa* samples from 14 hospital Trusts across the UK. Armed with these results, and trial data on new *Pseudomonas* detection and control technologies, he considers progress to date in controlling what he dubs 'this resolute and ubiquitous pathogen' in hospitals and other healthcare facilities.

It is hard to believe that it has been almost five years since I was asked to carry out the first independent validation reports for the majority of Northern Ireland's hospital Trusts following the fatal outbreaks of Pseudomonas aeruginosa in neonatal intensive care units. The outbreaks sparked the publication of the Health Technical Memorandum 04-01 Addendum: *Pseudomonas aeruginosa – advice for augmented care units*, and spawned the dawn of a new era in the monitoring and control of opportunistic nosocomial waterborne pathogens.
No longer is it acceptable to only sample for waterborne pathogens where we understand there may be an issue, as was the case with *Legionella*. Instead, a proactive water sampling regime for all augmented care outlets which have direct or indirect patient contact is advised every six months. Extensive resampling and remedial works are required at outlets that test positive for *P. aeruginosa.*

'Alarming virulence'

With its impressive resourcefulness, ability to develop resistance to multiple antibiotics, and alarming virulence among the immunosuppressed, nosocomial *P. aeruginosa* infections have been a problem for a long time. However, it is only relatively recently that we have truly begun to understand the crucial role that our hospital water systems play in the transmission of this opportunistic waterborne pathogen.

With data from over 6,000 *P. aeruginosa* samples that I have collected from 14 hospital Trusts across the UK, trial data of new *Pseudomonas* detection and control technologies, and my involvement with various Trusts as an Authorising Engineer (Water) and independent consultant, it is an appropriate time to review the findings from collection of the water samples, and to consider our progress in the control of this resolute and ubiquitous pathogen, with a view to better focusing our efforts.

A handwash basin used inappropriately for storage of used towels. Note the point-of-use filter fitted to prevent the release of Pseudomonas aeruginosa due to repeated colonisation of the outlet.

Persistent colonisation

In many cases, the data from which the following findings were derived were collected from hospital Trusts where *P. aeruginosa* colonisation had persisted, but was eventually brought under control through intensive remedial measures.

All samples were collected using aseptic techniques, into a wide mouth sterile container (Cribbar 500) containing sodium thiosulphate for neutralising oxidising biocides. The use of a wide mouth sample bottle permits outlets to be opened fully, which enables the scouring forces of flowing water to come into play, and thus produce a sample that is more likely to contain *P. aeruginosa* if it is present at the sampled outlet. Narrow-mouthed sample bottles do not readily facilitate the collection of representative samples.

The bottles used were also equipped with a double tamper-proof seal, and are fitted with a guard ring which prevents accidental contamination of the bottle top when removing the lid for sample collection. Up to 50% of people carry *P. aeruginosa* as a commensal microorganism on their skin, and so it is important to prevent cross-contamination of sample containers during sample collection.

All samples were placed immediately into chilled storage boxes (with temperatures of 2-8°C) and delivered to Cheshire Scientific Laboratories for analysis, mostly within two hours of sample collection. There were some occasions when samples were received by the laboratory later than the two hours after collection, but in such instances they were chilled and received within 24 hours, as recommended in the HTM 04-01 Addendum.

Water samples were submitted to Cheshire Scientific Laboratories because the company is UKAS accredited, and is efficient in the processing and reporting of sample results.

Fifty per cent contamination rate

Various studies have shown that it is not uncommon for >50% of outlets in augmented care wards to be contaminated with *P. aeruginosa.* My data confirms that some wards may have >95% positivity where the water systems are poorly managed and misused. On one occasion, 99.4% of tap outlets on a new, unopened ward tested positive for the bacteria after contractors had pressure tested the distribution system with untreated water, and left it idle for six weeks with an insufficient flushing regime.

In this instance it took the construction firm eight weeks of almost daily thermal pasteurisation, treatment with an oxidising biocide, and the flushing of all 235 outlets to drain for fifteen minutes a day, to reduce the contamination sufficiently to allow augmented care patients to occupy the building. Unfortunately, contamination of new water systems with *P. aeruginosa* is commonplace, with fifteen of the nineteen new water systems I tested testing positive for the bacterium at one or more outlets.

A surprising finding

Surprisingly, in some hospitals wards where there was poor compliance with water hygiene management, very few (or none at all in one case) water samples tested positive for *P. aeruginosa*. The reasons for the low positivity in these cases could not be ascertained.

In my experience, the most consistently low incidence of *P. aeruginosa* contamination of outlets was in the augmented care wards at Trafford District General Hospital, where there has been only two low-level positive samples recorded in almost two years of monthly samples. It is worthy of note that the two positive samples were negative on re-testing. The low positivity has been attributed to the thoroughness of the cleaning regime – with specific cleaners solely allocated to the augmented care wards, and the correct and regular use of handwash basins.

Highest and lowest recovery rates

In terms of the analysis of all samples, the mean positivity per ward for *P. aeruginosa* recovered from outlets was 3.2%, with the highest and lowest recovery rates seen in wards providing renal dialysis services (21.2%), and neonatal wards (0.8%) respectively. This may be the result of an increased level of understanding amongst neonatal staff of the dangers associated with the improper use of handwash basins, or it could reflect the mobility of dialysis patients and the propensity for improper use of handwash basins by clinical staff, e.g. using them for disposal of various dialysis fluids. Interestingly, with regard to my database, dialysis units had the highest probability of finding bodily fluid contamination in the hand wash basins, while neonatal wards had the lowest.

A heavily scaled plastic tap insert in an augmented care ward, which is also showing some evidence of biofilm.

Handwash basins that were manifestly contaminated with bodily fluids were 32% more likely to test positive for *P. aeruginosa* than those which were visibly clean at the time of sample collection.

Medical equipment and personal items

During sample collection, medical equipment and/or personal items were found in 4.1% of handwash basins. When sampled, these handwash basins were associated with a 14.3% increase in outlet positivity. Items found included toothbrushes, children's toys, used bedpans, saline drip bags, catheters, aspirators, and, to a lesser extent, identifiable body parts.

The presence of plastic tap inserts (flow straighteners or aerators) was associated with a 4.2% increase in positive samples. However, the reoccurrence of *P. aeruginosa* in these outlets within one year was 34% more likely than in those outlets that were replaced with a model without a tap insert or where the insert was permanently removed. There is insufficient data at this stage to be able to comment on the efficacy of flow straighteners, which are reputed to resist the accretion of biofilm.

EPDM hoses

The presence of EPDM flexible hoses within two metres of the tap outlet, either directly supplying the outlet or a thermostatic mixing valve (TMV), was associated with both an increase in the percentage positivity of the associated outlets (7.7%), and the reoccurrence of *P. aeruginosa* when resampled (21%).

Adjustable height baths containing flexible hoses and multiple shower heads proved to be one of the most difficult sites from which to remove *P. aeruginosa*, once colonised. In most cases, the baths were either replaced with a non-adjustable bathing facility, or extensive remedial works involving replacement of internal valves, hoses, and pipework, were required.

Where possible, the presence of TMVs was recorded, although the type of valve used and the distance the TMVs were located from the outlet was not logged. Additionally, due to other variables, a correlation between TMVs and the incidence of *P. aeruginosa* could not be accurately determined.

TMV strainers

P. aeruginosa was detected on multiple occasions on the surface of the TMV strainers. This was particularly apparent where excessive building materials had collected on the strainer mesh. However, it was evident that outlets in which hot water failed to reach 40° C during a 1 minute flush were 53% more likely to be positive than those that achieved 55° C within the 1 minute flushing period.

Thermostatic mixing valves are widespread throughout most healthcare premises. They are always required where whole body immersion takes place, such as in showers and baths, and where there is a high risk of scalding due to patients' mental or physical incapacities. However, the majority of TMVs in healthcare premises are fitted in taps at handwash basins in areas where there is very little scald risk.[2]

'Over-specification' of TMVs

In support of the control of opportunistic waterborne pathogens, one of my clients chose not to fit any TMVs at handwash

A TMV strainer with pipe joining compound, Boss White, accumulated on strainer mesh. Pseudomonas aeruginosa was recovered from this TMV strainer and many others within this particular system.

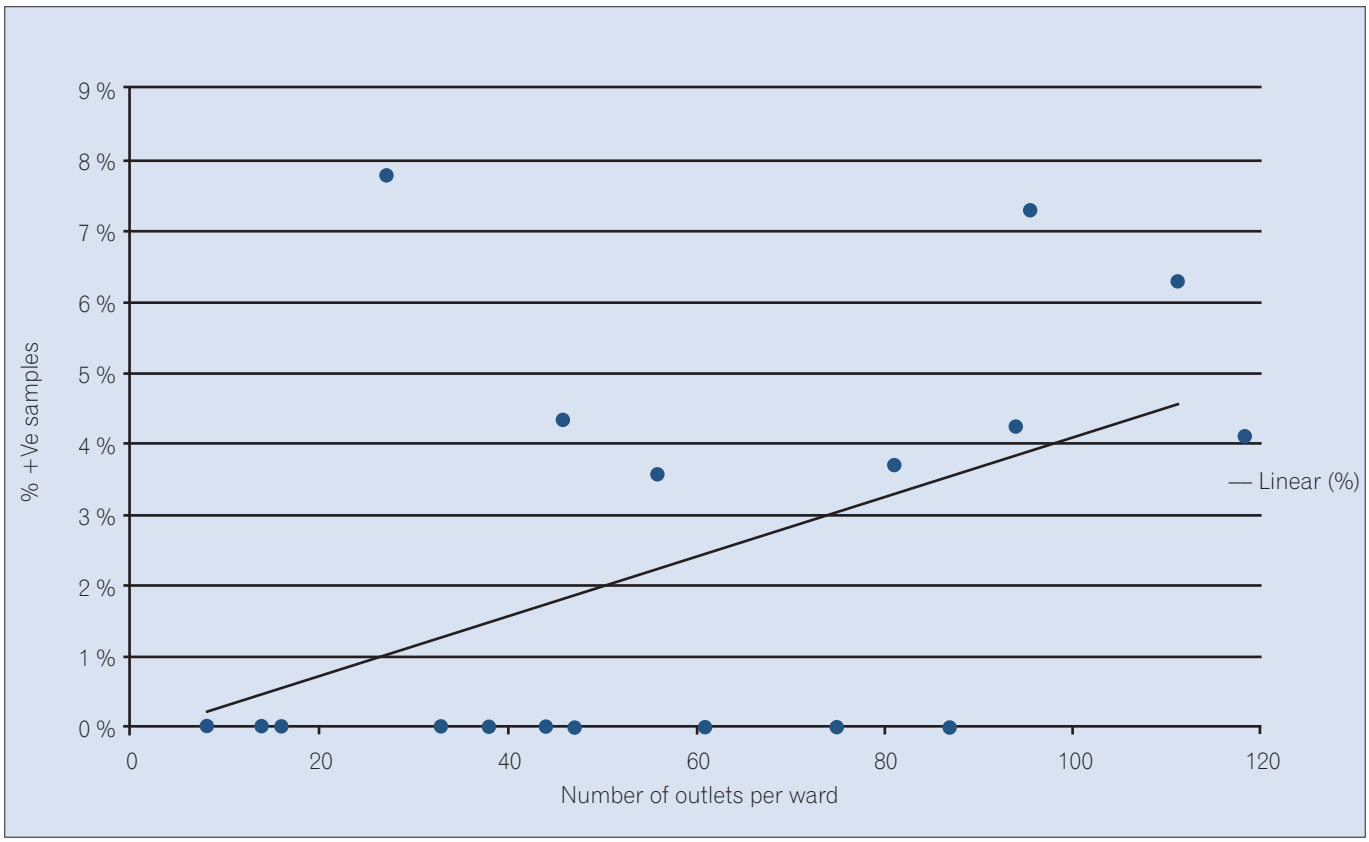


Fig. 1: Graph showing the correlation between the number of outlets present on each ward, and the percentage of outlets which tested positive for P. aeruginosa.

basins during the construction of a hospital, having first carried out appropriate risk assessments on the likelihood of scalding, in accordance with DoH and HSE guidance. The decision not to fit TMVs was supported by the organisation's records – showing that, in over 10 years, there had been just four reported incidents of scalding, only one of which involved a patient, and in each case there were no warning signs cautioning users about the presence of hot water. This again highlights the pervasive issue of over-specification of TMVs in healthcare premises, which is not only costly to our inadequately funded healthcare sector, but equally raises the risk of bacterial contamination of outlets.

The data I collected showed an interesting correlation between the number of outlets present on each ward and the percentage positivity of outlets, i.e. higher rates of *P. aeruginosa* contamination at taps occurred in wards where there were more outlets fitted. This would appear to indicate that the more outlets there are on a ward, the harder it is to ensure that all of them are used regularly and maintained effectively – see Figure 1.

No obvious correlation

From the 1,238 outlets that had been tested for both *P. aeruginosa* and *Legionella*, there was no obvious correlation between the presence or absence of either organism. This supports the already established precept that there is no predictable link between the presence of *Legionella* and general aerobic heterotrophic bacteria, otherwise referred to as total viable bacteria or TVC, which can comprise *P. aeruginosa*.

One of the many outlets recorded as 'little used'. P aeruginosa was infrequently detected at outlets with little human interaction.

It is difficult to determine the exact usage of a handwash basin within an operational augmented care ward without around-the-clock monitoring or the presence of an inline flow meter. However, where possible, outlets were categorised into four usage groups, 'High' (once or more per hour), 'Medium' (once every 2 - 12 hours), 'Low' (once every 12 – 24 hours), and 'little used' (>24 hours). The frequency of use was estimated based upon the comments from medical and estates staff, while the appearance and accessibility of the outlets were also taken into consideration.

'Low' use outlet category

Of the 2,209 outlets with estimated usage recorded, the presence of *P. aeruginosa* was found to be low in those outlets used most frequently (1.1%), with the highest number of positive water samples collected from the 'Low' use outlet category (9.2%). Paradoxically, further analysis of the data showed that those outlets which were not regularly used or cleaned for long periods due to access restrictions, i.e. that were behind permanently locked doors, or were in asbestos risk areas, etc., had the lowest positivity for *P. aeruginosa* (0.8%). This would appear to suggest that human interaction is the primary source of *P. aeruginosa* contamination at outlets in healthcare premises.

Once a water system is extensively colonised with *P. aeruginosa*, it is extremely difficult, if not impossible, to completely remove the organism. However, a combination of thermal disinfection and subsequent treatment with an oxidising biocide proved to be much more effective at reducing the incidence of positive *P. aeruginosa* samples than just thermal pasteurisation, or the use of biocides alone.

Preventing stagnation

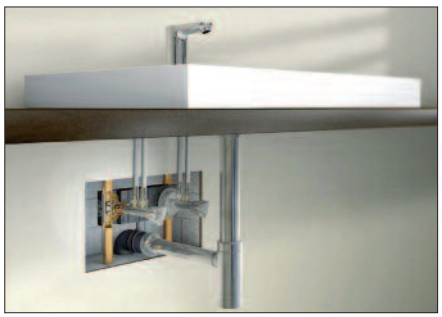
Regular movement of water prevents stagnation, and helps to control the accumulation of excessive biofilm. Unlike hot water in large buildings, cold water does not normally recirculate, and it can

be particularly prone to heat gain and the associated proliferation of waterborne bacteria. The Kemper KHS water system (*HEJ* – June 2014) uses the Venturi principle to create a pressure differential to force cold water around secondary loops to prevent stagnation. Of the 318 water samples collected from a water system where KHS was installed, *P. aeruginosa* and *Legionella* were not detected. Since the collection of the trial data, Kemper has now further adapted its water system to allow the recirculation of water up to and including the tap outlets (HyTwin) to reduce environments that are conducive to the proliferation of opportunistic waterborne pathogens. Further data from the analysis of the Kemper HyTwin system will follow in future publications. The Kemper HyTwin system allows water to recirculate up to and through the tap outlet, with the aim of further reducing environments for biofilm to develop.

Point-of-use filtration (POU) has proven to be an effective means of controlling the release of *P. aeruginosa* from tap outlets. Where POU filtration was fitted and the incidence of clinical infection and colonisation of tap outlets was compared, *P. aeruginosa* bacteria found at tap outlets (pre-filter) were not of the same sub-type as those recovered from clinical infections.

Poorly fitted filters

Some POU filters were poorly fitted, resulting in water leaking from the tap onto the top of the POU filter housing.



The Kemper HyTwin system allows water to recirculate up to and through the tap outlet, with the aim of further reducing environments for biofilm to develop.

Of the fourteen POU filters with leaking adaptors that were swabbed over a two-month period, six tested positive for *P. aeruginosa* despite claimed antibacterial properties of the filter housing. In some cases there was clear evidence of established biofilm on the filter housing, as opposed to transient contamination that can occur after the housing has been exposed to backsplashing and retrograde contamination during handwashing.

Due to varying designs and state of repair, it was difficult to ascertain exactly which outlets discharged water directly to drain. For example, some offset taps which are designed to deliver water to the side of the drain hole were observed to be deliberately adjusted to flow directly into the drain below the outlet. However, in outlets where water flowed directly into the drain, there was a 12.2% increase in positivity for *P. aeruginosa* compared with those outlets where there was low or no probability of water running directly to drain.

Items lodged within them

On further inspection, many of the outlets which ran directly to drain and repeatedly tested positive for *P. aeruginosa* were found to have items lodged within them which would prevent the effective draining of water, and on occasion may lead to a reflux of contaminated water from the drain into the basin. The blockages helped to retain organic materials that did not drain away, and which helped to promote bacterial accretion and proliferation.

Other opportunistic pathogens such as carbapenamase producing enterobacteriacea (CPE), and those which produce extended spectrum beta lactamases (ESBLs), present a significant threat to augmented care patients, as they are resistant to a wide range of antibiotics, and infections caused by some of these bacteria, notably CPE, are effectively untreatable. CPE and ESBLs were also discovered in drains which had items lodged within them.

The presence of such pathogens within the drains, and their contemporaneous recovery from patients, suggests that outlets running directly into the drain could be an effective means of transmission of waterborne opportunistic pathogens. It is worthy of note that while auditing water systems in augmented care areas, splashing caused by outlets running directly into drains at clinical handwash basins was observed on several occasions to exceed distances of four metres.

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Pre-disposing factors

While a review of the data from >6,000 *P. aeruginosa* samples confirms that there are a number of predisposing factors that increase the likelihood of an outlet becoming and remaining contaminated, there appears to be no single definitive factor that reliably predicts which tap outlets will become colonised with *P. aeruginosa* or other opportunistic pathogens.

Yet the data strongly suggests that patients, visitors, clinical staff, engineers, designers, planners, cleaners and plumbers, and others, all play a part with regard to the colonisation of outlets in healthcare premises with *P. aeruginosa* and other waterborne pathogens, and the associated transmission to patients. As we are all culpable, we need to address our respective responsibilities, and help control the nosocomial infections caused by our water systems in healthcare premises.

Acknowledgements

The author would like to thank the following:

- **Julie Christie**, director at Cheshire Scientific, and all the company's laboratory staff, for their excellent service.
- **Chris Reynolds**, estates manager at Trafford General Hospital (TGH), for permitting the publication of the *Pseudomonas* results from TGH.
- **Chris Rhodes** of Kemper UK for allowing the publication of the *Legionella* and *Pseudomonas* sample data from the hospital trials of the Kemper KHS system.
- **Dr Tom Makin** of Makin and Makin Consultancy 'for his continued and unwavering guidance and support'.

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