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Managing water safety in healthcare. Part 2 – Practical measures and considerations taken for waterborne pathogen control

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Abstract

These summaries form the second part of presentations made at a recent conference held at the Royal Society for Public Health in London, 16-17 May 2012, on the latest developments in combating waterborne hospital-acquired infections (nosocomial). The first part (*Ann Agric Environ Med* 2012; 19(3): 395-402) has focused more on the adopted strategies/approaches from the UK perspective, (some also from continental Europe), whereas the presented second part (sections 1-7 below), is dedicated more to practical solutions, and examples of features used in water systems that are or have been considered effective.

Key-words

water safety, pathogen control, perspectives

INTRODUCTION

Faced with the global problem of hospital patients becoming increasingly infected with pathogenic microorganisms through water supply/appliance systems, many remedial measures have been proposed. Most worrying is the emergence of opportunistic and antibiotic resistant strains of, eg. *Legionella*, *Pseudomonas aeruginosa*, etc. that often fatally target high risk patients such as the immunocompromised, the very young, the elderly, following transplants or those suffering with serious diseases [1, 2, 3, 4, 5, 6, 7, 8, 9]. Various practical designs of water systems/appliances are described, during and after building construction, together with monitoring methods and outcomes. These include disinfection treatment options, taps, circulation systems, thermal control, filters, mixing devices etc; design and construction considerations, such as safe plumbing systems (not necessary cost-effective), pipework material and corrosion/leakage issues are also dealt with. Notwithstanding the solutions adopted, the regular monitoring, maintenance and trouble-shooting within the context of a water safety plan managed by competent and responsible professionals is indispensable, i.e. a systematic approach. As in Part 1 [1], concluding remarks can be found at the end of each section.

1. Designing out water quality problems – managing water safety in healthcare. The presentation took the example of the problems of *Legionella* contamination in water systems from healthcare facilities, and how this is managed using thermal control measures to ensure adequate control and safety. Principle areas covered are water hygiene, backflow prevention, preventing scalding and wastewater disposal.

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Legionella are ubiquitous bacteria found naturally in environmental water sources at temperatures of 6 °C – 60 °C where their favoured growth ranges between 20 °C – 45 °C. The presence of nutrients is obviously crucial, (e.g. from other organisms in water), in sediment, sludge, scale and other materials, together with biofilms; all of which can harbour *Legionella*. If this is controlled, then also will numerous other bacteria. Infection is determined by conditions allowing multiplication, generation of aerosols, inhalation, and susceptibility to infection. Anyone can become infected with *Legionella;* however, those more likely to develop life-threatening symptoms are males, older people (>45 yrs), smokers, heavy drinkers, persons suffering from chronic breathing problems, and those with impaired immune systems. Vulnerable patients in healthcare facilities are especially at risk. Control measures include thermal control, (temperatures >60 °C kill), and water treatment. The presentation now focuses on thermal control.

At temperatures >65 °C *Legionella* die very quickly, while between 55-65 °C, the temperatures at which hot water is generated and distributed, they take longer to die. At 45-55 °C *Legionella* is active and likewise between 22-35 °C, (e.g. temperatures of humidifiers); however, its optimum activity ranges from 35-45 °C. Below 22 °C (i.e. the cold water maximum), *Legionella* is dormant, keeping in mind that the temperature of a cold tap water is around 5 °C. An important design feature is therefore for water delivery to avoid heat sources >20 °C. In the UK, extensive guidance is available based on statutory legislation/regulations which includes; the Health and Safety Executive (HSE,), Approved Code of Practice & Guidance L8 on Legionaries' disease and the control of *Legionella* in water systems, Water Supply and Fittings Regulations, Building Regulation Part G ('Sanitation, Hot Water Safety and Efficiency', relevant sections of the UK Health and Safety at Work Act, and the Department of Health HTM 04-01 concerning Legionella and safe water systems.

Essentially, hot water can be distributed in two ways; a 'Flow and return circulation' system where a pump circulates hot water around a 'loop' flow and a return spur to each terminal fitting or a single pipe – trace heating system with no circulation which has a heat maintenance system for keeping the temperature at 55 °C throughout. Water systems have to be designed so as to fulfil operational requirements at point of use for delivering hot water at 50 °C after 1 minute, (ideally 30 secs), indicating a deadleg of around 25m, and cold water <20 °C after 2 minutes with a deadleg of approx. 50m. Actual engineering guidance for buildings on the design, installation, operation and maintenance procedures for minimising the risk of *Legionella* infection in water systems are available from the CIBSE TM13: 2002 publication. Three types of TMVs, (Thermostatic Mixing Valves) are identified, one of which is required for some hospital and healthcare applications, with enhanced thermal performance complying with NHS Estates Model Engineering Specification D 08. For risk management in the UK, the owner of the building is responsible for the water system where a named individual is responsible for water hygiene, (i.e. an Operations Manager). Risk assessments for *Legionella* control are performed according to British Standard BS 8580 which takes into consideration the design and specification, the commissioning, operation and maintenance, as well as quality management.

The discussion then focused on the above-mentioned HTM 040-1 memorandum for suppressing *Legionella*. To ensure 'safe' hot water, thermal control/pasteurization, (55 °C), chlorine dioxide, (BS 6700), copper-silver ionisation or ozone and UV treatment are used, the latter being non-dispersive with no residual effects. For the former, either circulatory pumps ensure that temperatures are not <50 °C, or those without recirculation that hot water at 50-55 °C is available at all points within a minute. Hot water return should be at 50 °C.

When considering cold water storage and distribution, it is always assumed that *Legionella* is present in mains water. Here, temperatures should be maintained <20 °C with a design for interruptible service and storage of < 1 day. Water contact materials that may be a nutrient source are listed in WRAS; BS 6920, Part 1. Routine checking and inspection are required and due account is taken of how the building is operated if floors are taken out of use. Water pipework and valves should be appropriately insulated to ensure minimum heat loss for hot water and minimum heat gain for cold water and ensuring that the two are kept apart. During pipework installation, control is exercised over materials used and the workmanship of jointing and soldering. Flushing and disinfection is performed according to BS 6700, (which will be replaced in August 2012 by BS 8558), and after commissioning and handover the building needs to be re-disinfected if not brought into service within 30 days.

One of the dilemmas in hot water safety is to strike a balance between the scalding risk at temperatures at which *Legionella* are controlled, and the risk of an outbreak at temperatures that do not pose a scalding risk. In order to mitigate the risk in hot water systems, a series of measures can be adopted, such as: removing scale/debris that harbour bacteria, avoiding deadlegs, having the flow through expansion type vessels, presence of large calorifiers which avoid stratification, having point of use heaters, appropriate TMVs and adequate insulation. Likewise, for cold water, the latter is vital, but additionally, avoiding low usage fittings at pipe run ends, having Venturi-type valves to induce circulation, and purge valves to dump stagnant water. Disinfection becomes necessary, whether thermal or chemical, when routine inspections indicate so, if substantial alterations occur to the water system or in an outbreak of *Legionellosis*. Other sources of risk include humidifiers, ice-making machines, safety showers, water features and especially spa baths where several outbreaks of Legionnaires' disease have been recorded with some fatalities in Belgium and Holland. Various grades of fluid categories, (1 – 5), are used to indicate the level of risk in backflow prevention devices in line with water regulations, harmonised with Europe, together with definitions of water quality, such as; 'wholesome water' i.e. water fit to drink and complying with regulations made under the Water Industry Act 21991, corresponding with Fluid Category 1 of the EU Water Supply/Fittings Regulations of 1999, or 'Grey Water' which was originally supplied as wholesome water, but has already been used for bathing, washing laundry or dishes.

In the UK, the efficient design of water systems, fittings and appliances has really been driven by the aforementioned legislation and there is new interest in re-using/re-claiming non-potable water supplies (for purposes other than drinking), from grey water, borehole water, rainwater harvesting, and indeed black water; however, it is necessary to avoid any cross-connection with the drinking water supply. A BS 1710 compliant scheme is in place as recommended by WRAS. Many problems also arise from wastewater disposal concerning drainage systems and hygiene (e.g. leakage, foul odour/aerosol release, contamination, etc.). Water traps, preferably ventilated and external, for example, are mandatory according to UK bylaws to prevent foul odours in internal environments. Failures can also occur due to trap evaporation, self- or induced-siphonage, back pressure, surcharging of the underground drainage pipework or wind effects.

In the UK, it is concluded that thermal and water treatment are an effective means of control, good guidance is available, and operating systems require good maintenance and record keeping; nevertheless, a balance between the risks of scalding and infection needs to be found. A guidance document incorporating practical experience on water treatment and safe hot water delivery is currently under revision, (CIBSE TM13).

2. Safe commissioning of water systems and effective water management of new buildings – construction to handover. This was a presentation made by 'Land Lease Facilities Management' (LLFM), a company operating in the Private Finance Initiative (PFI) market), concerned with building construction and management, principally applied to the healthcare, education, retail and government sectors. It has 600 employees, operates 8 UK hospitals and was partly responsible for constructing the prestigious athletes' village in East London for the forthcoming Olympic games in the UK capital.

The practical realities and risks of water system construction were outlined, together with their unintentional consequences. Managing water hygiene risk in the UK costs £10 million in order to prevent/deal with microbiological outbreaks where generally Total Viable Counts (TVCs) have been reduced over the last 4 years.

At the beginning, a new building structure is constructed according to various regulations to meet construction requirements. Each element of the construction packages is then divided within the construction programme. A

design consultant is employed to write the Monitoring and Evaluation (M & E) infrastructure brief, who will not step beyond the relevant guidelines. This is then sub-contracted to M & E installers who sub-contract to sub-sub contractors. However, in reality – sometimes euphemistically called 'value engineering' – cost-cutting on materials and pipe work layouts occur. Furthermore, Construction Design and Management (CDM) regulation principles are used which, however, are vague with regard to water hygiene strategies. Several months before handover to the user, generally what happens is that the water pipework system is tested by filling with water, followed by a maintenance operation; but there is no monitoring management of water systems during the construction phase.

Chlorination is often performed by a water treatment company, and a Chlorination Certificate issued which should be in compliance with the health and safety plan. During the disinfection of plastic pipework, there are many concerns in industry about detecting liabilities and legacy issues with microbial contamination. Disinfection protocols do not use British Standards BS 8558 or BS 6700, and in addition, water hygiene challenges and the L8 requirements are not understood. It appears that things are done in a certain way simply because they have always been done that way.

In the design and monitoring, the LLFM adopts a 'Water Policy' when it comes to the management of partially- or fully-occupied buildings, including risk assessment, having a written scheme with schematic drawings, escalation pathways (and trigger points), monitoring temperature at sentinel points, and flushing showers at low use taps. A responsible person is always appointed together with an authorised person on all facilities management contracts. From the operational experiences of LLFM in buildings, it is vital to minimise risk and liabilities. Implementing and using L8 is undertaken according to the correct legal requirements. HTM guidance is used together with appropriate BSs. Special attention in all documentation is paid to correct drafting, clauses, wording, paragraphs, italics and the use of upper/lower case typefaces where appropriate. Annual in-house audits are also performed. The LLFM ensures its water hygiene staff are educated in microbiology and understand water hygiene requirements with clients and their knowledge so that the exposure to risk and liabilities is known. The creation of Steering Group meetings with, for instance, NHS clients, is useful, especially with infection control teams or hydrotherapy pool committees where the concerns and differing priorities of microbiologists and FM estates engineers need to be balanced and reconciled.

Microbiologists typically advise the Department of Health (DoH), on water organisms and assist in writing BS guidance; however, several areas have meanings unclear to engineers. These include definitions such as the phrase 'No abnormal change' in colony counts. Does this mean a safe situation? Or that TMVs are known to contribute towards contamination? Advisers, however, step back and say they may not be the cause of contamination in water systems. What does 'out of control' or 'under control' mean precisely? These terms are not in the L8; therefore confused areas such as these need to be addressed.

3. Treatment options (1) – a study comparing chlorine dioxide and hydrogen peroxide in four Italian hospitals. Occasional but regular outbreaks of various strains of *Legionella pneumophila* have been observed in four Italian hospitals during the last 15 years, together with the detected presence of *Legionella,* even when no patient cases arose. Two types of disinfection treatments, (as mentioned earlier) were therefore instigated to see which was the most effective. Although hydrogen peroxide is a weaker disinfectant than chlorine, it is used in combination with silver ions which act synergistically to attack proteins and penetrate deeply into and thus inactivating microorganism such as *Legionella*. Chlorine dioxide is a potent *in-vitro* oxidant that disrupts many cellular processes and has been widely and successfully used in industry and municipal water systems over many years, sometimes at concentrations as low as 0.1mg/L over a wide pH range.

Many other European hospitals have also used this treatment to good effect when dealing with *Legionella*. In the study, concentrations of disinfectants were measured in the distal and proximal sites of the hospitals' water systems as well as cfu/L of *Legionella*. It was found that temperature played a critical role when treatment with silver-hydrogen peroxide was used. At lower water temperatures (e.g. 30 °C), the time taken to reduce the bacterial role by a four log reduction was too high, (20 hrs at 1,000:1 peroxide:Ag ratio, concentrations ranging between 15-150mg/L and contact times ranging between 1.5-72 hrs); consequently, bacteria could not be rapidly contained, even when the disinfectant was immediately applied. At higher temperatures (e.g. 50 °C), the efficacy was low. In contrast, chlorine dioxide proved more effective even at higher temperatures although its stability was reduced – the time required for a six log reduction at 0.8mg/L was < 9 mins. In both cases, the detection of low disinfectant concentrations at distal sites permitted the introduction of corrective actions, such as replacing corroded pipework. As a result, replacing silver-hydrogen peroxide treatment with chlorine dioxide has led to a sudden fall in *Legionella* cases from 13 cases (four confirmed, nine possible) in 2011, to only one *Legionella* nosocomial case in 2012.

However, in all the hospitals there was no long-term reduction seen in *Legionella* cfu/L, despite using disinfectants at efficacy range concentrations. It was concluded that apart from disinfectant type and concentrations, other factors, such as *Legionella* strain, age of the building, general condition of the piping, biofilms, etc., contribute to the persistence of bacterial contamination. A 2007 study [10] has shown that the same strain of *Legionella pneumophila* (serogroups 1) persisted in an Italian hospital for 15 years (at 1000-100,000 cfu/L), with several cases of Legionellosis arising. This was in spite of different disinfection approaches being tried, including hyperchlorination. It was suggested that the resistance may be due to several *Legionella* genes encoding transporters for heavy metals and toxic substances.

It was concluded that the characterisation of the *Legionella* strain is important in establishing which strains have increased virulence, and to determine the most effective type of biocide treatment, together with investigating the water system itself.

4. Treatment options (2) – experience with copper-silver ionization and monochloroamine in the control of *Legionella* in hospital water systems. This presentation gave a USA perspective on *Legionella* where there has been a 217% increase in cases of Legionellosis in hospitals over the last few years [11], thus posing a major challenge for its control. The issues focused on were the best methods/devices for controlling this elusive organism, and questions were asked

about whether it can ever be eliminated given the serious health risk and effect on cost posed by outbreaks.

Legionella disinfection methods used for potable water include Copper-Silver ionisation (continuous), thermal shock (heat and flush at 70-77 °C), shock chlorination, (≥10mg/L residual) that may require water tanks to be at 20-50mg/L, continuous supplemental chlorination (2-4mg/L), chlorine dioxide, point-of-use filtration and new technology (e.g. monochloroamine *in situ* generation).

The methods discussed in detail were the copper-silver ionisation, and the last using monochloroamine. In the former, copper and silver ions are released from a flow-through cell into the hot water system and maintained at 0.2-0.4 ml/L and 0.02-0.04 mg/L, respectively. An example from the literature was quoted from hospital water [12] where the percentage of distal sites showing positive for *Legionella* was 0% within four weeks, but decolonisation to previous levels occurred in 12 weeks (i.e. 60% positive). Another study has reported the experience of the first 16 hospitals in the USA to use this *Legionella* control method [13] over 5-11 years, where 12 out of 16 hospitals had reported failures in previous attempts to control Legionella by other methods. It was found that in 1995, half the hospitals reported 0% positivity at distal monitoring sites, but by 2000 this figure was reduced to 43%. During the follow-up period, 15 reported no nosocomial Legionellosis cases and the remaining hospital recorded one case, but had not had any more in seven years. Indeed, a study back in 1998 [14] had actually demonstrated the effectiveness of this method – showing that there is really nothing new. The procedure used here was a short 30-day course of copper-silver ionisation at a low risk healthcare building where the % *Legionella* positivity at outlets fell from 70% before treatment to 40%, and around 5% in two weeks and six weeks, respectively, after the start of treatment. Throughout this time, the ion concentrations were monitored weekly. When the course was stopped, the positivity remained at around 5% after seven weeks but started to rise to 20% after another 14 weeks. It was concluded from this study, as well as from the current (2012) opinion that the advantages were less disruption to the occupants, compared to shock thermal or hyperchlorination methods. There were also no restrictions on water use throughout, no taste complaints and only minor plumbing alterations necessary. It was also additionally effective against other waterborne pathogens, had validated efficacy over time in many institutions and that the duration of the *Legionella* control effect lasts longer than shock heat or hyperchlorination. Some disadvantages were a one-week period to start-up, and the cost may exceed the thermal or hyperchlorination methods, periodic ion monitoring is required and *Legionella* will eventually recolonise. Some evidence was also presented that a short course could prevent *Legionella* resistance to the copper-silver method, although over time this may be questionable. The treatment is also only applicable to the hot water supply.

Monochloramine is a biocide approved for water treatment and EPA regulations in the USA limit the concentration to 4 ppm in public water supplies; a typical target level, however, is 3ppm. It is formed by the chemical reaction between ammonia and hypochlorous acid. A 2003 study surveyed 166 hospitals in the USA for *Legionella* risk and various methods of disinfection; it was found that monochloroamine-treated municipal water most strongly reduced the risk of nosocomial Legionella [15]. This finding was supported by many other studies, including a review [16, 17, 18] which demonstrated either a decreased risk of *Legionella* in those hospitals surveyed using chlorinated water, or lower *Legionella* colonisation in municipal buildings that used monochloroamine. A new development is to generate monochloroamine on-site and has proved effective [19] in the hot water system in an Italian hospital where significantly much less contamination of *Legionella* and *Pseudomonas* was observed, compared to chlorine dioxide treatment.

It was concluded that the new approaches to control are promising but require regular application, maintenance and monitoring. Short duration treatments may be effective in low risk buildings.

5. The long term effects of chlorine dioxide on water distribution system pipework. A presentation about corrosion and metallic materials was made by a leading and independent research institute from Sweden (Swerea KIMAB), sponsored and owned by the industry – both manufacturers and endusers. Its tasks include basic research on the corrosion properties of polymeric materials, commission work, failure analyses, and testing in extreme environments, eg. with H_2SO_4, HF, ClO_2, etc.

Factors that can limit the service life of polymeric materials are diffusion, swelling and degradation; for example, by antioxidant/additive destruction, oxidation and chlorination. Considering the latter, when used for water disinfection, the most common chemicals are chlorine (hypochlorous acid-HClO), chloramines and chlorine dioxide. All these come into contact with plastic pipes for drinking water made from either polyolefins (i.e. polyethylene, PEX, polypropylene, polybutylene), or PVC. The former are popular due to the following properties: strength and flexibility, low weight and cost, long service life, easy to install, low maintenance and good chemical resistance. The resistance to disinfectants, however, can be limited. This can be tested according to standard the methods ASTM F2023 and ASTM F2263 for the three aforementioned disinfectants, where chlorine dioxide is increasing in popularity. The degradation mechanism, at the macroscopic level, responsible for ultimate pipe rupture, is considered to be the same for all three disinfectants. It consists of stabiliser depletion at the inner pipe surface, oxidation and micro-cracking of the inner layer, crack propagation through the walls, (with oxidation in advance of the crack front), and final rupture of the remaining pipe.

A number of reports claim that chlorine dioxide is more aggressive than chlorine and chloramines. For example, exposing unstabilised polyethylene at 50 °C for nine days with 1mg/L ClO_2 resulted in the clear formation of many oxidised products in the effluent, compared to water where there were none, the maximum level of ClO_2 permitted in drinking water being 0.8mg/L. The reason why ClO_2 is popular is mainly that it is very effective in bacterial treatment, more so than chlorine for viral disinfection and deactivating the chlorine-resistant pathogens *Giardia* and *Cryptosporidium*. It also removes and prevents biofilm, destroys phenols, (that cause odour or taste problems), more effectively removes iron and manganese than chlorine, is efficient for *Legionella* prevention. ClO_2 generators are now being frequently installed in hospitals for controlling the *Legionella* risk. ClO_2 can be generated by either the reduction of chlorate or oxidation of chlorite, where the different chemistries used affect the purity of the end product. The most popular method is the 'Purate Process' from chlorate (EKA chemicals trademark), where a stable mixture of sodium chlorate and hydrogen peroxide is mixed with sulphuric acid in the generator. Chlorite reduction can however be achieved

by electrochemical, UV or HClO activation, acid (i.e. HCl) or acid cation exchange, or chlorine activation of either aqueous chlorite (Rio Linda Method) or solid chlorite.

A cross section of heavily-corroded polypropylene warm water pipe was shown which had been in service for eight years at 50-55 °C at ClO_2 concentrations of 0.5mg/L. Other examples were shown of pipes exposed for one or two years which had severe cracks; others exposed for 4.5 years with as yet non-penetrating cracks. Corrosion is often underestimated and there is a general lack of understanding in using ClO_2 generators where regular maintenance is necessary; residues of acid and chlorine will be present and the quality of the pipes requires consideration. Although polyethylene has been studied, nothing is known about PEX, polybutylene or polypropylene. In all, a balance must be struck between the need to fight *Legionella* while avoiding any risk of leaking pipes.

Summing up, although polyolefins are attacked by both chlorine and $CClO_2$, most work fine at the concentrations used, assuming regular maintenance. Pipe production methods and pipe material purity/quality require further study in terms of performance and testing under different environments, and reasons for pipe failure need careful analysis.

6. Proximity taps (faucets) in healthcare – infection control strategy or health risk. In the USA, proximity taps are commonly used in healthcare facilities and are suspected of being the source of microbiological contamination. The question of whether there is an increase in associated health risk was thus reviewed according to current evidence. A telling opening remark was made as follows:

> Meanwhile, there seems to be no good reason for permitting the use of a type of apparatus which may obviously contribute to the transmission of disease, even if it actually does so only occasionally.

Indeed, the problem of infection arising from taps was recognised in the USA as a distinct possibility as far back as 1925 [20]. The most common cause of USA hospital acquired Pneumonia in non-ICU patients *S. pneumoniae* (27%), *Enterobacteriacceae** (13%), *L. Pneumophila** (12%), *Asprigillus spp** (12%), *P. Aeruginosa** (12%) and *Acinetobacter** (7%), of which those marked with an asterisk are waterborne pathogens [21]. There are, in fact, many pathogens in water that also include *E. Coli* and GI pathogens, *Klebsiella oxytoca, Enterobacter cloacae,* and amoeba-resistant microorganisms, such as *Legionella*. Recent studies have indeed shown bacterial contamination associated with electronic faucets [22] as a new risk, and that non-touch fittings in hospitals are a source of *P. Aeruginosa* and *Legionella spp* [23]. In the latter study, 38 non-touch taps were compared to 10 conventional ones where P. Aeruginosa contamination rates for the former were 74% and 0% in the latter, and L*egionella* was found in all non-touch taps, but only three out of 10 in conventional taps.

Another, similar study [24], localised the problem to magnetic valves, mixing devices and outlets coupled with low water flows and lowered hot water temperatures. Recommendations were to replace non-touch taps with conventional ones. This was further confirmed by a study [25] performed in hospital kitchens showing high electronic tap contamination with *P. Aeruginosa,* which increased the risk, especially in high-risk hospital areas. Again, a return to old-fashioned taps was recommended.

The high levels of *Legionella* and other bacterial contamination of electronic taps reported in this study, were tested at 95% compared to 45% in manual taps. It was actually found that the electronic faucets are less likely to be disinfected with chlorine dioxide, and that all 12 internal components of the contaminated electronic taps had *Legionella*. Thus, periodic monitoring for *Legionella* was recommended and the removal of taps from high risk areas. Another *Legionella* study compared sensor taps with manual ones using solenoid valves and a controlled flow at three different flushing regimens; no differences were found – all were contaminated with *Legionella*. It was therefore concluded that it is very likely that faucets increase risk of infection in healthcare facilities.

7. Thermostatic mixing devices (TMVs) – balancing scalding and infection risks. Evidence was presented and discussed about which of the above represents the greatest risk to people in domestic settings and to patients in hospitals. Both the temperature level and time of exposure determine how skin burns. Secondary burns are seen in adults at 60 °C in three seconds (tertiary burns in five seconds), 55 °C in 20-30 seconds and 49 °C in nine minutes. Without doubt, severe scalding occurs with significant injury from immersion in hot bath water. A solution would be to install thermostatic mixer valves to prevent water being delivered above 46 °C. This has been implemented by the National Health Service (NHS) in the UK since the early 1990s, and has been updated in various guidance documents up until the latest – HTM 04-01 (DoH 2006), available free of charge from the NHS at [26].

Three types of mixing valves are recommended, one mechanical with a temperature stop, and two thermostatic, of which one has enhanced thermal performance-termed fail safe that comply with various UK official standards. The use of the third type was in fact recommended for all patient hospital areas, such as hand basins accessed by everyone, paediatric and general baths, showers, hair wash and bidets; each having a set maximum temperature varying between 38 °C – 46 °C. Other areas, such as staff only access rooms or sluice rooms, kitchens, pantries or sinks, could employ the mechanical mixing valve. Statistics for scalding are variable. The HSE reports annually 1,639 cases of scalding plus burns per one million – 88,000 cases. The agency at [27] reports 700-800 burn/scald deaths per year, and the National Institute for Health and Clinical Excellence (NICE) reports 2,500 children per year admitted to hospital with scalds due to bath immersion. In the UK, the National Burns Injury Database (NBID) takes UK data from an international burn injury database that collects data from specialised burn services in the UK. This is added to the data from the UK NHS Hospital Episodes Statistics, and augmented by periodic comparison with data from the UK National Burn Red Bureau (NBBB), both available from the links page. In 2012, this system recorded 95% of all burns that present to Accident and Emergency A & E) departments. The actual burns injury data from 1986-2007, showing the sources of injury for all ages, can be accessed on [28]. Roughly speaking, about 8,000 cases are shown, graded according to severity – insignificant-minor to severe-complex, and subdivided into various sources: bathing immersion, kettle, teacups, showers, taps, saucepans, etc., and frequency of occurrence. About 10% were graded as severe-to-complex; the majority arising from bathroom immersion (249), teacups (112) and kettle

burns (48). More of the same updated data type was shown from 1986-2012 where, by-and-large, a similar pattern was observed with some minor variation (site at [29]).

The time to kill 90% of a population of *Legionella* (D), when measured at different temperatures [30], forms the basis for control in hot and cold water systems: >70 °C ensures a 100% rapid kill, 60 °C kills in two minutes, 50 °C achieves a 90% kill in two hours, while 35-46 °C is the optimum temperature range, and at <20 °C Legionella is predominantly dormant but viable. Accordingly, in water systems, hot water should be circulated at 60 °C so that water at the tap reaches at least 50 °C within one minute, and cold should be less than 20 °C within two minutes of turning the tap on.

However, in systems with TMVs in the plumbing, *Legionella* control is lost where colonisation is very likely downstream of the TMV. It has been recognised for at least 30 years that taps, shower hoses and heads, can become colonised with *Legionella spp* and *Pseudomonas aeruginosa,* but this could be controlled by hot water flushing the outlet at 60 °C [31]. Introducing the failsafe TMVs (as aforementioned), however eliminates this method of control and probably leads to an increased incidence of *Legionella* in healthcare settings, although good surveillance evidence is somewhat lacking. A new, unused TMV anyway contains about 15mls of water on delivery which, not surprisingly, shows microbial contamination. The risk of colonisation of automatic electronic water taps has also been recognised as a problem since 2001. A common feature is to incorporate some sort of TMV downstream for which it is normally impossible to achieve high enough temperatures to control microbial growth. The design of modern TMVs, i.e. without swan necks, when incorporated into the tap body can now reduce but do not eliminate the problem of *Legionella* contamination.

It was concluded that fitting TMVs on all wash hand basins is not justified by the risk. There is an increased incidence of *Legionella* and *P. Aeruginosa* at outlets in hospitals that is difficult to control, leading to an increase in infections. Therefore, the relative risks of scalding and growth of these bacteria should be always considered before installing TMVs. The question remains as to whether failsafe TMVs should be fitted in areas other than ICUs, paediatric, geriatric and mental health units.

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