RSPH
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RSPH Water Webinar Series 2014

# Water Hygiene in Buildings

Supported by an Educational Grant from PALL Medical

# Acknowledgments

Reported by Dr Rosalind Stanwell-Smith, Deputy Editor, *Perspectives in Public Health,* in partnership with the RSPH Water Special Interest Group

**Educational partner**

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**Programme director**

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**This series was supported by**

# About the series

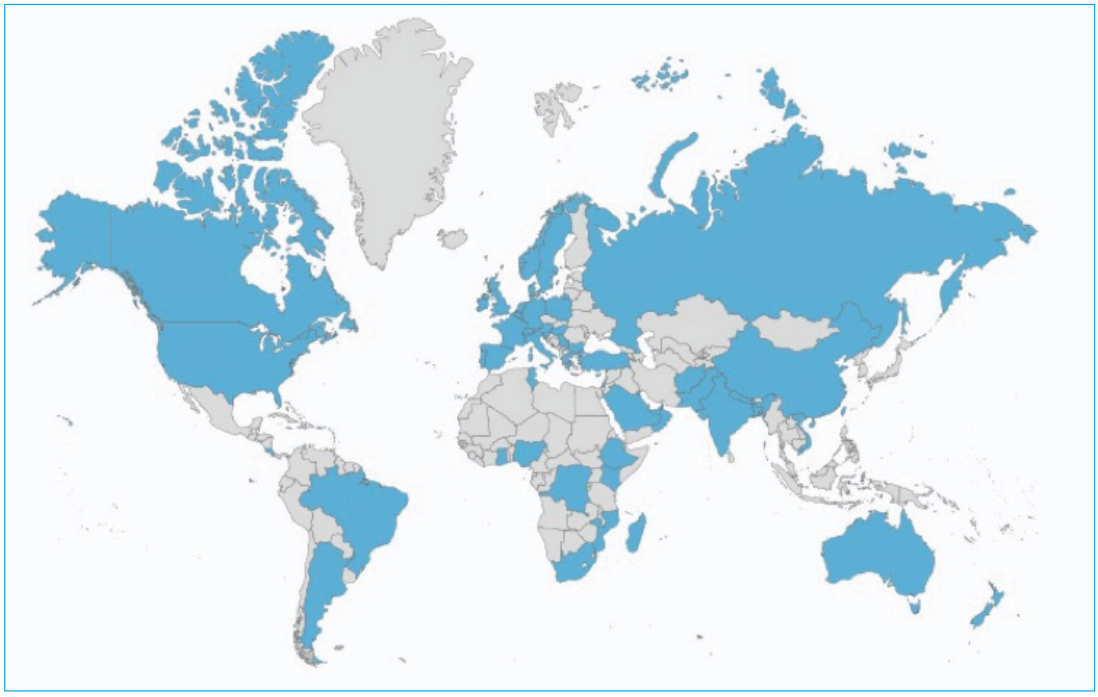
With over 3,500 registrations from 68 countries and every continent the series has had global impact.

Running throughout 2014, these 11 webinars brought together experts to debate issues and share best practice on international aspects of water hygiene. Live and free to access, continuing professional development (CPD) points were available following each webinar. This document provides a short synopsis of each webinar and is an ideal learning resource.

The RSPH would like to thank all those involved in creating and delivering the series of water webinars. Our particular thanks go to Program Director Dr Susanne Lee, the RSPH publications team, the RSPH Special Interest Group for Water, and to Pall Medical for their support via an educational grant.

The series was an excellent educational opportunity for: health professionals; facility management personnel; water consultants; clinicians; health authorities; healthcare and consumer water engineers; microbiologists; laboratories and students.

Figure 1: **Countries reached (in blue) by our 2014 webinar series**



Following the success of the 2014 webinar series, we are continuing our water hygiene education programme with a further Summer Series of Water Webinars in June 2015.

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# Water Safety and Water Safety Plans: A Global View

## 22nd January 2014

**Professor Jamie Bartram,** Don and Jennifer Holzworth Distinguished Professor, Department of Environmental Sciences and Engineering and Director, The Water Institute, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, USA.

Chaired by Dr Susanne Lee, Director of Leegionella Ltd and Chair, RSPH Water Special Interest Group, UK.

The first webinar in this innovative series heard Professor Jamie Bartram, who has worked with water in the UK, internationally at the WHO and now at the University of North Carolina, give a lucid and informative presentation on water safety and the framework for safety plans (WSPs).

There are still many people in the world without access to safe water, although access has improved since setting the millennium development goals in 2001. This is estimated to have reduced diarrhoeal disease around the world by 42% since 1990. There is some debate about how many people in the world still have an unprotected water source (37% in 1990, according to a study) and the deaths still occurring due to diarrhoeal infections indicates the scale of the problem: a global total of 1.5 million annually, including 33,000 even in developed countries in 2010.

Not all diarrhoeal infection is waterborne and water contamination causes other health problems, of course, but diarrhoea dominates and is more amenable to international surveillance. Surveillance detects only a fraction of these cases as the majority goes unreported. Professor Bartram emphasised that water safety needs to be considered alongside sanitation and hygiene - and in response to a question agreed that the progress made in water safety needs next to be matched by plans for assessing and improving sanitation.

Implementation of WSPs has been shown to reduce diarrhoeal disease: a study in Iceland, comparing rates of community diarrhoea before and after implementation found a statistically significant reduction linked to compliance with WSPs by water utilities. Community levels of pneumonia did not differ after introduction of WSPs, further supporting the evidence. It is interesting to speculate how many of the estimated cases of diarrhoea in other developed countries could be reduced by further implementation of WSPs.

**The principles of the Framework for Safe Drinking Water and the concepts and stages of a WSP were outlined in detail. The philosophy includes:**

- **Having measures in place to prevent contamination and not waiting for an incident to occur;**
- **Using a multiple barrier approach, so that the failure of one control measure does not compromise safety;**
- **Having robust management systems in place;**

**And, importantly:**

- **Every improvement is worth the effort and helps to improve public health.**

## Water Safety and Water Safety Plans: A Global View

A strong case was made for application of WSPs to water systems within buildings to improve water safety. Members of RSPH can access the useful slides on the RSPH website.

At the national level, each country needs health based targets and independent surveillance systems to back up and monitor WSPs. Monitoring does not just refer to water sampling but to checks all along the distribution system from water source [catchment] to the users and consumers, such as measuring changes in water pressure, levels of residual disinfectant in treated water and the integrity of storage systems. Each potential hazard needs to be identified, prioritised as to its likelihood and linked to ways to mitigate the risk – comparable to the HACCP system for food safety. A single cross connection can cause an outbreak, so the level of detail required when designing, constructing and maintaining systems is challenging, but achievable.

Professor Bartram made the case that WSPs also need to include contingency plans not just for predictable failures, such as power cuts and equipment failures, but also for major weather events, including floods, droughts and storms. In his conclusions, Professor Bartram mentioned the need for assessing the ability and willingness of institutions to adopt the WSP approach in order to be able to integrate the concepts of Water Sanitation and Health. Global targets for WSPs can be translated down to urban and the generally more risky rural supplies, and from there to households and the many types of buildings, not least hospitals with their range of water supplies for specific treatment areas. We have moved beyond a reactive approach to water safety: WSPs help to prevent hazards by asking the simple question at various points “Is the system working?”

## Discussion points from the question and answer session:

Questions included the role of plumbers in water safety: it was acknowledged that the contribution of well trained and competent plumbers, as well as water treatment specialists, are essential components of ensuring safe water. Other points made by participants referred to the need for WSPs to include minor water systems in hospitals, such as in treatment areas, safety aspects of grey water systems and city level sanitation plans.

# Waterborne Pathogens in Urban Areas: Myths, Presumptions and Facts

## 19th February 2014

**Dr Sebastian Crespi,** Head of the Clinical Laboratories at Hospital Policlinica Miramar in Palma de Majorca, Spain and President of Biolinea Int.

Chaired by Dr Catherine Whapham[1], Global Marketing Manager for Healthcare Water, Pall Corporation and member of RSPH Water Special Interest Group, UK.

1. The previously announced chair for this session, Professor Rodney Cartwright, was unable to take part.

This second presentation in the RSPH Water Webinar series considered the controversial topic of controlling waterborne pathogens in the urban setting. Dr Sebastian Crespi, with extensive experience of research and of advising on water quality in a wide range of locations, introduced the dilemma of providing definitive guidelines when the evidence base is inadequate. He cited the clinical example of fully correcting anemia in chronic kidney disease as well intended, but insufficiently researched: it was eventually proved to be harmful.

For water, myths and presumptions have often led to inappropriate conclusions or ineffective control regimes. In the early days of water treatment, it was commonly – and incorrectly - held that chlorine was effective against all water pathogens: a more persistent myth [a belief held despite substantial evidence against it] was that tolerance or resistance to chlorine does not develop. Presumptions – [unproved propositions] – are harder to deal with, since they may be true but the evidence is either absent or inconclusive. For example, the presumptions may be based on laboratory experiments or other partial evidence rather than real life scenarios. Examples of presumptions include the often stated 50-60C  temperature range as more effective than 40-50C  for *Legionella* prevention in hot water systems; and that counts of *Legionella* bacteria in water samples can be used to assess the risk of infection. The lesson here is that the evidence base must be critically examined. While controlled trials and well-conducted meta-analyses provide the highest quality evidence, evidence based on case studies, expert reports or in vitro research hold the lowest place in the ranking.

The story of chlorine disinfection of water tends to be presented as a revolution, dramatically reducing, for example, the death rate for typhoid fever. It played a major part, but we now know that other factors, such as safer sanitation and milk pasteurisation, also contributed to the decline. The disinfection activity can be expressed as the product of chlorine concentration and contact time (the CT factor, based on Chick's Law). *E.coli* is quickly inactivated at low concentrations (CT <0.25), but other pathogens such as *Giardia* (CT 37-368) may require prolonged contact times at higher chlorine residuals. *Cryptosporidium* (CT 15300) is highly resistant and requires impractical concentrations and/or contact times. In the real world, Chick's Law conditions are very rarely met. Turbidity – water cloudiness due to the presence of particles – and total organic carbon content increases chlorine demand.

# Waterborne Pathogens in Urban Areas: Myths, Presumptions and Facts

Another key point is the presence of the biofilms: complex mixed populations of microorganisms and organic matter lining water pipes and sanitary fittings that make the disinfection more difficult. Many virus species, despite relative sensitivity to chlorine, may survive extended exposure within cells or organic matter. *Hepatitis A* – a common cause of infective jaundice – is a good example of an organism shown to be readily destroyed by chlorine in the laboratory when freely dispersed in water, but much less effectively when embedded within protective cells, as usually occurs in nature. The organism responsible for cholera, Vibrio cholerae, illustrates the problem of resistance against chlorine. The rugose form of *V.cholerae 01*, a mutant variant, is much more resistant to chlorine (CT 40) than the smooth strain (CT < 0.5). The rugose strain has a greater facility to form protective clumps and thick biofilms, thus preventing access by chlorine.

Large waterborne outbreaks still occur due to pathogens surviving into the final treated water: the *Cryptosporidium* incident in Milwaukee, US in 1993 caused an estimated 403,000 people to have watery diarrhoea after consuming the municipal water. Contributory factors included decreased filtration efficiency at one of the municipal plants combined with deterioration in raw water quality caused in part by sudden melting snowfall. This and other incidents have underlined the importance of the multiple barrier concept of water treatment, including adding coagulant to remove organic particles, several stages of filtration and addition of disinfectant, as well as monitoring the stages carefully via turbidity and disinfection goals.

As for the case of *Legionella* levels, the dose-response curve has not been established and the infective dose is not known. Apart from rare cases acquired via aspiration of contaminated water, *Legionella* infection is usually acquired via airborne droplets, yet the potential for aerosol generation for each water system is variable and hard to predict. Also, it is known that environmental *Legionellae* present a wide range of virulence. Thus any risk assessment for *Legionella* must be qualitative rather than quantitative. International variation in critical limits for corrective actions on *Legionella* contamination of domestic water - and even more so for cooling towers - raises the question of how we derive microbiological risk levels: also how well we understand the distribution and survival of the organisms in water and interpret results.

# Waterborne Pathogens in Urban Areas: Myths, Presumptions and Facts

The use of high temperatures as a potential preventive strategy is based on a well-recorded experimental fact in the laboratory: *Legionella* dies quickly above 60C . However as the risk of scalding at 60C is very high, a compromise temperature of 50-60C is generally required in guidelines. But recent laboratory experiments confirm that at, 50C , the reduction of *Legionella* is quite low and that in the range 50-55C reduction rates are far from good. Some studies both in hotels and hospitals have shown a negative correlation between higher temperatures and positive *Legionella* results, but almost always in the range 55-60C . There are neither controlled trials nor case control studies confirming the superiority of the 50-60C range.

This is not merely an academic problem, since the matter of effective temperatures has both health and cost implications, for example in avoiding scalds from hot water and reducing energy use. Paradoxically the premature release of regulations can prevent undertaking further research on the problem. For example, in the hotel trade, which hotels would want to take part in a trial keeping temperatures at 40-50C , knowingly exposing visitors to lower than recommended standards? A certain tension between action and evidence is necessary. But in the end it is scientific evidence that is essential.

The two key messages from this fascinating and thought provoking presentation were, first, the need for conducting the necessary research to be able to validate or reject the main unproved recommendations and, second, the need to prepare evidence-based guidelines. The longer we take to get there, the longer it will be before we have the most effective and appropriate solutions for preventing water-borne diseases. Ending on a positive example, Dr Crespi cited the meta-analyses of trials that indicate the value of improved water quality, hygiene and sanitation in the reduction of diarrhoeal illness.

## Discussion points from the question and answer session:

Questions from webinar participants included the problem of who should take the lead in producing better guidelines. Dr Crespi emphasised that it is not who, but how these guidelines should be best produced – using an evidence base approach. Asked to comment on turbidity control and a two-stage chlorine treatment approach, Dr Crespi advocated turbidity control as the first line intervention, followed by other treatments. Similarly, regarding heat versus chlorine to inactivate *Legionella* bacteria, he commented that both have pros and cons. As an emergency measure, raising the water temperature can be rapidly implemented, but delivering water at 70C for several minutes in any point of use in a single run is very complicated, if not impossible, in many settings. A combination of thermal-shock followed by super-chlorination may be the most effective measure, where feasible. But to this and similar questions he stressed the need to consider the unique circumstances for control measures within a particular system and that this means generally adopting a multiple barrier approach. Discussion also covered the emerging evidence on creating a healthier 'microbiome' within water supplies – a balanced microbiological environment – rather than simply attempting to eradicate the known pathogens. Viable But Non-Culturable Cells (VBNC) and vulnerable users in healthcare settings were raised, in particular, as current quandaries for water treatment: these topics will be explored in the next water webinars with Professor Kevin Kerr and Professor Hans-Curt Flemming.

# Problematic pipes and troublesome taps: protecting the vulnerable from waterborne healthcare-associated infection

## 26th March 2014.

**Professor Kevin Kerr,** Honorary Clinical Professor of Microbiology at the Hull/York School of Medicine and Consultant Microbiologist, Department of Microbiology, Harrogate NHS Foundation Trust, UK.

Chaired by Dr Tim Boswell, Consultant Medical Microbiologist/ Infection Control Doctor, Nottingham City Hospital, UK.

Professor Kerr has a specialist interest in the role of the built environment in hospital acquired infection and this webinar focused on ways of reducing infection hazards from the water distribution systems and outlets in health care settings. Modern clinical care facilities often have labyrinthine pipe systems and also subsidiary networks for equipment: keeping these free of opportunist or other pathogens is a challenge and one that always makes media headlines if it fails. Florence Nightingale famously enunciated that the very first principle of a hospital is that it should do no harm: Professor Kerr reminded us that a century earlier the Scottish surgeon John Aitken observed that a disease produced by a hospital was a great "contradiction in the nature of things." In their days the pipework was simple or non-existent and the germ theory was not established until the 1880s. We have the advantages of much more knowledge than either of these practitioners: so why does health care acquired infection (HCAI) still affect one in ten patients overall and every fourth patient in an intensive care unit?

Hand washing (and the lack of it) is still an issue and treatment zones abound with equipment and surfaces that can be readily contaminated and not easily cleaned. There's an assumption that the mains water is safe and free from harmful microbiological contamination. This is usually true of the water supplied to the hospital, but its tortuous and meandering distribution creates the opportunity for the many microbes to contaminate pipes, taps or the soaps and sanitisers. Complacency is not justified – as surveys of organisms detected in water samples within health premises have included bacteria known to cause illness, such as *Pseudomonas aeruginosa, Legionella pneumophila, Stenotrophomonas maltophilia, Sphingomonas spp., Acinetobacter spp.,* and *Klebsiella spp.* as well as a diverse range of environmental organisms. These may also be a potential infection risk if they reach vulnerable, immune-deficient patients. The proportion of immunocompromised people in the community is rising, estimated at almost 1% in a US survey in 2000. Onset and progression of an infectious illness in the immunocompromised may be rapid and difficult to diagnose, especially if the culprit is an environmental organism, where its culture may be attributed to chance contamination during specimen collection rather than to the water supply or via therapeutic equipment. Also these microbes are often not easily culturable or may be masked by other contaminating microorganisms. In addition there is increasing antibiotic resistance now affecting up to one third of P. aeruginosa isolates in European studies, leaving fewer treatment options available to successfully manage HCAI. Critical care patients are sadly "sitting ducks" for the opportunist attack of environmental pathogens.

# Problematic pipes and troublesome taps: protecting the vulnerable from waterborne healthcare- associated infection

*Pseudomonas aeruginosa* is a prime example of an environmental bacterium, which can cause a wide range of local and systemic infection in vulnerable patients. It is now ranked overall 5th as a cause of hospital-acquired infections taken as a whole, and 5th in surgical site infections. It is also the second commonest cause of ventilator-associated pneumonia and urinary tract infection linked to the use of catheters. *P. aeruginosa* colonies have the ability to form sticky biofilms that adhere tenaciously to environmental surfaces such as pipework and worktops. Its versatility extends well beyond tap water and it has been isolated from respiratory equipment, ice-makers, flower vases, toothbrushes, hydrotherapy pools, mop buckets, toys, contact lens cleaning materials and even disinfectants and hand sanitisers. *P. aeruginosa* is resistant to several of the antimicrobial agents used for serious infections in intensive care units. *Stenotrophomonas* species are less well known but are also highly successful colonisers of water and healthcare equipment. *Stenotrophomonas maltophilia* can cause severe infection in all age groups including the newborn. Clinical manifestations of infection are broad and include haemorrhagic pneumonia and bacteraemia, which can be complicated by ecthyma gangrenosum [an ulcerating skin condition].

The evidence for hospital water as a source of these opportunistic pathogens can be drawn from a series of investigations, particularly in neonatal and adult intensive care units (NICUs/ICUs) and transplant units. For example, in one *S. maltophilia* outbreak in a NICU, environmental sampling implicated only the tap water and control measures that were introduced involved the use of sterile water to wash infants, plus alcohol hand rub for staff hand hygiene. Bottled water was the vehicle for a *P. aeruginosa* outbreak involving six ICUs in a German hospital. The bacterium has also been isolated from bottle-fed drinking water dispensers, highlighting the potential for contamination of the ubiquitous water coolers in hospitals as well as elsewhere. Both coliforms and strains of *Pseudomonas* have been cultured from water outlets in wards and administration areas in hospitals and often in numbers TNTC [too numerous to count].

Prospective studies have been undertaken to estimate the risk to patients from contaminated water sources and to prevent outbreaks. In a 6- month French study *P. aeruginosa* was isolated from 11.4% of samples from patients' room's tap water and the route of transmission was identified from tap to patient and from patient to tap for 32 patients.

# Problematic pipes and troublesome taps: protecting the vulnerable from waterborne healthcare- associated infection

A detailed study in Spain identified *P. aeruginosa* in over 60% of tap water samples in the ITU and was associated with colonisation or infection in 31 patients over the 3-year study period. In this study, tap water was sampled three times a week and the use of genetic finger printing techniques identified that the genetic subtypes of *P. aeruginosa* acquired by the patients were in many cases the same as in the water samples.

**Professor Kerr outlined the ways to 'close the loop' on hospital acquired infection related to water:**

- **Traditional infection control**
- **High level of suspicion and surveillance**
- **Education and training**
- **Employing a comprehensive, risk management based water strategy [water safety plan]**
- **Technological solutions**

While traditional infection control methods cover the importance of hand hygiene and environmental cleanliness, surveillance is an essential tool to target specific measures. For example, surveillance may indicate a rise in environmental isolates or positive blood cultures so that an outbreak can be prevented. 'Suspicion' includes inspecting washbasin taps, removing aerators and replacing taps with non-sensor-operated devices that reduce the risk of contamination. Increasing staff awareness and eliminating unhygienic practices also helps to avoid outbreaks. A study of opportunistic infection in ITUs in Singapore entitled "Bad design, bad practices, bad bugs" neatly summarised the control dilemma and the need for education on good and bad practice. Frequent hand washbasin "misuse" (use of basins for disposal of patient secretions or to wash/rinse re-usable patient care items) was identified as a risk factor for colonisation of taps with the outbreak strain of *Elizabethkingia meningosepticum* infection. Resurgence of the outbreak, despite a campaign of education and awareness regarding the correct use of hand wash basins, was associated with a return to bad habits in hand hygiene and basin misuse.

A robust water management strategy should include all the water sources (e.g. ice-makers, bottled waters, drinking water coolers, showers) and also acknowledge that surveillance programmes should include a range of organisms, not just *Pseudomonas* species. Fungi such as *Aspergillus* and *Fusarium* can also contaminate water supplies, often with seasonal variation.

## Problematic pipes and troublesome taps: protecting the vulnerable from waterborne healthcare- associated infection

Technological interventions that can assist with control include: heat treatment of the water; taps designed to avoid contamination, selection of materials more likely to resist contamination and biofilm formation as well as point-of-use microorganism removal water filters. Although nearly all studies on this topic focus on nosocomial [hospital acquired] infection, it is important to acknowledge that contamination risk is not confined to hospitals, and healthcare facilities including dentistry and a range of other water-based treatments in community settings also merit attention. As for household domestic water systems, a water strategy should take account of the increasing proportion of vulnerable patients having care in their homes. Summing up, Professor Kerr concluded that there is a strong evidence base linking the hospital water supply and infections in high-risk patients. Control measures should be proportionate and include the development of water safety plans as part of an integrated strategy involving infection control, effective surveillance and good antibiotic stewardship. John Aitken and Florence Nightingale would no doubt have agreed: there is nothing new about hospital-acquired infection, just new and waterborne ways of acquiring it.

## Discussion points from the question and answer session:

Regarding the role of antibiotics in resistance, Professor Kerr commented on the need to discourage over-use or inappropriate prescribing. A study examining the effect of point of use water filters in Germany had resulted in the good 'knock-on' effect of reduced antibiotic use, because fewer infections occurred. The misuse of sinks prompted a question about how the pseudomonads and other organisms transmit from the basin plughole. Sink design plays a role here, in reducing the likelihood of splash back and formation of aerosols, although the microbes can also be transferred via splash onto surrounding surfaces, hands, droplets on uniforms and inappropriate cleaning practices. An example of the latter is if the sink drain/plughole is cleaned first and then basin and tap surfaces wiped with the same cloth, transferring the microorganisms to the tap with the potential for further spread to patients and staff. Also, use of an alcohol rub after washing hand procedures is advisable in order to combat the potential for contaminated water during final rinsing. Another question theme was where the water contamination might occur: regarding *P. aeruginosa,* Professor Kerr has found this to be in the last few metres of the water pipework system, particularly in showerheads and tap outlets.

# Problematic pipes and troublesome taps: protecting the vulnerable from waterborne healthcare- associated infection

**References/resources:**

Website for water sampling guidance: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/140105/Health_Technical_Memorandum_04-01_Addendum.pdf [This refers to *Pseudomonas aeruginosa:* information on sampling techniques also available from the SCA http://www.environment-agency.gov.uk/research/commercial/32874.aspx]

BS7592 specific advice on *Legionella* sampling http://www.cieh.org/uploadedFiles/Core/Membership/Regional_network/South_East_region/News_and_activities/Milton_Keynes_SAMPLING.pdf

Pre- and post- flush water samples can help to identify whether the colonisation is immediately in the tap area or further back in the system, since the post-flush samples should be negative if the contamination is only at the water outlets and samples have been taken correctly. Detailed information on this sampling can be found online [see websites below]. Thermal disinfection of the whole water system may be ineffective, since it does not address the problem of resistant biofilms in pockets within the sanitary fittings, components and adjacent pipework. While point-of-use water filters may be used as part of a comprehensive strategy, Professor Kerr commented that many units are fitting these routinely to limit the contamination risk at outlets. *S. maltophilia* is slow growing and bacteria with more rapid growth, such as *P. aeruginosa,* may mask its presence, therefore investigators should be aware that selective media (supplemented with a carbapenem antimicrobial), as well as longer and lower temperatures may be needed in order to isolate an environmental outbreak strain.

Finally, a pertinent question referred to the risk of waterborne infection outside the hospital or clinic. There has been little research into the risk posed by domestic systems, but Professor Kerr agreed that the rising level of home care for vulnerable patients is a potential emerging problem, not least in the economic dilemma as to who pays for filters or other preventive measures in domestic settings.

## The last meters to the tap – where drinking water quality is at risk

8th April 2014

**Professor Hans-Curt Flemming,** Head of the Institute, Biofilm Centre, University of Duisburg-Essen, Germany.

Chaired by Dr Rosalind Stanwell-Smith, Honorary Senior Lecturer, London School of Hygiene and Tropical Medicine, UK.

The water webinar series has previously touched on the problems of biofilms in water pipes and this lecture provided an opportunity to consider the nature of biofilms and the micro-organisms within them in more detail. Professor Hans-Curt Flemming and his team at the Biofilm Centre in Germany have been researching these extensively and he was the ideal expert to describe the problems and possible solutions.

There are many hazards needing control on the long route from water source, treatment works and distribution but most consumers would be surprised to learn that the weakest point is in the water installation in homes and buildings at the end of the water's journey. Before it arrives here, it travels along pipes comprising a range of materials that may interfere with water quality. These include the corrosion that occurs in iron pipes, providing a surface for microbes to gather, or the biofilm that collects and lines polyvinyl chloride [PVC] pipes. The term biofilm refers to a collection of micro-organisms, for example bacteria or protozoa such as amoebae, the cells of which stick together on a surface and produce a slimy polymeric substance containing extracellular DNA, proteins and polysaccharides. The microbial cells become further embedded in this substance, so that the biofilm constitutes a secure habitat for them. Biofilms can form on living and non-living surfaces and in a variety of settings.

The biological material derived from living or recently alive organisms is known as the biomass and is an important part of the ecosystem as well as an energy source: in the context of water distribution, 95% of the overall biomass is located in biofilms. The negative effects of these include: water phase contamination elevating the colony counts; sheltering potentially pathogenic organisms; leaching of biodegradable substances from the pipes; increased demand for chlorine; greater tolerance against other disinfectants; odours; brown discolouration of the water; and microbially induced corrosion. Biodegradable substances leaching from pipework and components may also increase the potential for biofilm growth. It is not all negative: the biofilm encourages degradation of dissolved substances that makes a positive contribution to water stability. The water phase – the body of water moving through the pipe – is constantly in touch with the various collections of biomass but we have little information on the site and extent of the biofilms and where the colonies have built up sufficiently to be likely to cause contamination of the water. Knowledge of the behaviour of biofilms with different types of material provides a clue: for example, inner coating and valves containing rubber or synthetic rubber may greatly encourage biofilm build-up, if not certified for not supporting microbial growth.

# The last meters to the tap – where drinking water quality is at risk

**Other factors that predispose to biofilm formation include:**

- **Water stagnation or low pressure in the distribution system**
- **Warm water temperatures**
- **Use of unsuitable materials**
- **Faulty or poorly designed construction of the system**
- **Deficiencies in the supply system, including 'wet' fire extinguishing pipes connected to the drinking water system and expansion tanks (pressure vessels) that incorporate a diaphragm**
- **Unsuitable operating and management methods.**

Water companies are responsible for abstraction, treatment and distribution of water but the design of the plumbing of buildings is beyond their control and is the responsibility of the building's owner. Yet most consumers view water quality at the tap as the responsibility of the water provider. The water installation system in many buildings, including homes, presents a veritable 'twilight zone' of problems: it may comprise a variety of materials, mostly uncertified and unrecorded, as well as dead legs in the plumbing and varying consumption patterns that affect the quality of the water. There is little control over the health implications of these systems and the surveillance information is scanty. We can estimate the potential problems from factors such as the smaller pipes, tendency for stagnation in parts of the system with associated effects on water temperature and the use of biofilm generating materials such as rubber, plasticizers or elastomeric coatings [polymers with the elastic properties of natural rubber]. The elastomeric coatings may include paraffin and pigments, which are a nutrient source for microbes. Water softeners, filters and silicon tubes are also a potential risk. The incrustations (scale) sometimes visible on taps and valves are heavily colonised by biofilms. These can utilise biodegradable matter from the plasticizer and other plumbing constituents, providing a high concentration of nutrients at the surface for the microbial colonies. In the example of a shower tube, Professor Flemming showed how the various materials made biofilm formation inevitable, with contamination by *Legionella pneumophila* and Pseudomonas aeruginosa as well as other micro-organisms. In another example of a tap in a school shower area, the tap comprised many small metal and plastic parts, increasing the surface area for biofilms to form and making it a nightmare for disinfection procedures. The tendency is for increasingly intricate taps with numerous plastic components and 'no-flow' areas. The consequent biofilms nurture amoebae, which absorb *L. pneumophila* organisms, leading to possible blooming of colonies. It's no surprise that the contamination of these systems, particularly by *L.pneumophila,* sometimes hits the headlines, especially if it affects interesting locations such as Buckingham Palace!

# The last meters to the tap – where drinking water quality is at risk

There are solutions: chemical disinfection has a role in killing or inactivating cells in the biofilm, although it is important to remember that this does not clean the system and that rapid regrowth may occur, because surviving bacteria are "cannibalising" dead biomass, which represents a good nutrient source. Point-of-use filters are effective, but they are an expensive solution suitable mainly for healthcare settings – and again address the symptoms rather than the core problem. If drinking water supplies were sterile it would reduce the risk, but this would be extremely difficult and expensive to produce and would remove constituents of water that are beneficial to health. Drinking water is not required to be sterile and, after removal of known harmful contaminants, it still contains bacteria and other organisms that are classed as non-pathogens. The bacterial content is determined by growth on agar media. The results are expressed as "colony forming units" (cfu) and are checked and maintained at an assumed safe level of culturable bacteria, but the recognition of latent states in these organisms has complicated the microbial picture. This latent or 'viable but not culturable' (VBNC) state means that a negative water test result does not mean that there are no bacteria present in the sample, as these VBNC bacteria do not grow on routine laboratory media: but they are alive, maintaining an extremely low rate of metabolism – and they can be resuscitated. The VBNC state is frequent for organisms within biofilms. The dilemma for water quality analysis is that standards are based on culturable organisms, as is the case for quality assessment in food, pharmaceuticals, disinfectants and hospital equipment. The cynical approach would be to point at the absence of proved outbreaks, but Professor Flemming has researched the implication of the presence of so many VBNC organisms in the water supply. This 'silent majority' can be roused by laboratory techniques, so the aim is to make sure that they do not easily resuscitate in the pipework. He and his colleagues have explored the way copper ions inhibit bacterial growth, for example of *P. aeruginosa.* Copper does not kill these organisms, but helps to inactivate them by inducing the VBNC state, which may then be reversed by adding copper chelators in the laboratory within around 14 days of copper exposure. Tests detecting presence of ribosomal nucleic acid (RNA) and adenosine triphosphate (ATP) indicate that metabolism is occurring within these cells: dead cells do not produce protein. Experiments have shown that the bacterial cell membrane may remain intact and that tolerance of copper concentration is higher for the VBNC organisms in biofilms.

Organisms can be encouraged to remain in the dormant VBNC state by limiting nutrients, lowering the temperature and introducing other stress factors such as disinfectants. The key to control is awareness that resuscitation can occur, with the potential to cause infection.

The underlying problem of these organisms could be compared with the volume of ice lying beneath an iceberg as opposed to what can be detected on the surface. How infectious are these troublesome non-culturable organisms that elude standard detection methods - and how fast and under which conditions will they resuscitate? Research is continuing as to their ability to attach to host cells and express virulence factors, as well as the extent to which the host environment allows resuscitation – and whether VBNC organisms stimulate the immune system or are a potential hazard to consumers with low immunity. Studies suggest that *P. aeruginosa* is only cytotoxic in the culturable state, not in the VBNC state, but this may be reversible and may not be the case for all potential waterborne pathogens. While we seek further evidence and more sophisticated culture methods to resolve these issues, we already know that the potential of the VBNC state reinforces the need to maintain safe distribution systems, including an important role for the consumer and more control and certification of household system components.

**Concluding this fascinating webinar, Professor Flemming outlined his key points:**

- **Biofilms are ubiquitous in drinking water installations**
- **Limitation of nutrients, such as organic carbon, is a means of control**
- **Plumbing materials need to be carefully chosen to deter biofilms**
- **Taps and other equipment attached to the water system should be optimised for avoiding "no-flow" areas.**
- **The VBNC state is a potential risk to human health, easily masked and possibly reversible to an active, infective state**
- **Disinfection and point-of-use (POU) filters are effective, but do not remove the cause**
- **For high-risk locations, 'culture-independent' methods should be employed to assess the level of VBNC organisms and, for future research, wide scale use of molecular methods is needed to provide a better database.**

## Discussion points from the question and answer session:

Questions included whether there is a commercial test available to run in parallel with conventional water analysis: a suitable commercially available test is based on flow cytometry, but it is expensive. The method incorporates stains that can detect DNA and intact cell membranes, thus distinguishing live from dead cells.

# The last meters to the tap – where drinking water quality is at risk

There are also tests to detect protein production and other signs of life. Suitable metal chelators that may be used to resuscitate VBNC organisms are still at the research stage in the lab, particularly for metals other than copper. Regarding ideal chlorine residuals, relatively low concentrations are sufficient to reduce the risk at the tap: the only alternative to disinfection is to reduce the level of organic nutrients and to ensure system design that minimises the potential for stagnation and that is constructed of biofilm-unfriendly materials. Coliform standards for drinking water and other technical issues need further discussion and there is no quick or simple answer in this emerging field of water science. Professor Flemming recommended a report from the American Academy of Microbiology (2013) on microbes in pipes, which gives an excellent overview and strategies for management, as well as commenting on the very limited epidemiological evidence that is currently available: [http://academy.asm.org/images/stories/documents/mip.pdf].

Regarding the design of the tap and whether a simple manual tap has advantages over sensor or other sophisticated designs, Professor Flemming agreed, because of the difficulty of trying to clean the intricate parts of 'advanced' taps. Traditional copper pipework is also a means of limiting biofilms, although PVC pipes are acceptable if they are of good quality and certified regarding protection against leaching of nutrients. Biofilms can form even on copper, so it is not necessarily the solution. Finally, there was a question about whether using traditional water sampling methods on their own is futile, given the large 'silent majority' than cannot be detected: Professor Flemming suggested that the most important element of water testing is to detect organisms that pose a threat to health. Rather than abandoning current methods, standard culture needs to be supplemented by tests based on the growing evidence of VBNCs. Testing for organic carbon should include the potentially degradable carbon content, with a suggested acceptable range of around 10 micrograms/litre of assimilable carbon. Disinfection alone is not the answer, since it should be combined with cleaning the system to remove the microbial colonies. Meanwhile, boiling the water is an effective means of destroying pathogens (although not the spores of Gram-positive organisms). It should be kept in mind that during heat treatment of water in the pipes, it is important to ensure that the elevated temperature reaches the entire system, while being aware that it will usually leave survivors.

# Design of hot and cold water systems

## 21st May 2014

**Dr Yusen E Lin,** Professor and Director of the Center for Environmental Laboratory Services, National Kaohsiung Normal University, Taiwan and Visiting Professor, University of Pittsburgh, USA.

Chaired by Dr Susanne Lee, Director of Leegionella Ltd and Chair, RSPH Water Special Interest Group, UK.

The water network in a building is one of its most important components, yet the problems in keeping it safe are all too often considered very late in the planning process, or when the building is finished. The drive for more 'green', ecologically sensitive hospital buildings - and to save energy - means that specialists involved in infection control and in water management face a complicated array of challenges. This fifth webinar in the series about water examined how different designs of water systems affect control methods, with case studies demonstrating the problems encountered and the knowledge or skills required. Dr Y. Eason Lin, with distinguished experience in the measures needed to control waterborne pathogens such as *Legionella* and *Mycobacterium avium,* was our excellent guide to the design and evaluation of these intricate institutional water systems.

**Dr Lin identified four important skills for water safety groups and infection control practitioners, in addition to knowing about controlling pathogens:**

1. **Knowledge of engineering as applied to water plumbing systems**
2. **Cost evaluation of different control methods or design choices**
3. **Understanding the economic importance of infection control**
4. **Excellent communication skills to relate to the different groups of people involved.**

Control of Legionella is the best known challenge for institutional systems, with many guidelines available, the most recent focusing on the water safety plan approach. While *Legionella* control was the main impetus to such guidelines, the concepts are applicable to control of other waterborne pathogens. Temperature regulation is commonly advised, but there are problems involved in storing hot water at 60C or higher, distributing it at least 50C, while storing and distributing cold water below 20C. The latter is a particular challenge in warm countries or hot weather. In a hospital experiencing Legionella control problems, increasing the distributed hot water temperature from 45C to 60C reduced isolates of *Legionella* and eliminated the risk to patients, but resulted in mounting gas bills. This heat requirement does not fit well with 'Green Building' initiatives to reduce energy costs and requires widespread installation of thermostatic mixer valves to prevent scalding. One solution may be to examine whether site disinfection systems would be more cost effective. An increasingly popular option is to replace steam heaters with energy efficient heat pumps, which use outside air and a heat exchanger to control temperature. The energy cost saving of 30-50% is attractive, although the achievable water temperature in distribution drops to under 50C and the change usually involves a costly replacement of the old heating system.

# Design of hot and cold water systems

With this type of water heating, an often unforeseen consequence is that it is not usually possible to conduct a heat flush of the system to destroy bacterial colonisation in the system.

As for **taps** [faucets], many in hospitals have been fitted with electronic sensors to prevent both water wastage and contamination by hand contact: but several pieces of research have identified an increased infection risk, with evidence of colonisation by pathogenic bacteria, including *Legionella spp.* and *Pseudomonas aeruginosa.* This indicates that despite the energy saving, such automatic taps/faucets are not suitable for high-risk units in health care settings. The risk is lower if simple mixer taps, which blend hot and cold water, are replaced by cold water only taps.

Given the dilemma of needing to reduce **heating costs,** the priority is to lower the contamination risk by *Legionella* and other bacteria. This may involve removing dead legs in pipe-work, where stagnant water collects, and flushing out infrequently used outlets on a weekly basis. The maintenance regime should include also at least a quarterly clean and descaling of shower heads/ hoses and periodical clean outs of both cold and hot water tanks, the timing depending on risk assessment and water chemistry. If a hospital water system is already colonised with *Legionella*, removing dead legs alone will be insufficient as a control measure, although making sure that any replacement pipe work is as short and direct as possible will help, as will the use of materials (high quality plastics/ copper) that do not encourage microbial growth. Combining attention to some of these factors with disinfection, or making disinfection the first option, may be the most cost effective measure, if there are practical or financial obstacles to redesigning the system. Good insulation of pipes and tanks assists control, as well as addressing energy costs.

In the example of a 1200 bed hospital with a history of several legionellosis outbreaks, temperature control alone was costing around 100,000 US dollars a year. Cases were not restricted to intensive care units, making point of use (POU) filters too expensive to be installed at the many outlets. Chlorine dioxide was not available in Taiwan at that time, also not an ideal method because of the difficulty in maintaining concentrations in hot water. The evaluation focused on studying the water usage and identifying the areas most at risk for *Legionella* transmission, then introducing the expensive, but effective copper-silver ionization in those areas only – resulting in zero levels of *Legionella* positivity in water samples.

# Design of hot and cold water systems

In another example of a hospital water system colonised with Legionella, chlorine dioxide reduced positive samples, although odour problems prevented using it at a concentration that would keep the Legionella positivity at zero. The engineering department objected to using disinfection as the control method: investigation showed that this was because they feared disruption of the bacteria used in wastewater treatment – easily dealt with by ensuring that chlorine dioxide was neutralised before it reached the plant. The difficulties are compounded when a hospital has several buildings, such as the example of the 2000 bed hospital with seven 16-storey buildings and sub-water systems supplying different levels of each. Here, the control methods of chlorine dioxide and POU filters in ICUs could be compared in different buildings, resulting in a successful combination of the two methods. Another instructive case study concerned the use of superheat and flush or a hyperchlorination flush – if you don't know the design and details of your water system, the results can hit the TV news! The water pipe has to be large enough to take all the water going through, or a flood may occur.

A good **water system safety plan** involves:

- Practical knowledge about distribution of mixer and cold water only taps, which will affect the efficiency of flushing the system.
- Accurate information on hot and cold daily water usage (often the administrators will know this only from the water bills)
- Locations of hot water tanks and the heating method – to assess how long, for example, to allow for correct concentration of a disinfectant to be reached.
- Locations and volumes of cold water tanks.

Methods and procedures advised to deal with a water system should be evidence based and ideally linked to experience that an outside consultant's recommendation will work. A trial of any change is strongly recommended, preparing this for peer-review publication to share the experience. Last but not least comes the all important skill in communications with hospital administrative staff – and understanding that while the running costs of the system are a priority, they are equally concerned about protecting patients.

## Discussion points from the question and answer session:

When designing a new hospital, a single in-out water loop can be designed for areas where high-risk patients will be located: this greatly facilitates preventive measures and remedial treatment of that section of the system. Separating hot and cold water pipes and selecting appropriate materials are also good advance control measures. Biofilms were another point of discussion: while these are ever present, physical barriers such as POU filters and chemical disinfection both help to reduce the microbial risk. Use of chlorine dioxide was queried, regarding drinking water quality standards: the standard in the UK is 0.5 parts per million and that recommended by the WHO is 0.7 ppm. Adherence to guidance limits ensures that the water meets quality standards. Control involves measurement of chloride or chlorate levels in the water, although the latter may not be possible on site. The relative cost of energy and control measures was another point raised, with no easy answer to the dilemma of increasing costs of heating water. The topic of training to deal with water systems led to Dr Lin proposing that there should be a course on 'infection control engineering' – as well as better communications between engineers and the infection specialists: for example, the latter are often not informed that the heating system has been changed to a heat exchange pump.

# Water System Microbiological Chemical and Physical Control Methods

25th June 2014

**Dr Janet E Stout,** President and CEO, Special Pathogens Laboratory and Research Associate Professor, University of Pittsburgh, Swanson School of Engineering, USA.

**Elise Maynard,** Chair, Water Management Society, Independent Water Consultant and member of the RSPH Water Special Interest Group, UK.

Chaired by Dr Catherine Whapham, Global Marketing Manager for Healthcare Water, Pall Corporation and member of the RSPH Water Special Interest Group, UK.

Previous webinars have described water safety plans, practical aspects of waterborne pathogen control in urban areas and the potential problems with biofilms, pipes and design of water systems. For this 6th webinar in the series, two experts discussed the microbiological control of water systems within buildings in detail: Dr Janet Stout on chemical disinfection and Elise Maynard on the options for physical control methods. This brought together some of the aspects highlighted in the webinars to date, continuing with the international perspective and adding very useful technical advice.

## 1. Chemical control of microbiological hazards in water systems [Dr Janet E Stout]

Dr Stout focused particularly on the control of Legionella, while acknowledging that other pathogens may be present in a contaminated system. She first reviewed the progress in controlling Legionella outbreaks in healthcare facilities as well as in other buildings. Experience has produced a new paradigm of options for control, including recognition that this is a multi-disciplinary activity needing the collaboration of several professions. Despite the increased knowledge, we are still seeing outbreaks in healthcare settings and in many others, such as hotels and office buildings. An estimated 20% of US reported cases arise from water systems in the home.

**Current control options regarding disinfection may be summarised as:**

- **Thermal shock treatment (heat + flush)**
- **Shock chlorination (>10mg/L residual), which may require the chlorine concentration in tanks to reach 20-50 mg/L for a minimum of 2 hours, in order that outlets can be flushed with at least 2mg/L**
- **Continuous supplemental chlorination (2-4mg/L)**
- **Continuous copper-silver ionization**
- **Continuous Chlorine Dioxide (ClO2) treatment**
- **Point of use filtration.**

The key question in selecting one of these options is whether the disinfection is reactive for short-term management after identifying a case or outbreak, or required to be proactive for a longer-term solution. Disinfection is needed also when a water system is commissioned. It is worth noting that shock chlorination often needs to be repeated as recolonisation is sadly guaranteed, so a strategy needs both reactive and proactive elements.

# Water System Microbiological Chemical and Physical Control Methods

## Chlorine and its alternatives

When disinfection procedures for building water systems were introduced in the 1980s, **chlorine** was the only chemical option.
Soon the problems were discovered: *Legionella* is relatively tolerant to chlorination and can survive at concentrations of 50 ppm with subsequent rebound and recolonisation. So whereas 0.1mg/L of free chlorine will reduce 99% of *E.coli* (as determined by culture) in under a minute, it takes 40 minutes to control the proliferation of *Legionella* at this level under experimental conditions - and in practice, many of the organisms are likely to recover or may survive, particularly in the slime layers [biofilms] lining the pipes. Holding the high shock concentration within the system needs to be for up to six hours for effective control. **Chlorine dioxide** electrochemical generation and injection was developed to achieve higher concentrations, although 0.8mg/L is the maximum level permitted in the US and permits vary elsewhere (e.g. 0.5mg/L in the UK). Research by Dr. Stout and her colleagues showed that chlorine concentrations are well maintained in cold water, but the ClO2 is rapidly converted into chlorite and chlorate compounds in hot water, removing the free chlorine needed to control the microorganisms. But, while there are difficulties in treating the hot water system, this is where the bacteria need to be controlled. Disinfection by-products such as chlorite and trihalomethanes need monitoring because of potential health effects. Another problem is the chlorine odour that will be noticed by users.

**Copper and silver ionization** has the advantage of not needing pre-cursor chemicals and without the associated pipework corrosion problems. Flow cells are connected to a controller so that when electricity passes through the copper and silver alloys their ions are released into the water supply. It is applied to hot water because the recirculation of the water allows for effective control. To avoid scale building up on the electrodes, soft water is need to for effective control to remain established. Restrictions to the use of this method have been lifted in many countries but at present in Europe it is subject to a derogation from the EU authorities pending formal approval of data.

**Monochloramine,** a stable compound generated from mixing chlorine and ammonia, has advantages over using traditional chlorine treatment and significantly reduces culturable *Legionella*, although rarely removing it altogether, as with other disinfectant treatments. The reduction is usually sufficient to prevent cases of infection. One potential difficulty is that during warmer weather the chlorine content in the pre-cursor chemicals is rapidly degraded. Maintaining appropriate storage conditions and monitoring the reagent levels, as well as surveillance to detect any Legionella cases, are all essential to check that control is sufficient. The advised concentration to be achieved is 1.5-3.0mg/L.

# Water System Microbiological Chemical and Physical Control Methods

While suitable for both hot and cold water application, targeting the hot water is recommended. This promising new technology should be checked for permitted use at the national level.

## Evaluating efficacy

**Evaluating chemical disinfection is a four-step process, demonstrating efficacy in:**

1. **Lab-based experiments**
2. **Model systems**
3. **Single hospitals, e.g. on anecdotal reports**
4. **Multiple hospitals, based on prospective studies conducted over a sufficient time period (usually a year or more).**

Ozone, hydrogen silver peroxide and some physical water treatment devices (e.g. magnets, pulsed power or hydrodynamic cavitation) have not yet fulfilled all four recommended steps. In addition to efficacy, one must be mindful of unintended consequences, particularly the accelerated corrosion of pipes and need for expensive replacement. Plastic pipes can affect the efficiency of the disinfection and are vulnerable to the high levels of chlorine-based compounds: depletion of the inner pipe plastic stabilizer, oxidation of the inner layer or micro-cracking/ pipe rupture may occur. This is associated particularly with chlorine dioxide, although it is a hazard with all chemical treatments and metal piping is also vulnerable to corrosion by high levels of oxidizing biocides. A high iron content in the water may also affect the choice and dosage of chemical control.

In addition, efficacy is influenced by the microbiome, the microbiological community within the biofilm and the water that comes into contact with it. Phylogenetic research using DNA identification has revealed that this microbiome has a wide variety of organisms, the control task being to shift the proportions to minimise or eliminate pathogens, rather than the impossible aim of achieving a permanently sterile environment in the pipes. A study comparing a monochloramine treated building with a control building showed that monochloramine significantly shifted the composition of the microbiome, reducing *Legionella* and resulting in no increase in other pathogens, notably *Pseudomonas, Stenotrophomonas* and non-tuberculous *Mycobacteria*. Other organisms may survive or even increase: while the majority of these are not known as pathogens for people with normal immunity, the public health implications of this 'survival of the fittest' have not yet been fully assessed. Within hospitals, it is clearly essential to control recognised invasive pathogens, such as Legionella, in the water supply and an evidence-based review has examined the techniques [Lin, Stout and Lu, 2011 - see website http://www.legionella.org for free online access to this paper, general information and other publications].

In summary, Dr Stout affirmed that the answer to understandable 'legionella anxiety' is to follow a water safety plan [i.e. describe the system, assess its risks, implement suitable controls and audit the measures taken]. The long-term impacts include addressing factors such as permits for the chemical agents, monitoring requirements, water system impacts and costs for different countries. The key element is to realise that there is no 'one-off' solution and that follow up monitoring, with preventive measures to limit recolonisation, is the way to control these persistent microbiological challengers.

## Discussion points from the question and answer session:

Chemical concentration units can differ confusingly, but it was confirmed that 20mg/L is equivalent to 20 ppm. As to whether chlorination should aim for more than 50mg/L, the answer is that the bulk of the *Legionella* contamination would be controlled at free chlorine concentration of 20mg/L, but higher levels of chlorine would increase the erosion of pipes. Survival of *Legionellae* within amoebic cysts can be a problem, with transformation of the amoebae from the cyst to the trophozoite form occuring after shock treatment, allowing intracellular multiplication of Legionella bacteria as the concentration falls. Thus persistence of some within the biofilm – and rapid regrowth - is inevitable. Success in disinfection needs a different approach for cold and hot water systems: treating the cold water requires a much larger volume of disinfectant due to higher through-put, with associated increased costs. As the highest infection risk is often via the hot water, it may be only occasionally necessary to shock treat the cold water, although in some countries and circumstances cold water temperature may be at around 30C so this must be carefully assessed in the treatment plan. For monitoring results, specific genus probes or isolates are advised as total bacterial counts are an unreliable guide to the presence of pathogens including *Legionella*. Regarding selection of other disinfectants, Dr Stout observed that ozone and hydrogen peroxide are highly reactive chemicals and can only be effective for a short time, due to depletion of the active residual and are only effective at or close to the dosing point, if there is no system wide residual protection. This is why the 'four-step' evaluation of efficacy may not be met by these chemicals for the control of bacteria in water circulating within a building.

## 2. Physical control of microbiological water hazards [Elise Maynard]

For the physical microbiological barriers, Elise Maynard started with the point of entry – not just where the water enters a building but in specific mini-circulations involved in medical care (e.g. dialysis, endoscopy, hydrotherapy, neonatal units) or other purposes (e.g. staff changing facilities, canteens, boiler rooms).

**Ultraviolet germicidal irradiation (UVGI)** works by disrupting the DNA of microorganisms, leaving them unable to replicate - although some may recover following treatment . UVGI utilises short-wavelength UV (280-240 nanometres [nm]) with peak absorption by bacterial cell DNA at 260 nm. 90% inactivation requires a dose of 2,000-8,000 microwatts per second per square centimetre [uW-s/$cm^2$]. This method has been accepted for water treatment plants in the US and UK to remove viruses and the parasites *Giardia* and *Cryptosporidium* - these are more sensitive than Legionella to UV and a lower dose may be used. Points to look out for are high turbidity, which may reduce effective disinfection as the particulates make the water cloudy, shading the microorganisms from UV penetration: pre-filtration is the recommended way to avoid this. Waters with high levels of particulates may need a multistage filtration process prior to the UV to ensure effective treatment. While UVGI is relatively inexpensive to run, installation requires capital outlay and regular cleaning of the system is recommended for hard water areas. In addition to its drinking water applications, UVGI can be used to reduce the bioburden in grey water and wastewater. The flow rate through the UV unit needs to be strictly controlled so that it is not too slow, allowing water to heat up, or too fast so that the dosage/ dwell time for micro-organisms is insufficient.

**Filtration** – the mechanical or physical separation of solids from fluids so that only the fluid passes through - comprises a range of thickness from crude removal of gross particles of a certain size, as in sand filters, to microbial filters that achieve titre reduction of microorganisms, typically >$10^7$ cfu/$cm^2$. Examples include hollow fibre and cartridge filtration, the latter requiring less initial capital outlay, but both require regular maintenance, change-out for cartridges and cleaning (automated backwash) in the case of hollow fibre filtration. **Reverse osmosis** is a hollow fibre diffusion filtration method that removes large molecules and ions by applying pressure to a solution on one side of a semi-permeable membrane. Smaller ions and the solvent pass through. In large water treatment plants this is usually combined with prior water softeners, carbon filters and with chemical treatment.

# Water System Microbiological Chemical and Physical Control Methods

Where high purity water is required in a hospital, such as for endoscopy or dialysis, augmented care, an absolute or microbially rated filter may be needed to ensure removal of smaller water-borne bacteria.

Filtration and UV methods have an advantage over heat shock treatment in that the procedure does not require running all the water outlets or the risk of scalding. Also, the amoebic cysts containing Legionella organisms can be removed and, when well maintained, there is much less risk of recolonisation. One of the reasons for return of Legionella after shock treatment is the development and selection of heat resistant strains over time. **Venturi flushing systems,** involving continual circulation, are gaining support because they are a good option for cold water systems and reduce heat gain problems - but because of the installation logistics required may be most suitable for newly constructed buildings. They will not prevent problems posed by retrograde contamination at the outlet.

**Point of use (PoU)** ultraviolet treatment has proved very effective at removal of pathogens such as *Pseudomonas* under laboratory conditions. Small units can be installed in the wall behind washbasins and showers. Maintenance includes regular replacement of the UV lamps and such systems are more efficient if there is pre-filtration to remove larger particles. While having no effect on the biofilm, laboratory research has shown significant reduction in bacteria in water at tap outlets, providing the UV lamp maintains >80% efficiency. **PoU micro-filtration** units can be screwed on to most taps and showers. The hollow fibre or flat sheet membrane filters provide an immediate barrier to fungi, bacteria and parasites, although regular checks to detect blocked filters and changing according to the manufacturer's instructions for use is recommended in various guidance documents. Validation of the grade of filtration is essential where fitting in a high-risk area of a health care facility. While there are cost implications for these consumables, they have proved effective at reducing the human and economic cost of hospital-acquired infection. PoU filtration should be used alongside other engineering solutions but when a water contamination problem occurs, they are recommended (HSG 274 part 2) as a short term measure whilst longer term solutions are put in place.

As with the chemical methods, a risk assessment/ water safety plan is essential and a multi-barrier approach, as advocated by the WHO, is often the best strategy. When assessing risks, the water safety team should consider the implications of additional risk if the installation subsequently needs to be removed. As well as insisting on verification data from the manufacturer, it is advisable to carry out a verification assessment on site. Several guidance plans are available (see references below).

References/resources:

1) WHO guidance on water safety plans: http://www.who.int/water_sanitation_health/emerging/legionella.pdf accessed 04/06/2014

2) Memorandum 04-01: Addendum - Pseudomonas aeruginosa -advice for augmented care units http://www.dh.gov.uk/health/2013/03/pseudomonas-addendum accessed 04/06/2014

3) UK guidance for Legionella: http://www.hse.gov.uk/pubns/books/hsg274.htm

## Discussion points from the question and answer session:

There were questions about heat treatment and flushing, given that the WHO has recommended ,for disinfection purposes,water reaching 70C at the outlets for 30 minutes, which is difficult to achieve in complicated or large distribution systems – no easy answers here but it is still a useful method for smaller buildings although only effective as a short term measure. Thermal tolerance of *Legionella* organisms is being actively researched and this potential problem is a good reason for combining heat treatment with other methods. The efficiency of trace heating techniques – boosting the temperature as it flows through the system - depends on whether the trace reaches as far as the water outlets and achieves long term maintenance of the desired temperatures. . Venturi flush systems were another discussion point as this is a new technique: combination with other technologies may be advisable. Point of entry versus point of use filtration depends on the quality of water entering the building: staged filtration may be the answer if there are quality problems, with PoU filters at outlets requiring microbe-free water.

# Water Quality Legislation: Guidelines vs. Best Practice

23rd July 2014

**Dr Susanne Lee,** Director of Leegionella Ltd, UK on behalf of the International Forum of Water Hygiene in Buildings (IFOWAHB).

Chaired by Dr Paul McDermott, PJM-HS Consulting Ltd, UK.

Guidelines and legislation have been touched on in previous webinars in this series, but for many professionals involved in design and treatment of water supplies, the devil is in the detail. So this seventh webinar provided an excellent opportunity for an expert view on the options – and the potential pitfalls – involved in developing guidance and the associated legal statutes.

Laws regarding the availability of safe water go back to ancient times, for example the early Sanskrit writings about water purification techniques (c2,000 BC/BCE) and water treatment devices depicted in the hieroglyphs of the tombs of Egyptian Pharaohs. It is all the more shocking that poor water quality is still a global issue – and not just in poor or developing countries, as demonstrated for instance by recent outbreaks of Legionnaire's disease and infection by *Pseudomonas aeruginosa* in the UK.

**Outbreaks are usually attributed to poor water quality and management in buildings, associated with, for example:**

- **Sewage contamination of the water supply**
- **Flooding, especially for supplies vulnerable to surface water ingress**
- **Ingress by animals, birds or insects, for example in unsecured water storage tanks**
- **Inadequate design, incorrect plumbing installation, alterations, cross connections and the risk introduced by poor labelling of pipes.**

The likelihood of pathogen contamination is increased where supplies are intermittent, insecure or reliant on untreated source water, such as rainwater collection or recycled (grey water) sources.

As discussed in previous webinars, the presence of hazards such as *Legionella, P.* aeruginosa or high lead content does not necessarily mean that illness will result, but they are an agreed risk, with some systems presenting a more serious threat. A high quality of the supplied water is little protection if the water subsequently passes through poorly designed and maintained systems within buildings. Concentrations of metal and plastic by-product chemicals may rise due to corrosion and trace presence of microbial pathogens in the incoming supply may increase to levels capable of causing harm to health. In fact, given that water sampling may not detect very low levels unless very large volumes of water are used, it should be assumed that pathogens such as legionellae, pseudomonads and non-tuberculous mycobacteria (NTMs) are present in the supply as it enters the building.

# Water Quality Legislation: Guidelines vs. Best Practice

Large buildings with correspondingly complex plumbing inevitably increase the risk due to factors such as:

- **Poor flow or stagnation** in poorly designed parts of the system
- **Long branch pipes** and dead legs
- **Intermittent use** or extended periods with no flow
- **Poor temperature control** (including where faulty design has allowed proximity to hot water systems, cold water tanks in warm places or inadequate insulation)
- **Unsuitable plumbing materials** (e.g. boss white and hessian on joints)
- **Too many thermostatic mixers on taps** and problems with radiators etc.
- **Inadequate water treatment** allowing survival and growth of opportunistic waterborne pathogens

It is important to widen the focus from the known pathogens (Legionella, Pseudomonas) to the many naturally occurring microorganisms that are opportunistic threats to vulnerable people, including hospital patients. As Professor Kerr emphasised in a previous webinar, the resulting infections may be difficult both to diagnose and to treat.

Within buildings, there are many potential sources of contamination and routes of exposure although only a few apply to the population at large. The exposure routes may be summarised as:

1. **Direct ingestion** (drinking water or sucking ice)
2. **Indirect ingestion** (such as consumption of food/ beverages prepared with contaminated water)
3. **Contact with water (pools, spa pools) or water toys and inflatables**
4. **Aerosol inhalation** (cooling towers, decorative fountains, showers, toilets, nebulisers, misting devices etc.)

Taking into account the many potential sources means assessing all water connected/ water cleaned installations individually, from fire systems to dish washers – and not forgetting the risk of exposure due to proximity to people, including those particularly susceptible to such risks. In healthcare facilities this involves considering the potential hazards of wound cleaning, use of instruments and even disinfectants inadvertently diluted with contaminated water. Schools and other intermittently occupied buildings also need careful attention: the combination of old plumbing systems with new 'eco' installations such as rainwater collection may introduce a hazard – and leisure complexes with pools and other water-related equipment have also been associated with outbreaks. Staff in all these types of building may be temporary or insufficiently trained. Finally, use of nebulisers or related equipment in the home requires a water safety plan (WSP) approach.

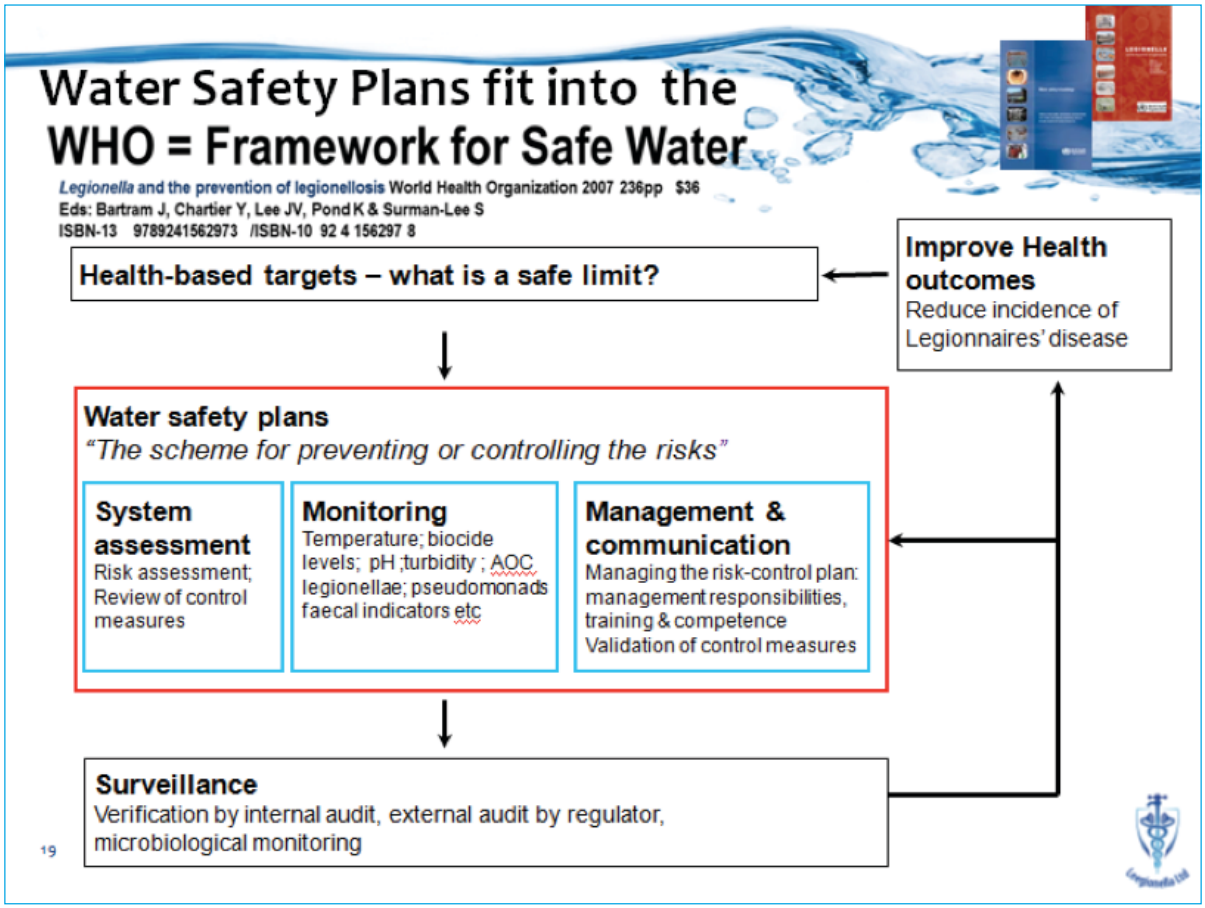
# Water Quality Legislation: Guidelines vs. Best Practice

## Water Safety Plans and managing the risk

Ideally, prevention or minimising the risk of waterborne infection should occur at the design and commissioning stages. The World Health Organization (WHO) has advocated the application of WSPs to water systems in buildings and specialised equipment as well as to the potable water supply (4th edition of WHO guidelines on drinking water quality) – see first webinar from Professor Jamie Bartram in our series for more details.

Drivers need to come from Government and regulators: at a time of competing requirements and strain on resources, the cost of water system maintenance can all too easily drop down the list of priorities. Notorious outbreak incidents have helped to instigate improvements and to develop a legal framework, in addition to shaping the current WSP approach (Figure 2).

Figure 2: Schematic diagram of WSP components (Slide 19 of Dr Lee's presentation)



# Water Quality Legislation: Guidelines vs. Best Practice

The first stage is to set water safety targets, usually set at the national level - e.g. freedom of drinking water supplies from faecal contamination but the process is not straightforward. Whilst a zero tolerance for faecal contamination of drinking water is a universally accepted target, the same cannot be said for indigenous waterborne pathogens, where differences in acceptable levels around the world show the difficulty in defining precise target. The international guidance – 'no harm should arise from water used for any purpose' - is insufficiently prescriptive, as is the detail for water sample volumes, media and laboratory methods. While sensitivity and specificity of methods for detection of waterborne pathogens vary across laboratories, action levels are generally consistent with the European Working Group for Legionella Infections (EWGLI). This is currently being updated but as yet lacks agreed specifications for factors such as surveillance frequency and methodology. A recent survey showed an encouraging convergence of international agreement on water heater temperature standards, although with variation in standards for the outlet temperature (current UK advice is to adopt a risk-based approach to use of thermostatic mixer valves (TMVs), e.g. where whole body immersion or exposure to more vulnerable people is involved). Interpreting guidance means considering the particular needs of each water system: for example, larger samples may be indicated for the detection of microorganisms in distributed mains drinking water to increase the sensitivity of the analysis.

## From policy to legislation

A policy outlines what a government, organization and individuals hope to achieve and the actions, methods and principles used to achieve them. A good policy is logical and simple and defines quick and easy actions needed to reach the objectives. The WHO drinking water standards date from 1958, associated with recognition of increased travelling to areas with poor water quality. These guidelines have been used to shape policy at government level, including the first step: deciding what objectives do you want to achieve. A legislation framework for ensuring safe water quality can include everything from food preparation to recreational water. When setting policies it is better to focus on what is achievable rather than aiming too high – also to ensure that prevention of infection is a specific and over riding aim. Outbreaks often provide the drivers for more specific and effective legislation. Yet, the dangers posed by *Pseudomonas aeruginosa* in hospital water supplies had been recognised by microbiologists for years before action was taken.

# Water Quality Legislation: Guidelines vs. Best Practice

One outbreak may, sadly, not be enough to prompt necessary legislation: for example; in the case of *Legionella* monitoring in one EU country, it took several outbreaks, a memorandum from public health specialists and parliamentary pressure to develop a modern technical guideline. One of the pitfalls to be aware of when developing legislation / guidelines is the lobbying or funding of research by biased parties – e.g. involved in producing materials or components that may adversely affect water quality. Unexpected implications include blocking of advice given by one government department, e.g. one responsible for health, by another with a different agenda, such as a department responsible for tourism. Involving all the stakeholders early in the planning process helps to avoid this.

There needs to be a combination of political good will, financial resources and the necessary infrastructure to implement legislation. Tough requirements, but part of the task is to convince those at government and local level of the economic benefits of clean water, within and outside buildings.

**So, turning policy into legislation needs at least the following infrastructure:**

**1. Expertise: e.g. water suppliers, engineers, water treatment specialists**

**2. Support services: e.g. legal/ public health/ accredited laboratories**

**3. Enforcers: Governments, regulators, inspectors, auditors**

**4. Measures of effectiveness: surveillance systems**

**5. Training: capacity to train all those involved, including e.g. operational staff, designers, manufacturers and installers.**

Using the UK as an example, legislation is now almost entirely the result of directives or regulations from the European Parliament. While it is still ratified by the UK Parliament, only minor amendments can be made and then only to add criteria (for instance, monitoring for *Cryptosporidium* was added to the UK Drinking Water Regulations). The over riding objective in Article 1 of Directive 98/83/EC specifies protecting human health from adverse effects by ensuring wholesome, clean water. Clearly this is formulated for the population as a whole, without aiming to protect the most vulnerable from opportunistic microbes that would not affect most people. In the corresponding water regulations for England and Wales, Scotland and Northern Ireland, wholesome water is further defined as not containing any microorganism or substance "which would constitute a potential danger to human health". This 'get into jail free' clause may be interpreted as covering all the opportunistic pathogens that may cause illness in the elderly or immune suppressed. The legal framework for water within buildings is primarily aimed at the risk from legionellae.

# Water Quality Legislation: Guidelines vs. Best Practice

The hierarchy of legislation is headed by Acts (such as the Health and Safety at Work Act, followed by Regulations, Codes of Practice and Guidance, the latter forming the base to the whole framework. Once legislation is in place, guidance serves to interpret the legal clauses and give practical advice. Your WSP should give support to decide how much time – and cost – to spend in complying with the framework: flexibility is accepted provided that alternative steps can be justified:

**"The degree of risk in a particular job or workplace needs to be balanced against the time, trouble, cost and physical difficulty of taking measures to avoid or reduce the risk."**

In other words, reasonable practicality can be balanced against the quantum of risk. But beware; law courts are not the place to start readjusting the WSP or pleading that the exposure risk appeared very low. A UK case in 1993 established the precedence that there is no need to prove that people are exposed to *L. pneumophila* if there is evidence of ineffective water management and a risk that the organism may be emerging. The accumulating red tape associated with water system controls prompted a government review and the Löfstedt report, 'Reclaiming health and safety for all'. The aim was to reduce the burden on businesses, examine whether regulation was proportional to risk and correct misconceptions as to law versus guidance. This 'proportionate risk management' essentially aimed to show that health management is a vital part of a business operation and not a 'bureaucratic paperwork exercise'. Generally helpful, there are unintended consequences to this approach, as in a requirement to write guidelines based only on necessary steps to comply with the law, rather than what is considered 'best practice'. For example, compliance with the culture standard may not predict the risk to patients – as in a demonstration that PCR identification of Legionella positives was more accurate than culture in water outlets within a contaminated hospital system. In addition, compliance with achieving defined temperatures at outlets, or dealing with positive and negative microbiological results raises questions about who determines whether legal limits are met and whether their training is sufficient and accredited. Monitoring samples, similarly, may not take account of features such as interruptions in supply or quality, dead legs/ blind ends and temperature fluctuations.

Reliance on regulatory end product limits may lead to inappropriate action and poor risk communication, as in an incident in Australia, which led to tap water being included in the definition of food and the application of HACCP principles.

# Water Quality Legislation: Guidelines vs. Best Practice

The outbreak of *E. coli* O157 and *Campylobacter jejuni* in Walkerton, Canada in 2000 was another wake up call to base monitoring on preventative, rather than reactive, strategies. The pathogens entered the water supply via run-off from farm manure and associated flooding: investigation revealed failure to maintain chlorine residuals, poor operational procedures and falsified records.

As well as consequences, look out too for unintended anomalies. In the UK under present legislation, it is legal to sell some unsuitable fittings and appliances – but illegal to install one.

## Discussion points from the question and answer session:

One question theme was about the balance needed for guidance based on evidence-based practice without being too aspirational. Dr Lee and Dr McDermott acknowledged the dilemma here, advising that guidance evolves as people gain experience of the systems they deal with. Action should be based on the risk assessment and on the types of user. There's no one set of guidance suitable for all situations. In response to a query as to whether there is anything on the horizon for this evolving area, Dr Lee commented that expertise should be concentrated in a few laboratories rather than try to develop some of the complex tests in small laboratories and that this is a likely future trend. The point about water fittings prompted the observation that the regulations for these are now old – but meanwhile, how to get manufacturers to realise the bigger picture? Not easy to answer, but the advice included the need to take precautions to ensure that contamination is not introduced when putting new fittings into a system. Regarding the volume of water samples to detect Pseudomonas in hospital waters, Dr Lee advised that 100 ml. is still appropriate. In some cases, smaller volumes may be applicable. Another question theme related to disinfection of water systems, including the issue that superchlorination is very costly and also destructive, due to corrosion. The chair and speaker agreed that recolonisation will occur after any method. The answer is to consider the design of the system and to examine areas where there is no flow and a higher risk. Sustained and managed disinfection, ideally associated with multiple barriers, is the only answer. Designing and commissioning a system to minimize the risks of microbial and other contamination is the basic stage for avoiding problems later on.

### Conclusions

**The key message is that compliance does not ensure a safe system! In addition, Dr Lee emphasised the importance of:**

- **A systematic water safety plan approach;**
- **Include all stakeholders in expecting good procedures to be followed;**
- **Beware the unintended consequences in bureaucracy and financial burden;**
- **Ensure presence of appropriate infrastructure and finance before implementation.**

# Best Practice Water Sampling, Testing & Analysis.

## 24th September 2014

**Janice Calvert,** Director of Latis Scientific Ltd, UK.

Chaired by Dr John Lee, Director of Leegionella Ltd and Chair, Pool Water Treatment and Advisory Group, UK.

This eighth webinar in the series focused on practical aspects of sampling and analysis, with an informative presentation from chartered chemist Janice Calvert, who has extensive experience in dealing with water quality problems, including those related to swimming and spa pools. Key points are summarised here as well as a list of the guidance on sampling [UK guidance listed below].

### Sampling programmes, containers and methods to protect the sample – and the samplers

Designing a sampling programme starts with its purpose and objectives, such as whether these are routine quality control measures, quality characterisation or to monitor control of a problem. Sample points and details of frequency, duration and analysis should be decided and recorded in advance. It is important to consider flow effects, such as whether it is laminar or turbulent or where there may be a risk of reverse flow that could contaminate a sample. Temperature conditions to note include the impact of meteorological conditions such as heavy rain. Samples should be timed to be representative of expected quality or variation, with the exception of *Legionella spp.,* when a sample should be taken at the estimated greatest time of risk for exposure. Also, increased sampling will be needed for persistent abnormal trends. While spot sampling with later laboratory analysis is usually sufficient, in situ sampling is needed to measure dissolved gases, sulphite and ozone residuals, all of which may change en route to the laboratory.

Containers for samples are an often neglected detail, with laboratory staff all too familiar with receiving inappropriate containers (including old coke bottles!) or those that allow absorption of chemicals and bacteria onto the container sides, such as some plastics. Laboratories are happy to advise on appropriate and tested container materials, including those that can be easy to clean and sterilise – re-used containers may result in a contaminated sample. Separate samples are needed for chemical and microbiological analyses: for physicochemical tests, the container should be filled with no air gap to avoid evaporation of volatile substances or precipitation of metal ions, while an inch of air space is advisable for bacteriological samples, to enable mixing at the laboratory. Samples for chemical analysis must be taken before those needed for microbiology.

**General rules of the size of a sample include:**

1. One litre for chemical analyses
2. 500 ml minimum for general microbiology
3. One litre for *Legionella* and enteric bacterial pathogens
4. 10 litres minimum for viruses
5. 50 litres for *Cryptosporidium*, or larger for continuous sampling procedures.

# Best Practice Water Sampling, Testing & Analysis.

The **aseptic technique** for the sampler includes minimising touching the sample with fingers, hands or gloves and avoiding any contact with the interior, rim of bottle or the inside of the container cap. Samplers should be trained in basic techniques and aware of the risk of cross-contamination. Any equipment used should be disinfected for 30 seconds and allowed to dry both before and after use. If there is any doubt about whether contamination may have occurred, the best course is always to discard and resample. In addition to preventing contamination, the aim is to minimise contact time of the sample with the container and to protect it from extreme temperatures, light and agitation during transport. Refrigeration and cool boxes are advisable, making sure also that hot and cold samples are in separate boxes. A chemical sample that cannot be delivered to the laboratory on the same day must be stabilised or preserved. When the sample is taken, care is needed to avoid disturbance around the sampling point, particularly in dusty areas such as loft spaces. As detailed in BS7592 for *Legionella* sampling, measures are needed to prevent the sampler being at risk and the ideal sampler should be a young, fit non-smoker, since immunosuppression, asthma and smoking have been identified as risk factors for legionellosis. It is around three times more common in men than women, and the best protection is to take every care to reduce or prevent any aerosolisation of this airborne pathogen. Additional points for *Legionella* sampling include taking the sample before an under-used outlet is flushed and to prepare separate containers with or without biocide neutralising agents, depending on whether a biocide neutralising agent is in use in the system. *Legionella* samples should not be chilled but maintained as close to the sampling temperature as possible.

## Common sample types

For **dip samples,** the sterile container is immersed completely to a depth of 200-400 mm, tilting it slightly to fill. A new pair of disposable gloves should be used each time or the hands should be rinsed with 70% ethanol/ propan-2-ol solution, also the outside of the bottle. Disposal dip samplers (with a stainless steel jug), as well as disposable wipes for the outside of containers, can be used to make this procedure easier. A **pre-flush sample,** aiming to identify colonisation at the outlet, is taken on immediately opening the tap [faucet] or other fitting and without disinfection. Ideally, the outlet should not have been allowed to run for two hours before the sample time and be labelled accordingly in advance. **Post-flush samples** require first running the water to waste: a volume of at least one litre or until it runs clear, or until an endpoint temperature is reached – for mixer taps, the temperature should be set at mid-point.

# Best Practice Water Sampling, Testing & Analysis.

Since the aim of post-flush sampling is to establish whether there is colonisation of the system, these are taken after disinfecting the outlet, for example with an external disinfectant spray and waiting 2 minutes, then flushing for 30-60 seconds before taking the sample. Check guidelines re: testing for *Pseudomonas* as the Department of Health (England) advises not to disinfect between samples.

Removal of hoses or shower heads depends on the purpose of the sample: if the test is for *Legionella*, contamination is likely to be high in the showerhead and it should be left in situ for the procedure: and the principle concern is to protect the sampler from aerosol exposure whilst acquiring a representative sample. A food grade plastic bag is sufficiently clean and should be snipped with scissors, tied round the showerhead and inserted into the container, collecting the sample while running the shower at maximum flow. To record temperature of a water sample, a thermometer should be inserted in the flow before sampling or immediately after – not in the sample itself (although not from a showerhead if there is known to be a high risk of the presence of *Legionella*, to avoid aerosol exposure). Guideline temperatures include 50C after 60 seconds for hot, 20C after 60 seconds for cold. **Biofilms** within the pipes should be sampled with a swab.

**Check list for a sampling kit:**

a. 500ml/ 1 litre bottles containing biocide neutraliser as appropriate

b. Disinfectant: 70% propan-2-ol/ ethanol or 1% sodium hypochlorite solution. Also flame gun and antiseptic wipes for external surfaces

c. Marker pen

d. Food grade plastic bags for *Legionella*

e. Sterile sample dipper

f. Thermometer

g. Disposable gloves plus personal protective gear such as mask where advised.

## Sample identification, records and the sampling kit

Janice Calvert's laboratory receives at least 30 samples a day without the client's name, an obvious major fault, but there are other points to be recorded on the sample label. These include the site and place within that site, whether the sampling point is a tap, showerhead or tank, the water category (potable, process, natural), date, time and whether the sample is spot, composite or continuous and pre- or post-flush. Field observations, including ambient temperature, may be helpful as are any details known of pre-treatment such as chlorination. Where legal action may be involved, the chain of custody must be observed. This requires signed documentation of the sampler, person delivering the sample, laboratory courier and receiver. Verification that all parts of the sample sent have been received (number of containers) must be recorded.

## Culture techniques and interpretation of the results

Single results mean little in isolation and the sampling circumstances should always be noted: also, remember that any results are a snapshot of a moment in time and that samples on different days may vary. Bacterial numbers can increase rapidly, or chemical contamination may rise, after the date of the samples. Rapid reporting is the aim, to reduce health risk and enable fast action to be taken.

# Best Practice Water Sampling, Testing & Analysis.

There are two main approaches for identifying *Legionella*: culture and PCR [Polymerase Chain Reaction, which amplifies the nucleic acid of the organisms present: the abbreviation 'qPCR' stands for quantitative measure of DNA/RNA sequences following each amplification]. Culture is accurate, allowing species typing and quantification, but not all viable cells can be made to grow and experience is needed to identify colonies and differentiate them from background flora. It takes 7-10 days to obtain results, which is why PCR may be recommended for urgent identification within a few hours. PCR does not distinguish between live and dead organisms and shows poor correlation with culture results: but it has the advantage that if no organisms are detected, *Legionella* is unlikely to be in the system. European guidelines for action, according to the number of colony forming units [cfu] per litre, include advising that the system is under control at up to 103 cfu/l, resampling at higher levels and remedial actions if more than 104 cfu are identified: check the guidelines for more detailed interpretation.

## Discussion points from the question and answer session:

For a question about sampling for the opportunist *bacterium Stenotrophomonas* in water systems, the advice was to take a pre-flush sample - as the majority of contamination is expected to be around the outlet – then to follow with post-flush sampling to check if colonisation has occurred further along the system. This also raised the issue of opportunist contaminants of water systems, discussed in previous webinars, since resistance factors can be transferred to other organisms, making them harder to remove.

Why not chill *Legionella* samples? Early on in the research into *Legionella*, it was found that chilling rendered the organisms non-culturable, but it was suggested that this advice could benefit from further investigation.

Regarding the recommendation of 10 L samples for the incoming supply to a building, this is not so much a regulatory standard as required when people are asking if a pathogen is present in the water, when a larger sample is advisable. On another topic, that of disinfection, it was advised that after disinfection of a system, a gap of seven days should occur before resampling.

# Best Practice Water Sampling, Testing & Analysis.

**References/resources:**

Current UK and ISO guidance for water quality sampling:

- BS ISO 5667/BS6068 -4,12 2006 – Water quality sampling, including specific types and sediments
- BS 7592: 2008 Sampling for *Legionella* bacteria in water systems. A code of practice [currently being revised but requires that a risk assessment has been undertaken and that suitable control/ monitoring procedures are in place]
- BS EN ISO 19548:2006 Water quality – Sampling for microbiological analysis
- BS 8554: 2015. DRAFT Code of Practice for sampling and monitoring of hot and cold water services in buildings BS 8552: 2012. Sampling and monitoring of water from building services/ closed systems

How far should PPE [personal protective equipment] go for samplers? If cases of *Legionella* have been confirmed, a mask should be worn in addition to the disposal gloves and also use of food grade plastic bags to reduce aerosol at showerheads (which are OK for sampling this organism as it will not be a contaminant of such bags). And on the subject of *Legionella*, the non-culturable proportion is unknown and may vary, with estimates based on detailed in vitro research rather than in the field. When sampling for *Legionella* in a cooling tower, the best site is the pond itself but to reduce the hazard of aerosol, the fan should be turned off and the pond allowed to settle for at least half an hour. Fortunately, many towers now have sampling lines with continuous circulation, although an advantage of sampling from the pond is that you can see what is going on within the tower, such as the state of the surfaces. Regarding Legionella identification techniques, quantitative polymerase chain reaction [qPCR] is UCAS accredited in many laboratories but ideally attempts should also be made to culture the organism and the interpretation problems must be considered.

**The ninth webinar covered the topical subjects of evaporative cooling towers, private water supplies and swimming pool water quality.**

## Specialist needs for Evaporative Cooling Towers [Dr Paul McDermott]

Cooling towers reduce water temperature by direct contact of water with a stream of air. Where an evaporative condenser is incorporated, the fluid passes through a heat exchanger, the latter cooled by water passing through an air stream. Evaporative cooling towers are now widely used for industrial processes, particularly because they are efficient and cost effective. But they present a legionnaires' disease [LD] risk: a recent survey conducted by the Health and Safety Laboratory and report from the Health and Safety Executive have identified this risk as high and responsible for large outbreaks of L*egionella spp.* infection. The risk, already well established, is reflected in the UK legislative framework, including the Control of Substances Hazardous to Health Regulations (2002), the 2014 Approved Code of Practice [ACoP, L8] and technical guidance HSG274, part I of which relates to these cooling systems. The hazard varies with the type of cooling tower. Cooling plants using evaporative condensers and closed circuit cooling towers provide cooling via a heat exchanger and lower volume of circulating water than earlier natural draft or mechanical fan designs. Some incorporate dry cooling with intermittent evaporative cooling, the latter introducing a potential LD risk. This risk depends on how the water is stored, whether it is recirculated or can generate aerosol, as well as the type of water treatment.

**ACoP L8 sets out the management principles:**

- **Risk assessment**
- **Appointment of competent persons**
- **Supervision and implementation of a control scheme**
- **Keeping records**

The guidance in HSG 274 is site and system specific, emphasising the need to include all parts of the water system, a schematic diagram with regular updating and inclusion of any elements that contribute to risk. This approach provides a 'route map' to make a reliable risk assessment. This must be done regularly, to note any changes to the system or its use as well as new information on control measures and monitoring data. Changes in key personnel are another indication to repeat a risk assessment, as is the occurrence of any case of LD that may be associated with the system. Managing a control scheme involves taking account of the multiple tasks and people involved, including third parties such as contractors for water treatment.

# Specialist water needs: cooling towers, private water supplies and leisure pools.

15th October 2014

**Dr Paul McDermott,** PJM-HS Consulting Ltd, UK.

**Dr Susanne Lee,** Director of Leegionella Ltd and Chair, RSPH Water Special Interest Group, UK.

**Dr John Lee,** Director of Leegionella Ltd and Chair, Pool Water Treatment and Advisory Group, UK.

Chaired by Professor Richard Bentham, Lecturer, Public Health Microbiology, Flinders University, Australia.

# Specialist water needs: cooling towers, private water supplies and leisure pools.

Communication lines should be clear, also roles and responsibilities: has the competence of all those involved been ensured and, just as importantly, is the management well documented?

Water treatment should relate to operating parameters and must include analysis of the make-up water, such as microbial activity. Corrosion, scale and fouling are potential risks and there should be a regular cleaning and disinfection programme. Weekly microbiological and biocide level monitoring is advised so that trends can be analysed. This is easier for oxdising biocides: the non-oxidising types are difficult to measure in circulating water but records of usage help in the assessment. The testing approach should be consistent in terms of timing, location, incubating conditions and staff training. Specific testing for Legionella spp. should occur at least quarterly (advice in BS 7592: 2008) and analysed by an accredited laboratory. Negative results do not guarantee absence of Legionella spp. – this is where a comprehensive risk assessment can provide clues to risk or more confidence in the results. HSG 274 gives advice on the evidence-based approach needed for assessing cleaning and disinfection. Where access to the pack is a problem, boroscopic [telescopic imaging] analysis can be considered.

## Specialist needs for private water and small community supplies [Dr Susanne Lee]

Private and small community water supplies [PWS] are widespread, including in the UK, yet there is no international consensus on how these are defined. The general definition is a system where the water is not provided by a company/ utility through a public distribution network. They can vary from simple point sources to sophisticated systems involving multistage treatment, storage and piped distribution. Within the EU, such supplies are defined as those supplying between 50 and 5,000 people or 10-1,000 cubic metres of water per day. A supply to less than 50 persons is defined as ‘very small’. This includes individual properties as well as farms. In England, more than half [18,976] of the 34,221 private supplies serve a single household and at least one in ten Europeans (40-50 million people) have small or very small supplies. For the USA, the proportion served by a PWS is 15%, or 45million of the US population.

Small supplies are mainly in rural areas but include holiday centres, campsites and trailer parks as well as villages and islands. Management may be by one individual or a community cooperative. Larger private water supplies are found at commercial premises such as breweries or hospitals and public buildings. In some cases such supplies are blended

# Specialist water needs: cooling towers, private water supplies and leisure pools.

with public supply water, possibly for economy. In an increasingly urbanised world, the risk assessment includes assessing the history of an urban area to understand whether industrial or farming processes have leached hazards into the surrounding aquifers and geological levels. Examples include mines, tanneries, metal works and orchards.

The quality of water in a PWS may differ substantially from that obtained from a public supply, even if the water is withdrawn from the same aquifer. While few English public supplies fail to meet EU/ national standards (0.03% in 2013), 7% of private supplies failed to meet these standards in the same time period, despite an improvement to the 9.6% of supplies failing in 2010. This difference in quality is partly due to lower regulatory requirements, or, in the case of very small supplies such as to a single dwelling, monitoring occurs only if requested by the owner. The Drinking Water Inspectorate (DWI) for England estimated that 494,759 people lived or worked in premises relying on a private supply, with a further 7.8 million people who attended festivals or other events served by a temporary water supply. Compared with public water supplies, these sources pose a risk 35 times higher. In Canada, 45% of waterborne outbreaks are estimated to involve non-municipal systems. Globally, more than 700 million people lack access to improved sources of drinking water, of which nearly half reside in sub-Saharan Africa (WHO 2014). A WHO/UNICEF monitoring programme reported in 2014 estimated that 1.8 billion people have to drink faecally contaminated water, with 1.1 billion consuming water at moderate risk i.e. more than 10 faecal indicator bacteria per 100ml.

Outbreaks associated with PWS have been attributed to a wide range of pathogens: enteric bacteria such as *E.coli* O157, *Campylobacter* and *Salmonella*; viruses, including *Enterovirus* spp., *Astrovirus* and *Norovirus*; and parasites, notably *Cryptosporidium* and *Giardia*. Contamination occurs due to ingress of faecal pathogens from sources such as run off of water / slurry from grazing areas, broken sewers, poorly maintained septic tanks and flooding.

Many of the PWS sources are unprotected and the WHO Water Safety Plans have been developed to allow comprehensive risk assessment and management. These were covered by Professor Bartram in the first webinar in this series. The principles for small community/ private supplies include assessing both obvious potential sources of contamination (e.g. surface water run-off from farmland), as well as the potential for ingress through fissures in the underlying geological strata.

**Non-microbial hazards include:**

- **Arsenic – as well as natural contamination, it may be present due to historical use of arsenical pesticides (e.g. in orchards), industrial run-off or wood preservatives.**
- **Fluoride – in low natural or added levels, this prevents dental decay but high levels cause painful skeletal fluorosis.**
- **Nitrates and nitrites may be present due to breakdown of nitrogen compounds in the soil. Human activities leading to excess of nitrates/ nitrites include contamination by human and animal wastes, slurry spreading, use of fertilisers and landfills/ rubbish dumps. The 'blue baby' syndrome due to these chemicals has been largely eliminated from public supplies.**
- **Heavy metals, herbicides, pesticides and radioactive substances present in the underlying geological strata. Again these can be introduced as well as naturally present.**

# Specialist water needs: cooling towers, private water supplies and leisure pools.

A sudden change in the local environment (e.g. heavy rainfall or floods) or consumer complaints about illness, taste, colour or smell should prompt assessment to confirm that the drinking water is safe. Any identified risks should be managed by a multibarrier approach, such as filtration and disinfection and incremental improvements based on water quality targets or objectives.

## Leisure pools and spas – health risks and their prevention [Dr John V Lee]

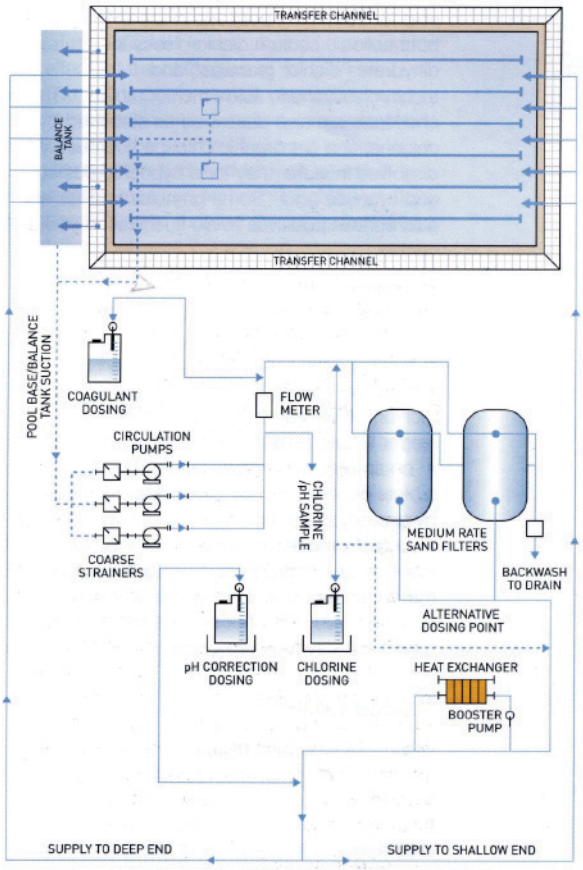
Artificial or man-made pools have been around for at least 5,000 years, but the large increase in swimming pools is a late 19th/ 20th century development. These have become ever more complex, incorporating wave machines, interactive features and use for toddlers and hydrotherapy, as well as the popularity of whirlpool spas and hot tubs. The risks relating to poor design or management encompass physical (slips causing injury), chemical (chlorine overdosing or skin discolouration) or infectious diseases. In addition to faecal pathogens, *Staphylococcus aureus* and Papilloma virus may contaminate the water and the indigenous microbial population may include *Legionella pneumophila* and other legionella species, *Pseudomonas aeruginosa, Cryptosporidium* spp., *Giardia* spp. and Mycobacteria. Between 1992 and 2010, 80 outbreaks of infection associated with pools, interactive water features and spa pools occurred in England and Wales. A spa pool on display at a flower show in the Netherlands in 1999 caused 226 cases of Legionnaire's disease and 28 deaths. In New York in 2005, an interactive water feature was associated with 1,374 cases of illness, of which 425 were confirmed as cryptosporidiosis. Inflatables used in pools pose a potential hazard, for example an outbreak of folliculitis in 35 children in England in 2002. These soft inflatable devices may be used for water assault courses.

Pools become contaminated by humans (sweat, urine, faeces, hair, skin flakes etc.) and outdoor pools are vulnerable to dust, leaves, animals, rain or algal growth. Without active management this dirt builds up, microbes flourish and the organic load renders biocide inactive. In addition to appropriate design and treatment (Figure 3) the input of pollution must be managed by good personal hygiene, controlling the bather load and replacing water according to the number of users: 30L/bather/day, while maintaining the total dissolved solids at no more than 1000mg above the source water content. Sand filters should be monitored to detect pressure loss across the filter and backwashed at least weekly, or ideally at the end of the day. Chlorine treatment for swimming or hydrotherapy pools should aim at 1-2mg/L at pH 7.2-7.4.

# Specialist water needs: cooling towers, private water supplies and leisure pools.

Spa pools require a higher concentration of 3-5mg/L at PH 7.0-7.6m. Combined chlorine level should be zero, ideally, but never exceeding 1mg/L and always less than half the free chlorine.

Figure 3: **typical layout of a pool, showing filtration and disinfection Chlorine**




## Typical layout for pool with filtration and disinfection

- Note
  - Balance tank
  - Most of pollution is in surface layer therefore 80% (minimum 50%) of water removed from surface ideally by deck level channels
  - Coagulant dosing (e.g. alum, polyaluminium chloride, PAC) –
  - Medium rate filters (10 – 25m/h) Chlorine before or after filter
  - pH correction after filter

**Chlorine** is well tried for pool water treatment, with the additional advantages of being cheap, relatively easily managed with automatic devices and little chance of pathogen resistance. While chlorine is an effective disinfectant, it can react with organics in pool water to produce chloramines and nitrogen trichloride, which may irritate the skin or provoke asthma attacks. By-products such as trihalomethanes have been implicated as carcinogens.

# Specialist water needs: cooling towers, private water supplies and leisure pools.

Thus removal of organics is part of good management, achieved via filtration, coagulation, controlling bather load, washing before bathing and making sure users know there should be no urination in the pool. This allows minimal use of chlorine. The multibarrier approach is essential, since some pathogens are destroyed quite slowly in chlorinated water, for example 16 minutes for *Hepatitis A*, 45 minutes for Giardia spp. and 255 hours for *Cryptosporidium* spp. Filters help to combat the level of these pathogens, with more than 90% removal of Cryptosporidium in a single pass if also associated with coagulation. Secondary disinfection with UV units is advisable if filtration standards are poor, with the advantage of also breaking down chloramines and other organic pollutants by photo-oxidation.

## The problem with spa pools

The temperature of spa pools, between 30-40C, encourages bacterial growth and this is compounded by high organic load (skin, sweat, bath oils, cosmetics) and high bather density. Biofilms develop readily, with the pipes and balance tanks frequently found to be inaccessible for biofilm removal. A single modern spa pool may contain as much as 75 metres of flexible and fixed pipes, giving a total surface of 5.5m2, all vulnerable to biofilm. Thus it is not surprising that spa pools are the 3rd commonest cause of legionellosis, a common cause for *P.aeruginosa* folliculitis and occasionally mycobacterial pneumonitis.

**Safe operation of all pools includes:**

**1. Staff training so that they understand why tasks are necessary**

**2. Continual monitoring (automatic for pH and chlorine, backed up by manual checks several times a day for chlorine, combined chlorine and pH)**

**3. Daily inspection to check for leaks, water clarity, chemical levels in storage tanks, pressure gauges and flow meters. Maintenance records should be kept and additional inspections and microbiological testing made after a shutdown for any reason, or contamination has been noticed, or to validate any changes in the treatment regime.**

**4. Backwash of filters at the end of the day, at last weekly, checking calibration of dosing and monitoring equipment**

**5. Good hygiene and cleanliness [and for the users this includes showering with soap, hand washing after changing nappies or toilet use, taking children to the toilet before they swim and not swimming for 48 hours after any episode of diarrhoea (2 weeks if cryptosporidiosis has been diagnosed)]**

**6. Clear policy for recognising and reporting faecal accidents.**

# Specialist water needs: cooling towers, private water supplies and leisure pools.

Microbiological monitoring of swimming and spa pools should be at least monthly, aiming for <10 aerobic colony count/ml and to ensure absence of coliforms per 100ml. A count of 10 coliforms is acceptable if all other criteria are met, but *E.coli* should be absent. Quarterly testing for Legionella spp. is advised for spa pools and microbiological monitoring of hydrotherapy pools should be done weekly because of use by a more vulnerable population.

The contemporary challenges for pool management include the new features, such as splash pads, while the perceived risk of chlorination by-products has led to use of copper silver ionization as an alternative, or provision of a 'natural' undisinfected pool. Water replacement to account for bather load is threatened by concerns about water and energy saving. Guidance for effective use and testing of pool and spa disinfectants is available (OECD 2012). See references for other recreational water guidance.

## Discussion points from the question and answer session:

Questions on cooling towers: There is a requirement to notify local authorities of the location of evaporative condensers and cooling towers to local authorities, in case of outbreaks. They came into force in 1992 and haven't kept up with advances in cooling tower design so the definitions are too narrow. Some of the wet cooling systems may meet the definition of an evaporative condenser and each needs to be considered case by case. If the water is applied directly and involves a draft of air, these must be notified. The important point is that a risk assessment should be carried out on any system used, particularly if an outbreak occurs in the community. Around 350 cases occur annually, in which, for the majority, the source is not identified. So at present, despite lack of evidence, no device can be assumed to be safe. Regarding closed systems with no access for inspection, it is important to be able to see inside the tower to assess cleanliness – or to clean it. Alternative approaches include using a camera on a cable, inserting it down into the tower or other parts of the system. Cleaning in-situ with a wide range of chemicals is now possible, even without direct access. Private water systems: how common is arsenic in European waters? A study by HPA showed that some areas of UK have a problem, for example Cornwall. The report is on National Archives website.

**References/resources:**


WHO 2014. http://apps.who.int/iris/bitstream/10665/112727/1/9789241507240_eng.pdf

The WHO water safety plan manual: http://whqlibdoc.who.int/publications/2012/9789241548427_eng.pdf?ua=1

OECD (Organisation for Economic Cooperation and Development) Guidance document for demonstrating efficacy of pool and spa disinfectants in laboratory and field testing. http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=env/jm/mono%282012%2915&doclanguage=en

WHO 2006 Guidelines for safe recreational water environments Volume 2: Swimming pools and similar environment

Pool Water Treatment Advisory Group (PWTAG) 2009 Swimming Pool Water: Treatment and Quality Standards for Pools and Spas www.pwtag.org

CDC 2014 Model Aquatic Health Code (MAHC) 1st Edition and Annex http://www.cdc.gov/healthywater/swimming/pools/mahc/structure-content/index.html

Joint HSE & HPA Guidance: Management of Spa Pools: Controlling the Risk of Infection. London: Health Protection Agency. 2006 ISBN 0 901144 80 0 Can be downloaded from the Public Health England https://www.gov.uk/government/publications/legionnaires-disease-controlling-the-risk-of-infection-from-spa-pools

# Risk Assessment & Audit on Healthcare Buildings

## 26th November 2014

**Dr Susanne Lee,** Director of Leegionella Ltd and Chair, RSPH Water Special Interest Group, UK.

Chaired by Professor Jamie Bartram, Don and Jennifer Holzworth Distinguished Professor, Department of Environmental Sciences and Engineering and Director, The Water Institute, Gillings School of Global Public Health, University of North Carolina at Chapel Hill, USA.

In this penultimate webinar, Dr Susanne Lee focused on the WHO Water Safety Plan (WSP) approach of identifying and managing hazards to reduce risks of in-premise water contamination and waterborne infection. It reviewed the three main areas of water system assessment covered within the WSP guidance – Monitoring, Management and Communication.

Initially WSPs were developed to support the municipal water provider; however whilst there are relatively few distributed water providers, there are many more buildings where water is distributed, there are many factors within individual buildings that can lead to poor quality of water, including bacterial contamination at levels which may cause illness in susceptible individuals. Adopting the WSP approach within individual buildings, despite good and safe quality influent water, is therefore highly relevant.

With ill-advised design and poor management, biological and chemical hazards can increase within the in-premise water system to levels that may cause disease or other unwanted effects. This may be caused by leaching from plumbing component materials or ingress of pathogens as a result of a contamination event. Some potential pathogens, such as pseudomonads, legionellae and non-tuberculous *Mycobacteria*, are ubiquitous in water and it is logical to assume presence, at a low level, in influent supply waters. These levels may not be detectable by routine methods or sample volumes –at the building input, influent water should be sampled in much larger volumes (e.g. 10 L) to increase the sensitivity of the detection method. The larger and the more complex a water system is, the greater the potential for microorganisms to increase within that system, particularly when not in regular use. Physical hazards also need to be considered, such as the potential for scalding of vulnerable users particularly where there is whole body immersion with showering and bathing.

Health based targets are normally set at the national level by a competent authority (within national or state legislation; codes of practice etc.), however they usually lack practical detail on how to achieve these targets. The WSP system assessment, or risk assessment, is the key component and basis for putting together a scheme of control to meet set targets. If this is not carried out by competent, experienced assessors with an understanding of the specific system(s), the hazards associated with them - potential hazardous events which may lead to increases in risk to levels which may cause disease - then the assessment will not be worthwhile. The control programme should be reviewed alongside and not in isolation. Ideally monitoring targets should be easily measurable in real time (e.g. temperature, target levels of disinfectant, turbidity of incoming water etc.). The individuals involved in the management and operation of control measures, need to be trained and competent.

# Risk Assessment & Audit on Healthcare Buildings

Healthcare premises need special focus as many water users are at higher risk than the general population with increased susceptibility to infection because of their illness or treatment. The WHO advises that WSPs should be developed for all healthcare premises, and should have specific water safety plans as part of infection control to address issues such as water quality requirements and include cleaning specialised equipment and control of microorganisms in ancillary equipment. Actions and targets may need to be adjusted to take account of patient vulnerabilities and water management enhanced to ensure that all relevant staff are aware of the risks to more vulnerable patients. Surveillance may also need to be enhanced, with input from public-health water microbiologists and infection prevention specialists as appropriate. Microbiological monitoring may need to be extended to take into account the hazards of relevance (e.g. monitoring for *Pseudomonas aeruginosa* in neonatal intensive care units).

The first step in the WSP is to appoint the Water Safety Team (WST). People with a range of competencies should be assembled to share responsibility and take collective ownership for the WSP. The team should be multidisciplinary and have members with sufficient experience and expertise to understand the risks associated with all water uses within their buildings. Within buildings such as leisure complexes and hotels, this may include expertise in managing swimming pool water quality and associated equipment. In large buildings, particularly in healthcare, the assessment of potential hazards and hazardous events is more complex so external expertise may be useful. However the WST should have sufficient knowledge experience and competency to be able to assess the validity of any work carried out by an outside contractor and the competency of those appointed to carry out work on their behalf. It is essential that the WSP is managed and communicated effectively both within the WST and upwards and downwards within the organisation, with supporting programs to ensure good communication practice.

Audit of the WST should be completed in order to assure appropriate expertise, that the members are familiar with the system, correctly trained, understand the role they have undertaken, and that regular, well attended meetings are occurring. The team skills, reporting mechanisms, understanding of Health & Safety, impacts of water system controls and their positive and negative effects on water system response should be checked.

# Risk Assessment & Audit on Healthcare Buildings

An important role of the WST is to prioritise where upgrades / remedial work is needed, ensuring the best use of available funds and budget requests. Any 'improvements' should be validated and verified over an extended period of time to ensure no unanticipated detrimental effects. The WST should be involved from the design of the building (or extension or refurbishment), water system review and input for water safety requirements depending on intended purpose, materials both specified and existing within the water system, suitable control measures, commissioning a water system (which is the most vital time in the buildings life) and ongoing maintenance programs.

In addition to audit of the competent WST, there is the auditing of risk assessments – for which Dr Lee explained that there are no suitable "off-the-peg" WSP as each building and user group are unique. If there are the resources available, the WSP may be developed in-house, but for large, complex water systems many WSTs employ specialist firms to compile and carry out the system risk assessment. The WST must carefully review this and carry out an internal audit to verify nothing has been missed and that the assessment reflects the risk to the user population. Not all risk assessments are the same; the quality of the content can vary tremendously and despite sometimes high cost they can be of low value.

Subsequent steps of the WSP rely on the information gathered for the system description. The system description must accurately reflect the current state of the system and how it is managed. In the Food Safety environment, Hazard Analysis Critical Control Points (HACCP) is used to ensure product safety, and the process has similarities with the WSP approach. HACCP was originally devised by Pillsbury in 1959 to ensure the safety of food and beverages from microbiological hazards for the first NASA manned space missions in order to prevent astronauts falling victim to gastroenteritis whilst gravity-less in space!

**The Codex Alimentarius guidelines for HACCP (1997) identify a 7 step process:**

1. Conduct hazard analysis
2. Critical control points
3. Critical limits
4. Monitor controls
5. Correct action(s)
6. Verification procedures
7. Documentation of the previous steps

# Risk Assessment & Audit on Healthcare Buildings

If legionellae is taken as an example, the influent water supply into a building is the first point where a target can be specified. It is not realistic to have an influent supply which has zero opportunistic pathogens including legionellae, however routine culture methods are too insensitive for very low incoming numbers, plus they may be non-culturable (in a Viable But Non-Culturable state) from the cold water temperatures. The temperature of water is a critical control - we know that legionellae do not grow significantly below 20C and at these low temperatures do not appear virulent. If low influent cold water temperatures cannot be maintained, alternative strategies such as chlorination at the point-of-entry may be employed, and then maintaining an adequate level of chlorine becomes a critical control parameter. It is advisable to install a multi-barrier control system, so if one control measure fails there is a backup system, particularly with vulnerable users in high risk areas.

Even with good general influent water quality at the point-of-entry, acute contamination can occur as a result of ingress due to sewage leakage, flooding, animal, bird or insect ingress, poor plumbing techniques etc. Strict audit of monitoring results - such as turbidity, water temperature, chlorine residuals and relevant microorganisms - will give some indication of the consistency of water quality and likelihood of microbial growth. It is important to monitor throughout the year to achieve an accurate baseline, as there will be significant changes between the seasons.

HACCP analysis is not a holistic approach lacking the supporting programmes within a WSP. The WSP includes what the hazards are, what could go wrong, how likely it is to happen and what are the consequences or how much harm could be caused. This last area is usually the most difficult to assess and agree as a WST; realising that contamination may make water unfit to drink is easy to agree versus assessing how much harm it would cause if ingested. In quantifying risk, it is difficult to get a consistent assessment between different assessors even when using a risk assessment tool. A “traffic light” approach can be an effective and non-complex system to adopt for risk assessment which is easily understood including by non-professionals. As part of the risk assessment process, schematic drawings of a water system should be checked for accuracy and to assess if the critical points – where contamination could occur - have been correctly identified. The schematic drawings do not need to be detailed technical drawings but should identify important components, materials, connections, flow directions etc., and should be simple enough for non-engineers to understand. They should be used to assess the likely points where failures may occur (e.g. pump breakdown) and identify suitable monitoring points.

# Risk Assessment & Audit on Healthcare Buildings

Audit of monitoring data (temperature profiles may indicate potential points where the risk of colonisation and growth is higher) and analysing complaints – these may be an early indicator of a problem such as change in taste, odour or colour – would include whether have they been followed up and actions taken as appropriate. Additional verification to ensure that people dealing with complaints operationally have necessary competences, and that quality checks on works done are completed, should also be part of audit.

Drinking water is not just used for quenching thirst and all routes of exposure need to be risk assessed and addressed.

**In complex buildings with multiple-users there may be additional routes other than direct ingestion, such as:**

- **Indirect ingestion: consumption of food and beverages irrigated or prepared using contaminated water**
- **Aspiration: where patients have poor swallow reflex or following head and neck surgery**
- **Contact: bathing including the use of hydrotherapy pools, spa pools and whirlpool baths, toys, floats / inflatables etc.**
- **Aerosol inhalation:- cooling towers, hot and cold water outlets including showers, taps , toilets, spa pools, decorative fountains, irrigation systems , misting devices, medical nebulizers etc.**

All systems, including extensions such as mops, buckets and equipment, need to be included in the assessment and compiling an asset register can ensure that all potential sources and uses are recorded. It is important to ensure that all systems are assessed individually, taking into account the proximity and susceptibility of the user population and mode of transmission from the water source. For each system the potential for hazards and hazardous events should be assessed.

Waterborne hazards that can cause harm to health may be physical, biological, chemical or radiological. Hazards may be specifically associated with a particular system which means that appropriate controls and monitoring procedures can be put in place, e.g. the likelihood of a faecal accident (hazardous event) in the leisure industry - swimming pool operators vary greatly in their assessment of likelihood from rarely to frequently which most likely would reflect the pool user profile. The likelihood that the faeces could contain a pathogen (risk) and the user impact if present (weighted risk) then needs to be agreed.

**Consideration needs to be given for water used in, or associated with, procedures such as**

- **Cleaning wounds, oral hygiene, ear rinsing,**
- **Inadequate protection of indwelling venous catheters during showering, bathing, shaving etc.,**
- **Treatment using instruments and/or equipment rinsed using contaminated water e.g. endoscopes, dialysis machines etc.,**
- **Cleaning solutions or disinfectants diluted with contaminated water (e.g. Pseudomonas is known to colonise disinfectants and liquid soaps).**

This may be seasonal; there are often peaks in pool-associated *Cryptosporidium* infections in late summer when people return from holidays abroad. A faecal accident in a pool, if not recognized and acted upon, could lead to an outbreak of *Escherichia coli* O157, and possibly lifelong consequences for those affected.

Earlier in the webinar series, Professor Kevin Kerr clearly explained that legionellae is not the only waterborne organism of concern. Many other species can cause morbidity and mortality in the user population, many are difficult to diagnose, have limited treatment options as many are inherently resistant to commonly used antimicrobials and some, such as the pseudomonads, can act as reservoirs of antibiotic resistance. Not all waterborne hazards are associated with just the water system infrastructure. There are many damp places that can harbour biofilms containing pathogens. Certain plumbing components such as infra-red proximity taps, certain plastic materials, new fittings which have been pressure tested with water during manufacture and then installed with a pre-existing biofilm have all been identified as critical points increasing the risk of colonisation.

Control measures are not a panacea, and any interventions must be validated i.e. shown to be effective in the specific water system. Monitoring should be completed in the areas where risk is perceived greatest, and within healthcare the following should be included when weighting risk.

- **Immune status of the user population**
- **Skin integrity**
- **Implants / foreign materials**
- **Steroid / antibiotic therapy**
- **Patients in "overflow" areas (when beds are at capacity in intensive care areas etc.)**

Enhanced risks, not suitable for susceptible patients include ice/ice-machines, drinking water fountains, bottled waters, large buildings with high water volumes and increased stagnancy rates, and hot water temperatures < 55C. Enhanced control measures for high risk areas may include increasing the hot water temperatures, adding chemical disinfectants to cold water (in very high risk areas it may be necessary to chill the cold water) and installation of point-of-use water filters.

In reducing one risk, the WST should be aware of increasing another – and there is no doubt that scalding is a serious risk to vulnerable groups such as the very young, elderly, those with neurological disorders and where there

is potential for whole body immersion. In these specific areas, hot water temperatures should be restricted at the outlet by installing thermostatic mixing valves (TMV) – preferably with the TMV positioned immediately at the outlet to reduce the level of biofilm and pathogens downstream. Sampling and monitoring through outlets fitted with TMV should be interpreted in that context – water samples should normally be taken from separate hot and cold water outlets which are not blended.

Continuous audit is an essential supporting component of a water safety plan and it may be helpful to utilise independent resource to support the WST by reviewing the risk assessment, selected control measures, training and activities of the WST. Checklists can be a useful aide memoire but they must also be under continuous review in order to avoid tunnel vision. It is important to recognise that you cannot audit effectively as a desk top exercise.

At the start of this RSPH webinar series, Professor Bartram discussed the global burden of waterborne disease and the benefits of managing water systems using the water safety plan approach.

### A WSP approach

- **Is the most effective means of consistently ensuring the safety of water**
- **Offers a comprehensive and documented risk management approach for the safe operation of water systems**
- **Encompasses all steps from water source through treatment and distribution to consumers.**
- **Ensures that effective controls and multiple barriers are applied to minimize risks to acceptable levels,**
- **Includes monitoring of the controls and barriers to ensure that safety is maintained.**
- **Ensures supporting programmes are in place**

## Discussion points from the question and answer session:

The question session, directed by Professor Bartram, highlighted the audience issues and experiences including

- Fungi in water supplies, which have been recognised, reported and documented by a handful of authors including Anaissie and colleagues in 2002.
- Lack of communication – particularly about ward closures where stagnation can quickly lead to adverse microbial problems – can lead to failures which could be easily preventable and planned for. There should be procedures for the water control and safety for non-routine conditions such as a room or ward or floor or even building being decommissioned.
- The scalding risk which tends to be exaggerated for most populations but was confirmed to be a higher risk in paediatric and infant units, elderly care and in wards housing neurological impaired patients. Here TMVs would be expected to be installed, however they tend to be seen in multiple areas and without any evidence of scalding in the normal user population.
- Where the hospital is partnered with a PFI it is important that the WST has both parties fairly represented and they need to have conflict management as part of their program.

**References/resources:**

Anaissie, E.J., Stratton, S.L., Dignani, C., Summerbell, R.C., Rex, J.H., Monson, T.P., Spencer, T., Kasai, M. et al. Pathogenic Aspergillus species recovered from a hospital water system: a 3-year prospective study. Clin Infect Dis 2002; 34: 780–789.

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# Surveillance and Critical Event Management

## 17th December 2014

**Dr Birgitta de Jong,** Senior Expert, European Centre for Disease Prevention and Control (ECDC), Sweden.

Chaired by Dr Susanne Lee, Director of Leegionella Ltd and Chair, RSPH Water Special Interest Group, UK.

The final webinar dealt with the important topic of surveillance and managing critical events where water may be implicated. The size and impact of waterborne outbreaks is often under-estimated. Dr de Jong referred to several large outbreaks in Europe, but started the discussion with the major outbreak of *Cryptosporidium parvum* in Milwaukee, USA in 1993. An estimated 403,000 cases included 4,400 requiring hospital treatment. The reported attack rate of 25% reflected the high level of contamination as well as the low infectious dose required for this organism to cause illness. The many lessons learned for surveillance and management included the potentially high cost of waterborne disease at this level: the total expense of outbreak-associated illness was estimated to be $96.2 million, two thirds of this in loss of work productivity and a third in treatment costs.

### Surveillance systems in the European Union (EU)

During the last two decades, several systems have been established in Europe to monitor a wide range of disease. In addition to TESSy, the European surveillance system, and the Epidemic intelligence information system (EPIS), there are specific networks for Legionnaires' disease (ELDSNet), for water and food (FWD network) and for preparedness and response to critical events. The systems aim to ensure health security at the EU level, in close cooperation with EU Member States, through the following actions mandated for the European Centre for Disease Prevention and Control (ECDC):

- Detection
- Assessment
- Response
- Preparedness
- Communication

The ECDC gathers epidemic intelligence and scientific opinions, operating an early warning system and response as well as communicating with the scientific community and the public. At this level, all data are anonymised so that the identity of individual cases is protected. Risk detection, monitoring and assessment are conducted with the Member States of the EU, with risk management – the implementation of control measures – the responsibility jointly of the European Commission and its Member States. The ECDC has over 350 staff recruited from all Member States and elsewhere, including experts in communicable disease, epidemiology, epidemic intelligence, risk assessment, communication, information technology, training, scientific methods, microbiology and biopreparedness.

# Surveillance and Critical Event Management

A web-based surveillance atlas of infectious diseases displays notifications of infectious diseases, with indicators set individually for each disease to facilitate appropriate actions [see source below for this useful new tool, which aims to share the data that ECDC collates]. The assessment of different signals/threats is discussed in the EPIS platform, including exchange of information about current or emerging public health threats and an international communication platform to allow an expert network to rapidly share the information and data. While EPIS provides the expertise for assessing threats, risk management, control measures and policy is organised by EWRS, the Early Warning and Response System.

### European Legionnaires' disease surveillance network (ELDSNet)

Surveillance of illness due to Legionella spp. is carried out by ELDSNet, one of the seven disease specific networks. It covers 28 EU Member States, Iceland, Norway and other contact points, producing an annual report, operating procedures and arranging meetings as well as surveillance, response to travel-associated clusters, quality activities for laboratories, training courses and support to ESGLI (former EWGLI). ELDSNet detects around 100 clusters of travel associated Legionnaires' Disease annually, of which an estimated 40-55% would be missed without this network. Analysis of data shows a constant trend of cases being more common from early summer to early autumn. Overall, ~10% of cases are fatal and among travellers ~ 5 % are fatal.

### The Food and Waterborne diseases and Zoonoses [FWD] network

This well established network covers 21 diseases, including several classified as commonly waterborne, such as campylobacteriosis, cholera, cryptosporidiosis, giardiasis, Hepatitis A, norovirus, typhoid and paratyphoid fevers and STEC/VTEC infection. In fact, there are few diseases that cannot be waterborne, so others such as leptospirosis, shigellosis and salmonellosis should be remembered, the latter obviously more commonly foodborne as a high infectious dose is usually required to cause illness. The FWD system includes announcements of human cases of enteric pathogens and possible contaminated foods, urgent inquiries to allow early detection of multinational outbreaks, technical discussions, coordination of investigations across countries and providing updated technical information and reports. Because water incidents are geographically localised, cross-country surveillance is rarely involved, an exception being an outbreak of cryptosporidiosis in Sweden where an international competition resulted in cases in several countries.
Both EU and non-EU experts in epidemiology and microbiology can access its information.

# Surveillance and Critical Event Management

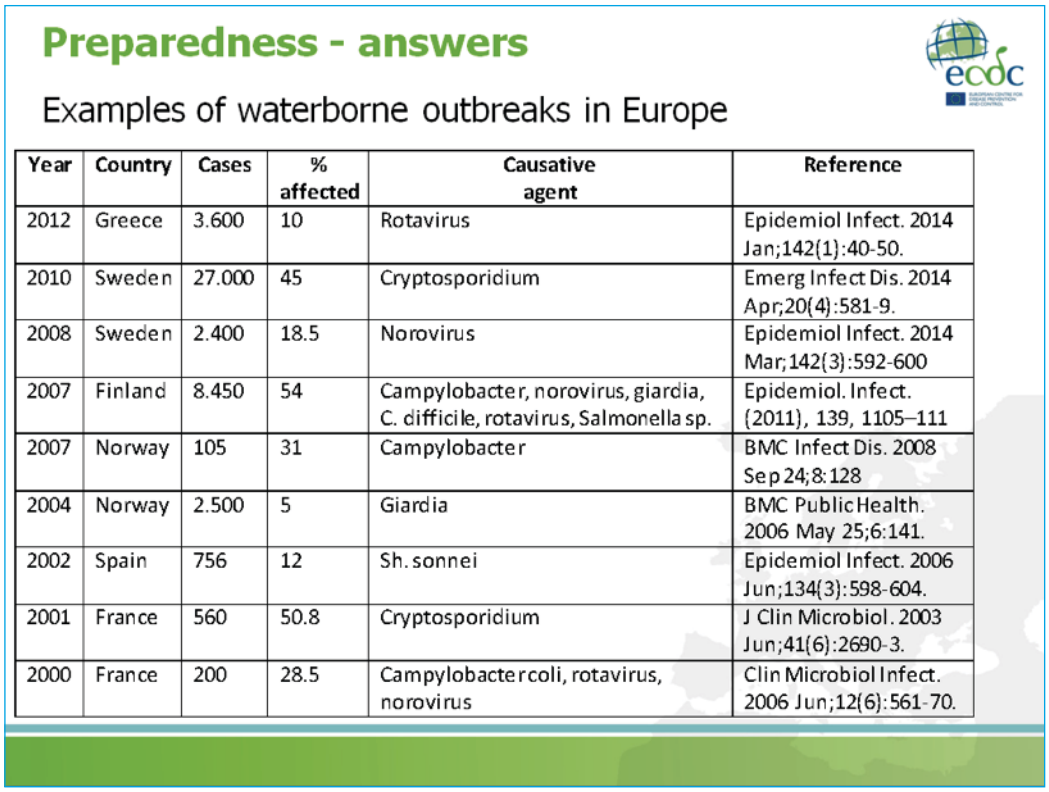
## Critical event management

Preparedness for events means challenging the complacency of statements such as “Our water source is well protected”. Dr de Jong illustrated this with an incident where the source was surrounded by a fence, but with no protection against sewage from a blocked pipe that seeped into the water. The surveillance system shows widely varying reports from other countries (Figure 4). This is partly related to differences in water drinking habits, the development of surveillance and differences in approach, such as an increase in reports in Finland after the compulsory requirement to notify waterborne outbreaks after 1997. Outbreaks need to be investigated to identify and control the source; also to prevent future outbreaks by identifying risk factors and detecting systematic errors. Routine surveillance is only one of the sources of outbreak information, which may also come from the media or the general public. Once confirmed, an outbreak control team is established to oversee immediate control measures such as isolation of cases and public warnings; and to instigate further investigation of the aetiological agent, mode of transmission, population at risk and the exposures that have caused illness. The key questions of when, where, how, who, what and why all need to be answered: the example of Dr John Snow’s investigation of cholera cases in London in 1854 demonstrated how these questions are deceptively simple, well established – and not necessarily easy to address. The first report of an event may be misleading as to numbers, which may increase by a factor of ten or more after thorough investigation. Analytical epidemiological methods, such as cohort and case-control studies are the recommended way of sorting out the key suspected factors. Communication with the public is relevant at all stages to allay anxiety about a known outbreak.

**In summary, the steps are:**

1. Confirm the outbreak and diagnosis
2. Case definition
3. Case identification and information gathering
4. Collection and analysis of data
5. Hypothesis development
6. Testing the hypothesis by analytical studies
7. Special studies as required
8. Communication of results, including an outbreak report
9. Implementation of control measures

Figure 4: **Examples of waterbourne outbreaks in Europe**



**Preparedness - answers**

Examples of waterborne outbreaks in Europe

| Year | Country | Cases | % affected | Causative agent | Reference |
|---|---|---|---|---|---|
| 2012 | Greece | 3.600 | 10 | Rotavirus | Epidemiol Infect. 2014 Jan;142(1):40-50. |
| 2010 | Sweden | 27.000 | 45 | Cryptosporidium | Emerg Infect Dis. 2014 Apr;20(4):581-9. |
| 2008 | Sweden | 2.400 | 18.5 | Norovirus | Epidemiol Infect. 2014 Mar;142(3):592-600 |
| 2007 | Finland | 8.450 | 54 | Campylobacter, norovirus, giardia, C. difficile, rotavirus, Salmonella sp. | Epidemiol. Infect. (2011), 139, 1105–111 |
| 2007 | Norway | 105 | 31 | Campylobacter | BMC Infect Dis. 2008 Sep 24;8:128 |
| 2004 | Norway | 2.500 | 5 | Giardia | BMC Public Health. 2006 May 25;6:141. |
| 2002 | Spain | 756 | 12 | Sh. sonnei | Epidemiol Infect. 2006 Jun;134(3):598-604. |
| 2001 | France | 560 | 50.8 | Cryptosporidium | J Clin Microbiol. 2003 Jun;41(6):2690-3. |
| 2000 | France | 200 | 28.5 | Campylobacter coli, rotavirus, norovirus | Clin Microbiol Infect. 2006 Jun;12(6):561-70. |

## Discussion points from the question and answer session:

For questions about reported clusters/outbreaks of legionnaires' disease outside the EU, Dr de Jong explained that the first step is to inform the country, the WHO and tour operators, if a hotel is involved. Public health authorities and hotel owners are asked to investigate and progress is monitored. Involvement by non-EU countries is encouraged, for example less clusters have been reported from Thailand following improved communications. Where control measures are not promptly implemented, it is important to know that ECDC has no authority to pursue this.
Some countries, including some eastern countries within the EU, do not have sufficient funds to fully contribute to the surveillance, including the laboratory costs of operating the EQAs. This means that some travel-associated cases may not be reported: the ECDC is addressing this through offering training courses as well as the freely available tool kit for outbreak investigation which is posted on the ECDC website.

**References/resources:**

ECDC site with summaries of the networks and reports: http://www.ecdc.europa.eu/en/activities/surveillance/european_surveillance_networks/Pages/european_surveillance_networks.aspx

European Surveillance System (TESSy): http://www.ecdc.europa.eu/en/activities/surveillance/tessy/pages/tessy.aspxA

The Surveillance Atlas Of Infectious Diseases. http://www.ecdc.europa.eu/en/data-tools/atlas/Pages/atlas.aspx

European Legionnaires' Disease surveillance: http://www.ecdc.europa.eu/en/activities/surveillance/eldsnet/pages/index.asp

Food and waterborne disease surveillance: http://www.ecdc.europa.eu/en/publications/surveillance_reports/fwd/Pages/fwd.aspx

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## About the Royal Society for Public Health

The Royal Society for Public Health (RSPH) is an independent health education charity, dedicated to protecting and promoting the public's health and wellbeing. We are the world's longest-established public health body with over 6000 members drawn from the public health community both in the UK and internationally. Our operations include an Ofqual recognised awarding organisation, a training and development arm, health and wellbeing accreditation, and a certification service. We also produce a wide-variety of public health conferences; our publishing division includes the internationally renowned journal Public Health; and we are developing policy and campaigns to promote better health and wellbeing.

**For more information:**
**www.rsph.org.uk;**
**twitter: @R_S_P_H**

# Join us and set yourself apart

RSPH
ROYAL SOCIETY FOR PUBLIC HEALTH
VISION, VOICE AND PRACTICE



**The Royal Society for Public Health** is a leading public health charity. We have a diverse membership of over 6000 public health professionals who all benefit from being a part of our community.

Membership of RSPH demonstrates your commitment to public health and your career and enables you to be a contributing voice to public health.

As a member you will benefit from using prestigious post-nominal letters, allowing you to stand out in the competitive workplace. You will also be able to stay up to date with current topics through our journals, newsletters, regular member events and online Members' Area, as well as receiving discounted places to attend the full range of RSPH courses and conferences.

RSPH membership is international and diverse, covering all aspects of public health, from health promotion to microbiology, medicine to pest control, and environmental health to nursing. Whatever your speciality or interest within public health, we are confident that we will be able to help, interest and benefit you professionally.

As a public health professional we would like to welcome you as a member to the RSPH, so that you can take advantage of the benefits we offer and ensure your voice is heard in public health.

Join online today at www.rsph.org.uk

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**Royal Society for Public Health**

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