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Managing water safety in healthcare. Part 1 – Strategies and approaches for waterborne pathogen control

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Abstract

Summaries in 2 parts are presented from a conference held in London at the Royal Society for Public Health on 16-17 May 2012, on the latest developments in dealing with waterborne hospital-acquired infections (nosocomial), from the UK perspective. Also included were some views from continental Europe. The first part, focuses on management strategies and plans that are either in use or recommended by domestic/international guidelines, such as the WHO, for prevention, control and risk assessment of disease outbreaks resulting from the presence of these pathogenic microorganisms in water appliances/supplies. Various solutions are discussed, some more effective than others, but all require a comprehensive strategy and technical expertise run by properly trained and dedicated professionals.

Key words

water safety, waterborne pathogens, strategy

INTRODUCTION

It is recognised worldwide that nosocomial infection is a serious and growing problem in developed countries, not to mention developing ones, where the incidence of patients succumbing to waterborne disease during hospital treatment/stay has increased within recent years. The emergence of opportunistic pathogens and those with increased antimicrobial resistance, such as *Legionella* and *Pseudomonas aeruginosa*, are a particularly a cause for concern where vulnerable patients, e.g. the immunocompromised, the elderly, the very young, those suffering from severe illness and disease or in an intensive care unit (ICU), are most affected, often fatally. Thus, the extra and ever-increasing burden imposed on healthcare systems requires addressing. The first part of the summaries, focuses on management strategies and plans that are either used or recommended by domestic/international guidelines, such as the World Health Organization (WHO), for prevention, control, monitoring and risk assessment of disease outbreaks resulting from the presence of these pathogenic microorganisms in water appliances/supplies. Various solutions are discussed, some more effective than others, but all require a comprehensive strategy with technical expertise run by properly trained and dedicated professionals. Concluding remarks can be found at the end of each section.

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An overview of waterborne pathogens in healthcare. The presentation embraced two of the latest emerging and opportunistic pathogens that have been identified as being of the most concern in healthcare settings. These are particularly found to be the cause of infection in vulnerable patients, such as those receiving intensive care. It is now recognised that a key problem area are water/plumbing systems which act as environmental reservoirs wherever the moisture or humidity is high. This has been illustrated by the very recent outbreak of *Pseudomonas aeruginosa* in hospitals in Northern Ireland (with 3 baby fatalities), which was traced back to water taps in sinks. Other sources can include showers, disinfectants/sanitisers, respiratory therapy equipment, ice makers, flower vases, saving/toothbrushes, hydrotherapy pools, mop-heads/buckets, bronchoscopes, contact lens cleaning materials, and bath toys. Another genus of gram negative bacteria mentioned as being on the increase (around 70% from 1985-2000) was *Stenotrophomonas* (especially the *maltophilia* type species) which, in addition to the places already mentioned, are often found in haemodialysers, deionised water dispensers, nebuliser chambers, humidifier reservoirs, bronchoscopes, arterial pressure monitors, urinary catheters and ventilator circuits. It is a metabolically diverse organism ubiquitously found in aqueous environments, ranging from such unlikely places as drug preparations and explosives [1, 2]. Due to broad-spectrum antibiotic resistance, infections are difficult to treat in severely immunocompromised or debilitated patients who suffer high morbidity and mortality rates, mainly due to pulmonary infection. Diagnosis is also not easy; however, *Stenotrophomonas maltophilia* has low virulence and removal of the infected source is frequently sufficient for a cure in non-immunocompromised cases.

The rest of the presentation focused mainly on *Pseudomonas aeruginosa,* an equally metabolically diverse and versatile pathogen able to colonise a large variety of niches, but which is of much greater risk [3]. In the USA, this bacteria occupies 6th place among hospital acquired infection determined from a large study [4] of 463 hospitals, (>28,000 recorded cases). The European Antimicrobial Resistance Surveillance System (EARSS), recently published resistance rate data [5] from 33 European countries showing, respectively, 0-51%, 9-50.5%, 7.2-51.9% and 4-48.5% for aminoglycosides, carbapenems, quinilones and ceftazidime. This was supported by another survey study [6] of increasing resistance in *Pseudomonas aeruginosa* isolates from intensive care units (ICU) in 8 European countries, which is not not surprising given the frequent use of antibiotics in such settings. Especially worrying, however, is the loss of carbapenems due to emerging carbapenases in multi-drug resistance (MDR) strains, now exacerbated by a strain reported [7] to be resistant to coliston, an antibiotic of the last resort, thus creating pan-resistance at a cancer centre ICU in Slovakia where 5 patients died as a result. In terms of pinpointing problem areas in hospital environments, the recent developments in new molecular typing methods now not only enable confirmation that hospital water supplies are responsible, but also allow the actual point source in a system to be identified. Several examples of such reports were then summarised including remedial action taken; an outbreak of *Stenotrophomonas maltophilia* in a neonatal ICU, traced to tap water, resulting in changes made in baby- and hand-washing practices [8], and contaminated bottled water resulting in 19 ICU patients becoming infected [9] and outbreaks of other *Pseudomonas* types [10, 11, 12, 13, 14]. As a result, guidance documents about washing has been introduced into UK hospitals and are now acted on. Despite variations in study design, several prospective studies have shown hospital water to be the source of *Pseudomonas aeruginosa* infection [15]. For example, following taking weekly specimens from patients as well as water hospital outlets and using PFGE typing analysis, a 6- month study in an ICU concluded that the sources of contamination were both tap water and the patients themselves [16]. Various measures have been employed, however, to successfully control pseudomonads in hospital water. This includes introducing point-of-use filters on all ICU water inlets/outlets, which proved to be effective, as opposed to a previous strategy of patient digestive tract decontamination or using sterile water and intensive personal hygiene methods [17]. A twice-weekly filter change also led to large savings in the use of antibiotics, (e.g. ceftazidime or carbapenems). Installing point-of-use filtration also effectively eliminated an outbreak of *Pseudomonas aeruginosa* infection in a haematology unit [18], as well as in removing harmful filamentous fungi.

Another ICU study on patient infection associated with taps demonstrated that increases in water temperature, copper and silver ionisation, replacing tap water with bottled water, and reinforcement of hand hygiene precautions led to significant decreases in patients infected with exogenous strains, unlike those infected with a unique genotype representing an endogenous infection [19]. As a result of increasing infection and colonisation by epidemic and sporadic *Pseudomonas aeruginosa* clones in a neonatal-ICU, enforcement of a strict regime of hand disinfection was effective in managing this outbreak following surveillance and appropriate microbiological sampling/analysis, together with staff education [20].

In conclusion, there is plenty of evidence showing that hospital water supplies are the source of pseudomonad infection for vulnerable patients, and most frequently comes from taps. A range of measures are used to control this problem; however, they can be technically difficult and expensive to use. The emergence of antibiotic resistance is a great concern, therefore prevention is important. A comprehensive and standardised multi-faceted approach for infection control is thus recommended, including common sense use of antimicrobials and hand hygiene.

Water hygiene in healthcare premises: the water safety plan approach. A detailed description of the recommendations put forward by the International Forum for Water Hygiene in Buildings (IFOWAHB) as applied in healthcare premises was presented. This International Forum [21] came was established by Professors Hartemann and Exner during the European Working Group on Legionella Infections (EWGLI) in 2004, and included the foremost international experts from the WHO concerning water safety in buildings. The principal aims were a focus on all pathogenic microorganisms in buildings, taking into account regional water quality differences, and to provide expert guidelines advice, information exchange, recommendations, procedures, and study support to ensure safe water for all purposes in healthcare facilities.

Waterborne healthcare premises infection, due to opportunistic pathogens is recognised as an increasing source of healthcare acquired infection (HAI). Vulnerable patients are most at risk – especially those immunocompromised – from infective agents, such as *Legionella*, *Pseudomonas aeruginosa*, *Stenotrophomonas*, non-tuberculous mycobacteria (NTMs), *Aspergillus,* etc. [22, 23, 24, 25, 26, 27, 28, 29]. Safe water is vital to ensure patient safety and reduce costs where waterborne infections cause increasing morbidity, mortality, treatment costs, compensation claims and longer hospital stays. According to the WHO definitions, a waterborne hazard is the agent (i.e. bacteria/chemical/toxin) that causes disease where microbial hazards continue to be the primary concern in both developed and developing countries. Hazardous events are defined as incidents/situations that can lead to the presence and/or increase of a hazard in a water system which causes an adverse effect – what can happen and how. Such events can arise from failure in control measures, (dosing system, boiler breakdown, etc), ingress of nutrients (poor quality water and delivery systems), and growth of microflora/biofilms in all parts of a water system, stagnant areas and interfaces. A couple of classic practical examples were *Pseudomonas aeruginosa* infections in whirlpool baths and hydrotherapy pools [30, 31], affecting both patients and therapists. In fact, about 40% of all Pseudomonas aeruginosa infections can be traced back to the water pipe system in hospitals. Both chemical and microbiological hazards can potentially increase from point-of-water supply to point-of-use. Factors governing disease causation include; ability to survive/multiply within given environments, organism virulence, duration and frequency of exposure, dose required to cause infection, and susceptibility of the individual. Contamination of drinking water systems mainly arises from; faecal contamination (sewage or animal), an intermittent or untreated water supply, inadequate plumbing, heavy rainfall/

flooding, or animal/bird/insect ingress into unsecured water storage. Non-intestinal risks linked to drinking water systems can result from the growth or regrowth of naturally occurring microorganisms, (as mentioned above), and may be introduced via building, installation, maintenance, repairs, cross connections (backflow, siphonage), etc. Chemical contamination may also cause disease due to corrosion and/or leaching from system components.

A further problem is that waterborne pathogens can constitute a reservoir of antibiotic resistance, as illustrated recently by a major university hospital outbreak of a multi-drug resistant strain of *S. Marcescens,* caused by tap water contamination during drug administration [32], and a multi-resistant Pseudomonas aeruginosa outbreak in a major teaching hospital in Australia, arising from a biofilm in the plumbing of a staff hand-held basin from a water-saving device [33]. It is important to note that water is not just used for drinking, food preparation or personal hygiene in hospitals, but also for diagnosis and treatment. Some potential sources of infection are: respiratory/ inhalation equipment, hydrotherapy, contaminated water (used in cleaning, wounds, entry catheter points, oral hygiene), endoscopes, dialysis, contaminated disinfectants, water dispensers, toilet flushing, dish washing, bathing, humidifiers, condensers, fire systems, fountains, bottled water, and many others. On the other hand, potential routes of exposure include ingestion, (e.g. contaminated drinking water, food prepared with the latter, etc.), contact with water, (e.g. immersion), aerosol inhalation, (e.g. flushing toilets, showers, taps fountains, spas, jet washers, hoses, sprinklers, etc), and specialised water therapy devices, (e.g. podiatry, whirlpool, audiology tissue debridement equipment). The WHO has compiled a list of stakeholders that most likely influence/compromise water safety. This includes, among others, construction workers, developers, architects, manufacturers, suppliers, building users, service providers, infection control hospital teams, regulators, public health officials, certifiers, and those providing training and laboratory analysis. While there are many regulations on the quality of drinking water based on the lifetime health effects on the general population, no account is taken of people with increased susceptibility to infection, insufficiently broad water quality indicators are used (e.g. do not include the opportunistic pathogens), and there is a lack of guidelines covering all the different healthcare settings. With this in mind, the WHO has developed Water Safety Plans (WSPs) for preventing or controlling the risks through system assessment, monitoring, surveillance and management/ communication, so that health outcomes can be improved, i.e. a systematic approach is required to secure microbial safety. Implementation of WSPs in healthcare should take into consideration the water quality for each type of risk patient (susceptible), purpose, system or equipment. From this, the IFOWAHB in turn has produced guidelines and recommendations on using and developing targeted WSPs for all water used within healthcare buildings/facilities intended for human consumption, patient treatment, diagnosis and nursing. Thus, a risk-management approach is ensured for microbiological safety of water, and that good practices are established in local water distribution and supply. Some examples of Cfu/L targets (colony forming units) for various risk category groups from various European countries were given, ranging from <50 – 1,000).

The implementation of a WSP in healthcare premises was then described in some detail, covering all identified aspects of safety and needs, with the first step being the setting up of a suitable qualified water safety management team. The IFOWAHB recommendations include the design, construction and commissioning of water systems and equipment where additional factors were also considered, such as quality/availability of alternative supplies, reliability of power supplies, availability of chemicals/materials/ laboratory facilities, as well as trained staff/training programmes, communication systems, and emergency procedures. Account is also taken of the different situations existing in developing countries with poor infrastructure and harsh environments. Areas not covered are in sterile water used for injections, wound/tissue treatment, and for drinking, as quality standards are already described in the International Pharmacopoeia. Also, there are no accepted quality limits for technical waters, grey water nor recycled water.

In conclusion, the IFOWAHB has developed healthcare guidelines and recommendations on water safety management based on the WHO approach which accounts for consumption by all patient types, together with diagnosis and treatment. Responsibilities, documentation, training and communication systems are defined and strategies put forward on what is both reasonable and practicable, based on an acceptable level of risk and cost.

Risk assessing hospital water systems for opportunistic pathogens including *P. Aeruginosa*: the water safety plan approach. It has long been recognised that water systems and water containing equipment have been the source of waterborne infections in healthcare facilities. Until recently in the UK, the emphasis has been on *Legionella* and focused on distributed drinking water. Following the outbreak in Belfast which caused the deaths of babies from *Pseudomonas aeruginosa*, there is a heightened awareness that opportunistic pathogens other than *Legionella* may colonise systems/ equipment and cause harm to vulnerable patients [34]. It is known, for example, that 40% of all *Pseudomonas* infections in intensive care units can be traced back to the water pipe system.

Microorganisms are common in drinking water, even when it meets the highest regulatory standards; however, the majority are considered normal background flora (TVC) and do no harm to the population in general. Opportunistic waterborne pathogens, even when present, also usually cause no harm, e.g. *Pseudomonas aeruginosa* or *Legionella*. Rarely can infection result from water use in healthy individuals, e.g. keratitis from washing contact lenses in water, but they can cause serious disease and death in some patients, such as those highly susceptible to infection – the severely immunocompromised, neonates, the elderly, and diabetics. In addition to those pathogens mentioned, others include those that are Gram negative, such as: *Stenotrophomonas, aeromonas/maltophilia*, *Halomonas*, *phocaeensis sp. nov*), fungi (e.g. *Aspergillus flavus, Fusarium spp.* [35, 36, 37], and Non-Tuberculous Mycobacteria (NTMs; [38, 39].

Provision of water in healthcare facilities should be safe for all types of use and type of patient, however, many opportunities can arise for contamination of water system; for instance, exogenous hazards, such as a faecal contamination event from salmonella, *E.Coli 0157*, *Cryptosporidia*, *Giardia*

etc. Indigenous hazard organisms which occur naturally and grow naturally within water can be pseudomonads like *P. Aeruginosa, legionella*, and NTMs. These may be introduced from mains water or ingressed during building, maintenance, alterations, repair, cross connections, backflow, siphonage, and introduction of new components. Polymicrobial infections can arise from cool water used in burns first aid treatment [40], and waterborne pathogens in healthcare may also be a reservoir of antibiotic resistance [32, 33]. Chemical hazards are mainly from copper, lead or cadmium as a result of corrosion or leaching of system components.

Hazardous events described in the previous section are defined by the WHO as being where RISK is 'the probability of injury, disease, or death under specific circumstances'. The European Union (EU) has a legal requirement for conducting risk assessment, serving as a useful enforcement tool, which are incorpratedinto UK law and approved codes of practice and guidance (e.g. L8, BS 8580). The WHO developed a WSP which takes into account the WHO Guidelines for Drinking Water Quality and potential; the sources of infection have already been discussed in the previous section. There are 5 steps to risk assessment of the UK framework for controlling Legionella and other potential pathogens, adopted by the Health and Safety Executive (HSE), and include Health-based targets (e.g. Nos. of *Legionella* cases per system, water temperatures, levels of biocides, such as chlorine and *Legionella* at <100cfu/L etc). The WSP are there to prevent or control risks, and include system assessment, monitoring and management and communication. Following on surveillance, the results then lead to whatever the Health outcome turns out to be – hopefully a reduced incidence of waterborne infections. The actual Risk assessment process is according to 80/1107/EC, 88/642/EC and WHO 2001. For each hazard identified (bacteria/toxin or chemical), assessors must ascertain the ability of the hazard to survive in the environment, the potential for hazard increase per given system, microbial hazard virulence, dose required to cause infection, length and frequency of exposure, and susceptibility of the individual.

Essentially, there are 4 types of health-based targets based on the latest WHO Guidelines for drinking water (4th edn., 2011). Firstly, there are the health outcome targets, primarily applicable to reducing microbial hazards by a quantifiable reduction in disease incidence, where opportunistic pathogens result in a measurable and significant burden of infection. Then there are water quality targets for individual water constituents that represent a health risk, and are expressed as guideline concentration values. Performance targets are technology-based for generally preventing infection, and finally specified ones applying to devices/processes/situations identified to be crucial in any given water system. In order to carry out these often complex risk assessment procedures, a multi-disciplinary team must be assembled with a team leader who has overall responsibility, which includes risk communication. Frequently, complex buildings require specialist assessors. As well as in dealing with potential microbiological hazards, WSPs are working documents that should be updated and reviewed annually, especially in cases where there are changes made to the water system.

Preventing waterborne infections – optimising infection control practices. The presenter described the above as it is adopted in France. The talk was divided into Risk Assessment (including hazards and the epidemiology of waterborne outbreaks), and Risk Management (including prevention and control), in order to enable the development of the most effective strategies for prevention.

There are many reports of nosocomial waterborne outbreaks (hospital-acquired infections), of which in France the 2 most notorious cases were Legionellosis at the Georges Pompidou European Hospital, and Osteomyelitis, M. *xenopi* at the Clinque du Sport, both in Paris. Genotyping in these examples was found to be difficult for making a precise attribution of cause. In developed countries, the microorganisms most responsible for nosocomial infection are: Gram negative bacteria (*Pseudomonas, Xanthomonas, Acinebacter*, KES, *Legionella* and *Yersinia*), Gram positive bacteria (*Listeria*), Mycobacteria, Viruses, Fungi (*Aspergillus, Fusarium*) and Amoeba. Ways of transmission are associated with the following bacterial types, oral route – (*Pseudomonas aeruginosa, Aeromonas species {spp}, Campylobacter spp*), respiratory route – (*legionella pneumophilia*), and the cutanaeous exposure – (*Pseudomonas aeruginosa*). Other water-associated nosocomial pathogens under discussion were: *Legionella spp, Pseudomonas spp, Burkholderia cepacia, Ralstonia picketti, Stenotrophomonas maltophilia, Serratia spp, Acinetobacter spp, Enterobacter spp, Rahnella aquatilis*, atypical Mycobacteria, and other amoeba associated bacteria.

Some case reports were then presented: a major 7-year study [41] performed in 2 hospitals on severe nosocomial pneumonia requiring ICU admission (16 and 20 beds, 67 cases), showed high mortality associated with the most frequently isolated pathogen *Pseudomonas aeruginosa* – 51% of the patients developed septic shock and 53% died. Chronic obstructive pulmonary disease was linked to poor prognosis. A review of hospital water supplies revealed them to be the sources of nosocomial infections [42], and showed 43 outbreaks in the USA between 1966-2001, with 1,400 deaths due to *Pseudomonas aeruginosa* alone. New and appropriate guidelines and preventative action, such replacing hospital water with sterile water, were recommended. Further USA studies showed that prevalences of >40% and >30%, respectively, in ICU and normal wards of water associated nosocomial *P. Aeruginosa* infection [43], where those patients infected had a significantly longer hospital stay compared to controls (median of 51 vs. 3 days). A 3-year investigation [44] was conducted at another major USA teaching hospital ICU on 98 intubated patients, where overall 53 presented colonisation with Pseudomonas aeruginosa and 30 was located in the trachea; 31 patients acquired ICU colonisation of which 10 occurred at intubation; and *Pseudomonas aeruginosa* was found in 62% of tap water samples from the patients.

It was concluded that early identification followed by eradication plus infection control measures are the key measures in preventing pulmonary infection. The risk assessment process consists chiefly of hazard identification, dose-effect/response functions, exposure calculation, risk calculation (according to various scenarios), and determination of limit values (derived from acceptable, no risk levels, etc). However, there are limitations, such as some hazards not being well described, an absence of knowledge about dose response function, various risks from the same exposure (e.g. differences in immunological status), and conditions of exposure.

Risk management covers issues on what is an acceptable level of risk, and the principles of prevention and precautionary. There are a large number of important questions that need to be addressed for these 2 processes, among them:

1. Which hospital waterborne pathogens are relevant, how are they transmitted, where do they come from, how and why do they persist?
2. What is the role of disinfection, plumbing and sanitation systems, clinical, epidemiological and economic consequences?
3. Which legal requirements exist/are developed, technical and monitoring strategies?
4. What are the microbiological criteria?
5. How effective is disinfection and point of use filtration, outbreak management and sampling strategies together with clonal identification in isolates, (from an outbreak or the environment)?

Despite the introduction of pathogens into the plumbing (such as *Legionella, P. Aeruginosa*, enterobactor or fungi) at low concentrations, if the conditions are favourable then biofilms will build up. Factors encouraging this include temperature (>20 – <55 °C), stagnation, (several days), plumbing materials, nutrients or that there have been no disinfectants used like chlorine, chlorine dioxide or monochloroamine.

The French guidelines follow those of the WHO Drinking Water Guideline of 21 September 2004 concerning healthcare facilities, as well as large buildings where cfu/L limits are defined for individual locations. Preventing infection requires acceptable water quality intended for consumption, a suitably planned and constructed plumbing system, avoidance of biofilm formation when plumbing is fitted, appropriate water management, i.e. no stagnation, appropriate flow, temperature and disinfection; monitoring, e.g temperature, microbial indicators, and point-of-use filtration at high risk areas, and sanitation.

The Hazard Analysis and Critical Control Points (HACCP) system described elsewhere in depth [45] was then considered, which is widely used in both the food and pharmaceutical industries and could be adopted to water safety. Although the system is excellent from the legal and pedagogical viewpoint, outstanding issues nevertheless need to be accounted for, such as immunological status, outdated microbial target alert levels, inadequate faecal indicators, non-standard analytical methods, viability of non-cultivable bacteria and avoidance of cheap and unvalidated methods. Key analytical requirements are specificity, sensitivity, detection and quantification limits.

In France, the cfu/L target and alert values for hospitals are set at <1,000 and >1,000, respectively. For hospital immunocompromised patients, the target, alert and maximal cfu/L values are set at absence of *legionella*, 250 and 250, respectively. The incidence of Legionnaires disease has seen a constant increase in France (measured per 100,000 inhabitants), from a plateau of <0.2 between 1988-1996 to a peak of 1.3 in 2005, followed by a decrease to 1.0 in 2009. Comparative data of exposure to Legionella in a French region, between travel sources and hospital sources, showed that in 1998 the exposures were roughly comparable at 60 and 80, respectively, but between 2004-2008 changed markedly to 75-87 and 218-253, respectively. This indicates travel as now being a more serious culprit, as well as showing that *Legionella* is now more controlled in hospitals. Several studies [46, 47] have illustrated the effectiveness of various solutions in limiting Legionella infection, such as point-of-use filtration for high risk patients, and other comprehensive multi-barrier approaches coupled with appropriate advanced planning, facility remodelling, reconstruction and disinfection.

In conclusion, developing the most effective strategies needs to include strong education as the link between nosocomial infection and waterborne pathogens is only recent, awareness by healthcare professionals that plumbing and water outlet systems are an important reservoir for infection, and that complete prevention of waterborne pathogens is impossible; however, the risk can be minimised by filtration and disinfection. Control over systemic contamination of the plumbing is essential where flushing-out is inadequate, and where non-touch fittings have now also been identified as sources of *P. Aeruginosa* and *Legionella spp,* and therefore should be reduced or eliminated.

Monitoring hospital water systems. In order to achieve and maintain control over water systems at safe levels in healthcare facilities it is vital that microbiological monitoring is performed. The presentation in turn considers, from the perspective of the UK Health Protection Agency (HPA), issues on why and what to monitor, and some practical aspects concerning *Legionella, Pseudomonas aeruginosa,* endoscopy rinse water, and hydrotherapy pools.

Monitoring water quality is necessary not only in identifying risks and being part of risk assessment, but ensures compliance with statutory regulations/guidelines, and demonstrates due diligence and assists with investigations of any problems arising. It does not, however, replace ongoing management of water systems. Areas that require monitoring are hot and cold water systems for *Legionella,* augmented care wards for *Pseudomonas aeruginosa,* and waters used for endoscopy rinsing, hydrotherapy and renal dialysis. In the case of *Legionella,* the Approved Code of Practice (L8-2000) requires that the sources of risk are identified and assessed, a scheme is prepared for risk prevention/control, monitoring control measures are introduced (including testing for bacteria), records of controls are kept, and that a person is identified who is responsible for water management. Monitoring of *Legionella* is essential where water temperature is inadequately controlled, insufficient biocides are used, in high risk wards, and when outbreak/cases are suspected. In addition, cooling towers/condensers, respiratory devices and humidifiers should be monitored. Although for *Pseudomonas aeruginosa* it is normal to find low numbers in water systems, 'at risk' groups have been linked to infection through colonisation of this bacteria. Water outlets from which water makes contact with patients, staff hands or equipment in contact with patients, should all be initially assessed through monitoring. This should be performed every 6 months thereafter if results are satisfactory, but earlier if results indicate otherwise, in clinically-suspect cases, or if refurbishment has taken place.

The UK Department of Health (DoH), has guideline actions related to various Cfu/100ml levels that may occur: 0 – statisfactory; 1-10 – requires a retest, and reference back to those responsible for the WSP to determine what actions are required, including a risk assessment in the use of water; >10 – requires the cause to be investigated and corrective actions implemented, as well as considering a survey of the water system and further sampling. If the pre-flush and post-flush

levels are respectively >10 and < 10, then this suggests a local outlet problem. If, however, pre-flush and post-flush systemic problem is suggested. Procedures for decontaminating endoscopes should consist of manually cleaning the channels with a fine brush, high level disinfection (traditionally gluteraldehyde), rinsing to remove residual disinfectant, and forced air drying. Automated washer disinfectors are now available for these stages.

Some examples of recent outbreaks and their causes were mentioned, for example, in bronchoscopy procedures the infective organisms were in turn *Legionella* (1997), *M. Tuberculosis* (1997), *Pseudomonas aeruginosa* (2000), *Mycobacterium chelonae* (2001), and *Mycobacterium gordonae* (2002). The respective causes were contaminated rinse water, inadequate cleaning, inadequate maintenance of washer/disinfector, biofilm contamination of washer/disinfector, and failure to maintain and change washer/disinfector filters. Furthermore, in 2010, a *Klebsiella pneumonia* outbreak occurred in an Endoscopic Retrograde Cholangiopanceatography (ERCP) procedures due to inadequate cleaning of channels and a M. Chelone outbreak in 2006 during laparoscopy was due to contaminated rinse water.

A 'Health Technical Memorandum 2030' from 1995 has set some standards in endoscopy washing where using sterile water is stipulated, as well as other issues, including finding no bacteria in twice 100ml weekly testing, and no mycobacteria in 100ml for annual testing. The European Standard ISO 15883-4:2008 requires the absence of *Pseudomonas aeruginosa,* atypical mycobacteria and *Legionella spp* where for the latter a 10 day test is needed on 1 litre of water. Hospital water management system should also include control of *Legionella*. Some methods of removing bacteria are by filtration, UV light, an antibacterial agent (superoxidised water/ozone), using sterile water and reverse osmosis. In the latter, this removes chemical and microbiological contaminants, but the membrane will start to deteriorate from the first use, and water purity will deteriorate if regular checks and maintenance are not carried out. Failures can also be avoided by using additional 0.2µ filters, regular filter changes, daily disinfection and biofilm removal. A 2004 review conducted on 20 endoscopy units in Southampton, UK, tested 418 samples in 4 months, of which 62% were unsatisfactory, 51% were due to aerobic bacteria, and 32% due to mycobacteria. No units had achieved sterility in every sample tested.

A question now arises as to what level of bacteria counts as a problem? ie. any bacteria at all, a high level of bacteria, only Pseudomonas, only mycobacteria or endotoxin and when should we stop using the machine? The experience of the HPA is that throughout the UK there is generally a poor understanding of how water contamination relates to patients, and that outbreaks/pseudo-outbreaks are largely due to gross maintenance problems of washer/disinfectant. Some HPA studies, however, suggest that the rate of pathogen transmission during gastrointestinal (GI) endoscopy was 1 in 1.8 million, and follow-up studies of frequent bacterial contamination did not indicate any clinical complications. Overall sterility is difficult to achieve and corrective actions are time-consuming and expensive. There is also a danger that some negative monitoring findings may lead to complacency as problems may exist in places not considered; therefore there is a need to focus attention on the real problem areas. HPA working guidelines on Aerobic Colony Counts (ACC) (cfu/100 ml), recommend the following actions; 0 – satisfactory, 1-9 – acceptable, and indicates reasonable level of control, 10-100 – unsatisfactory; necessary to investigate potential problems and superchlorinate with 10,000 parts/million), >100 – unacceptable; necessary to take washer/disinfector machines out of use until water quality is improved. When interpreting results, the identification of isolates is not generally recommended, and the ACC is an indicator of treatment efficacy, but not a way of finding the pathogenic microorganisms present.

Various common sense guidelines were outlined on how to react when failures occur, and also the appropriate places on where to sample during an investigation, making sure that the samples are subsequently stored properly in containers prior to analysis. An example of an endoscopy water system was also described which consisted of mains water to break tank to softener to water treatment unit before being used in the washer/disinfectant machines. The elimination of biofilms was stressed wherever they occurred, ensuring new water systems or equipment free of biofilm are put to use immediately, that there is a regular maintenance/disinfection programme in place, and that biofilm is removed physically by abrasive cleaning or pipework replacement whenever it occurs. After decontaminating the endoscopes, drying is important otherwise the contamination risk increases [48]; filtered air is recommended instead of the previously used isopropyl alcohol; according to the British Society of Gastroenterology. Channels should, however, be rinsed with sterile water just before use.

The procedure for the daily monitoring of hydrotherapy pools were described – temperature, pH ±disinfectant, and weekly maintenance – filter back-flushing, together with microbiological monitoring – to be performed twice weekly, before first use, and after periods of shutdown. Guideline levels of ACC/ml at 37°C for taking action, were as follows: >10 –borderline; necessary toresample if coliforms/E. Coli also present, >100 – unsatisfactory; necessary to investigate immediately. Coliforms should be absent. *Pseudomonas aeruginosa* in 100 ml; 1-10 – borderline; necessary to re-sample, >10 – unsatisfactory; necessary to investigate immediately, and >50 – unacceptable; necessary to close the pool. Tests for *Legionella, Cryptosporidium* or *Girada* are only performed if adverse effects are associated with pool users. Recommended actions were also outlined for pool failures. These and other guidelines can be accessed from the HPA site in [49].

In conclusion, microbiological monitoring is needed for water system control where regular maintenance of tanks/pipes/taps avoids biofilm build-up. Early intervention is required where results indicate problems, and good communication is desirable between estates, infection control and contractors.

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