NHS National Services Scotland

Evidence Tables

Infection prevention and control (IPC) for safe healthcare water systems

Version 1.0

29 July 2024

ARHAI Scotland

Antimicrobial Resistance and Healthcare Associated Infection

Version history

Version	Date	Summary of changes
1.0		Final for publication

Approvals

Version	Date Approved	Name
1.0		ARHAI Scotland Infection Control in the Built Environment & Decontamination (ICBED) Working Group
1.0		ARHAI Scotland Community Infection Prevention & Control (CIPC) Working Group

Contents

Introduction

All studies which are critically appraised as part of the literature review are assigned a grade of evidence based on the SIGN 50 methodology grading system, which allows scientific studies to be assessed for quality using a number of reviewing forms.

The main conclusions from the studies are summarised along with a brief description of the study quality in an Evidence Table. Studies, which have sufficient quality and specifically answer a defined research question are grouped together to enable formation of a “considered judgment” based on this information. This “considered judgment” is then used as the basis for formulation of recommendations.

This system allows formulation of recommendations supported by good quality observational studies in the case when Randomised Control Trials (RCTs) are not available for practical or ethical reasons, as is generally found in infection control literature.

Levels of evidence

The following grades were given to the papers included in this evidence table:

Grade	Description
1++	High quality meta analyses, systematic reviews of RCTs, or RCTs with a very low risk of bias
1+	Well conducted meta analyses, systematic reviews of RCTs, or RCTs with a low risk of bias
1-	Meta analyses, systematic reviews of RCTs, or RCTs with a high risk of bias
2++	High quality systematic reviews of case-control or cohort studies. High quality case-control or cohort studies with a very low risk of confounding, bias, or chance and a high probability that the relationship is causal
2+	Well conducted case control or cohort studies with a low risk of confounding, bias, or chance and a moderate probability that the relationship is causal
2-	Case control or cohort studies with a high risk of confounding, bias, or chance and a significant risk that the relationship is not causal
3	Non-analytic studies, for example case reports, case series
4	Expert opinion

Research questions for evidence tables

1. Which organisms associated with healthcare water systems are responsible for colonisation/infection of patients?

2. How do healthcare water system-associated organisms survive in the environment?

3. What are the causes/sources of environmental contamination with healthcare water system-associated organisms?

4. Which patient populations are considered as being at increased risk of colonisation/infection with a healthcare water system-associated organism?

5. What types of infection can healthcare water system-associated organisms cause?

6. What are the incubation periods of healthcare water system-associated organisms?

7. What is the period of communicability for healthcare water system-associated organisms?

8. What are the known transmission routes of healthcare water system-associated organisms?

9. Which healthcare procedures present an increased risk of transmission of healthcare water system-associated organisms?

10. What are the microbiological water testing requirements at commissioning?

11. What are the responsibilities of the IPC team in regards to water safety at commissioning?

12. Is routine water testing to detect healthcare water system-associated organisms recommended?

13. What are the recommended microbiological limits for healthcare water system-associated organisms?

14. How frequently should routine water testing be conducted?

15. When should routine water testing frequency be increased?

16. Where should routine water samples be taken from (which outlets, how many samples)?

17. When should water samples from further back in the system be taken?

18. Who should water test results be reported to?

19. How should routine water test results be interpreted?

Question 1: Which organisms associated with healthcare water systems are responsible for colonisation/infection of patients?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and environmental microbiology 2019; 85.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing.	Sample type, number of positive samples, CFU counts, MIC, PFGE type.
Assessment of evidence					
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca.*					

Assessment of evidence
Transmission mode: contaminated water-based equipment. Clinical setting: perinatal setting/children's hospital, Germany. Source: Isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Washing machine was a **reservoir** (residual water) that facilitated transmission, it was not the source. Control measures: environmental monitoring, admission screening, IPC training HCWs, renovation/contamination sinks, etc. All garments worn by newborns and children were laundered by professionally service. The washing machine was removed. The use of professional washing machines and routine checking with a temperature logger are urgent requirements.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Campos-Gutierrez S, Ramos-Real MJ, Abreu R, et al. Pseudo-outbreak of *Mycobacterium fortuitum* in a hospital bronchoscopy unit. American Journal of Infection Control 2020; 48: 765-769.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a pseudo-outbreak of *Mycobacterium fortuitum* in Spain (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *M. fortuitum* isolated from a water sample (tap) were compared.	Number of positive samples, sample type, typing results (by restriction fragment length polymorphism and by enterobacterial repetitive intergenic consensus sequences).

Assessment of evidence
The hospital water supply showed to be contaminated with *M. fortuitum*, which is why its use in the rinsing of high-level disinfection led to a recontamination of the bronchoscopy. Organism: *Mycobacterium fortuitum.* Transmission mode: contaminated water-based equipment. Clinical setting: pneumology bronchoscopy unit, Spain. Source: the hospital water used by the bronchoscope automatic washing machine (without antibacterial filter). Control measures: not using the washing machine without manually cleaning and disinfecting it with prefiltered water using the Pall AquaSafe Water Filter until purchasing a new washing machine. As a surveillance measure, an environmental microbiologic study of the hospital water was established every 15 days, in which, since this outbreak, an RGM study was included. Installation of filters in those taps where water is taken from to rinse invasive instruments after disinfection. The authors describe a pseudo-outbreak as real clustering of false infections or artefactual clustering of real infections, which is often identified when there is increased recovery of unusual microorganisms. They however call it a pseudo-outbreak because there was no clinical impact on patients.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Heireman L, Hamerlinck H, Vandendriessche S, et al. Toilet drain water as a potential source of hospital room-to-	Outbreak investigation	**Level 3**	The aim of this study was to investigate a OXA-48-producing *Klebsiella pneumonia* outbreak in Belgium (including finding the source) and to determine the	Molecular typing results between patient strains and *Klebsiella pneumonia* isolated from environmental/water	Number of positive samples, sample type, whole-genome sequencing results and phylogenetic analysis.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
room transmission of carbapenemase-producing *Klebsiella pneumoniae*. Journal of Hospital Infection 2020; 106: 232-239.			impact of infection prevention and control measures.	samples were compared.	

Assessment of evidence

All patients were negative on admission, suggesting acquisition on the unit. Toilets and drain water appeared to be the source of this outbreak. The common strain found in all outbreak isolates suggests that the strain may have spread between rooms by drain water.

Organism: OXA-48-producing *Klebsiella pneumonia.*

Transmission mode: contaminated water systems.

Clinical setting: burn unit of University Hospital, Belgium.

Source: toilet drain water as reservoir.

Control measures: Bleach added to daily toilet cleaning regime, sampling of toilet water (even though did not completely prevent the presence of carbapenemase-producing *K. pneumonia*). One week after the last application of acetic acid, the water of all three toilets screened positive for carbapenemase-producing K. pneumoniae. By contrast, all the toilets disinfected with bleach tested negative for carbapenemase-producing K. pneumoniae. Neither disinfectant prevented recolonization after discontinuation - the effect of disinfectants is only temporary since biofilms are not disrupted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Constantinides B, Chau KK, Phuong Quan T, et al. Genomic surveillance of *Escherichia coli* and *Klebsiella* spp. in hospital sink drains and patients. Microbial Genomics 2020; 6: 4-16.	Surveillance study	**Level 3**	The aim of this study was to investigate the prevalence of contamination of healthcare sinks by strains of *E. coli* and *Klebsiella* spp.	Phylogenies of sink drain aspirates sampled over 12 weeks across three wards and patient samples.	Number of positive samples, sample type, whole-genome sequence analysis (including metagenomic sequencing).

Assessment of evidence

In this study isolates were identified from sinks from different hospital wards and were linked retrospectively to isolate results from patients staying in the same units during the same time period. Genomic overlap with sink isolates was only identified in 1/46 of all sequenced isolates causing clinical urine-infection over the same timeframe, associated with acquisition from a sink source.

Organism: Enterobacterales species (*E. coli* and *Klebsiella* spp.)

Transmission mode: not confirmed.

Clinical setting: general medicine ward in hospital, England UK.

Source: possibly a sink.

Control measures: not documented.

Even though isolates from the sinks were compared to isolates from patients' samples there was no epidemiological data used to investigate whether this correlation is actual true. Both microbiological and epi data is needed to link strains to infection. This study

Assessment of evidence
provides evidence that sinks can be colonised with a wide abundance of microorganisms that are associated with healthcare-associated infections, indicating a possible reservoir and risk of infection. This study provides evidence for the source of infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jung J, Choi HS, Lee JY, et al. Outbreak of carbapenemase-producing Enterobacteriaceae associated with a contaminated water dispenser and sink drains in the cardiology units of a Korean hospital. Journal of Hospital Infection 2020; 104: 476-483.	Outbreak investigation (with case control element).	**Level 3**	The aim of this study was to investigate a carbapenemase-producing Enterobacteriaceae outbreak in Korea and to find the risk factors for acquiring CPE.	Epidemiologic links between patients and potential environmental sources.	Number of positive samples, sample type, typing (PFGE analysis).

Assessment of evidence
Sinks in patient rooms and water dispenser acted as reservoirs (PFGE confirmed). The water dispenser for provision of water to patients was located near a handwashing sink; of note, used dialysing solution after haemodialysis was emptied into this handwashing sink.

Assessment of evidence
Organism: CPE, *Citrobacter freudii, Enterobacter cloacae* Transmission mode: contaminated water systems. Clinical setting: cardiology ICU, Korea Source: not confirmed. Sinks as reservoirs. Control measures: Sink drain treated with bleach (5500 ppm), water dispenser removed and water replaced with bottled water. All sink drains in the ICU were replaced.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Takajo I, Iwao C, Aratake M, et al. Pseudo-outbreak of *Mycobacterium paragordonae* in a hospital: possible role of the aerator/rectifier connected to the faucet of the water supply system. Journal of Hospital Infection 2020; 104: 545-551.	Outbreak investigation.	**Level 3**	An increase in the rate of *M. paragordonae* positive clinical samples was observed following hospital renovation; aerators/rectifiers were fitted to most taps of the water supply system in the hospital.	N/A	Positive patient samples. Positive environmental sampling. Molecular typing.

Assessment of evidence
No patients were infected; positive samples were obtained from 15 patients however it was not possible to determine if patients were colonised or if the clinical samples were contaminated (i.e. patient may have gargled tap water prior to sputum collection, and the bowel prep was mixed with tap water taken from aerator-fitted taps). Additional isolates were from gastrointestinal samples (3 via intestinal lavage via colonoscopy, 1 stool sample). Environmental sampling identified *M. paragordonae* from tap water from taps with aerators, from tap water from taps without aerators, and from endoscope-cleaning and disinfecting devices. Aerators were tested separately; small particles i.e. plastic pieces were trapped due to the mesh structure possibly indicative of biofilm; samples were positive. This Japanese study serves as evidence that NTM can survive in hospital water systems even when ongoing chemical treatment is within recommended limits. Rates of positive clinical isolates following the control measures were statistically significantly lower than pre-control measures ((19% vs. 3.1%, P=0.026). Organism: *Mycobacterium paragordonae.* Transmission mode: contaminated water systems. Clinical setting: multiple wards, Japan Source: Tap water from taps with aerators, from tap water from taps without aerators, and from endoscope-cleaning and disinfecting devices. Aerators were tested separately; small particles i.e. plastic pieces were trapped due to the mesh structure possibly indicative of biofilm – these tested positive. Control measures: Patients (particularly immunocompromised) instructed not to drink tap water unless it was first boiled, not to gargle with tap water prior to providing sputum samples. Bottled water was used for colon cleaning prior to colonoscopy. Aerators were removed from taps. Limitations: Although rates of positive clinical samples were lower following control measures (19% vs. 3.1%, P=0.026), water testing was not conducted to determine the level of contamination. Limited information regarding specific water testing (i.e. if it was pre or post flush), and actions related to endoscope decontamination. No follow-up water testing was conducted to determine if the measures were successful.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M, et al. Pseudo-outbreak of *Mycobacterium chimaera* through aerators of hand-washing machines at a hematopoietic stem cell transplantation center. Infection Control and Hospital Epidemiology 2019; 40: 1433-1435.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera.*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results.

Assessment of evidence

Sensor-operated hand washing 'machines' in patient rooms supplied filtered sterile water from the central water supply through a 0.1-µm filter and then irradiated the water with ultraviolet light at 100–280 nm inside the faucet to prevent backward contamination. At the faucet of the machine, water was delivered through a metallic aerator to ensure a straight and evenly pressured shower-like stream of water.

Outbreak investigation. a genetic relationship was found between the clinical and environmental isolates.

Organism: *M. chimaera.*

Transmission mode: contaminated water systems.

Clinical setting: stem cell transplantation centre, Japan.

Assessment of evidence
Source: contaminated tap - biofilm on the aerators of the handwashing machines in each patient's room. Control measures: Regular replacement of faucet parts can prevent biofilm formation and pseudo-outbreaks of M. chimaera through aerators. Communication with facilities maintenance personnel including officers and mechanics, and we improved the procedure for managing the units to incorporate routine work to replace aerators and their related parts every 6 months. Definition of pseudo-outbreak not defined. From context in paper, it seems to refer to cases who do no experience clinical illness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lv Y, Xiang Q, Jin YZ, et al. Faucet aerators as a reservoir for Carbapenem-resistant *Acinetobacter baumannii*: A healthcare-associated infection outbreak in a neurosurgical intensive care unit. Antimicrobial Resistance and Infection Control	Outbreak investigation with case control element	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Acinetobacter baumannii* (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2019; 8 (1) (no pagination).					

Assessment of evidence

Typing results found that the outbreak strain was only found in the faucet aerator of the dining room, used by HCWs. The faucet aerator may have acted as a reservoir for bacteria in the outbreak, and contamination of the faucet aerator might have occurred from splashes originating from handwashing by the healthcare workers (HCWs).

Organism: Carbapenem-resistant *Acinetobacter baumannii* (CRAB).

Transmission mode: possible transmission from the contaminated tap to the patient via contaminated HCW hands – not confirmed.

Clinical setting: neurosurgical intensive care unit (NSICU), China.

Source: unknown (could have been municipal water, pipeline, or hands of medical staff). Faucet aerator was a likely reservoir – see limitations.

Control measures: Intensive infection control measures (strengthening hand hygiene measures, isolation, fluorescent labelling to control cleaning, aerosolized hydrogen peroxide to carry out terminal disinfection, contact precautions, unnecessary transfer of patients, retraining of staff) and environmental microbial sampling were implemented immediately, but their effects were poor. Stop of use of all faucet aerators in the NSICU.

Following the emergency response process, an outbreak control team was established including an infection control officer, bacteriologists, cleaning staff, NSICU doctors, and nurses.

Limitations: The sampling was carried out AFTER control measures were implemented, therefore may not have represented what was present at the time of infection/colonisation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
de Jonge E, de Boer MGJ, van Essen EHR, et al. Effects of a disinfection device on colonization of sink drains and patients during a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 2019; 102: 70-74.	Outbreak investigation	**Level 3**	The aim of this study was to study the influence of installing disinfecting devices on sink drains on colonization of sinks and patients in a Dutch ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa.*	Isolated cultures of multidrug-resistant *P. aeruginosa.* before and after the 'intervention' (installation of disinfecting devices).	Number of positive samples, sample type.
Assessment of evidence					
The study was described as a 'two-armed intervention trial' with disinfecting devices installed in sink drains in ICU A and new conventional PVC plastic siphons installed in sink drains in ICU B and described the effects on sink and patient colonisation. The disinfection device aims to decontaminate wastewater in the siphon basin by applying repeated heating (to at least 85°C) and electromechanical vibration. Prior to the intervention, MDR-PA was cultured from sinks in ICU units. The siphons draining sinks in ICU subunit A were replaced by devices applying heat and electromechanical vibration to disinfect the draining fluid. Siphons in other ICU units were replaced with new polyvinyl chloride plastic siphons ('control'). The study reported that installation of the devices in ICU A resulted in a decrease in colonisation of patients in the subunit from 4.8 to 2.1 per 1000 admission days while colonisation of sink "almost				

Assessment of evidence
disappeared". Patient colonisation dropped further to between 0 and 0.2 per 1000 patient days when the devices were installed in both subunits (ICU A and B). These devices appeared to be successful at decreasing the colonisation rates of sink drains however they were not 100% effective; some sink drains occasionally tested positive for MDR-PA. This suggests that other components/distal regions of the sink plumbing remained colonised or were re-contaminated. Baseline colonisation rate of sinks was 51% in ICU A and 46% in ICU B. In ICU A colonisation decreased to 5% (P<0.001) after the intervention whereas it was 62% in ICU B. After installing the disinfection devices in ICU B, colonisation rate was 8% and 2.4% in ICU A and B respectively (both P<0.001 compared with baseline). Organism: multidrug-resistant *Pseudomonas aeruginosa.* Transmission mode: contaminated water systems. Clinical setting: ICU, the Netherlands Source: sink drains as a reservoir, and potential source. Control measures: Installation of disinfecting devices on sink drains. Limitations: The 'intervention' setting was an active ICU unit therefore not controlled or randomised; low quality evidence.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Weng MK, Brooks RB, Glowicz J, et al. Outbreak investigation of *Pseudomonas aeruginosa* infections	Outbreak investigation	**Level 3**			Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in a neonatal intensive care unit. American Journal of Infection Control 2019; 47: 1148-1150.					
Assessment of evidence					
Outbreak report: Molecular typing confirmed reservoir in sink plumbing and possible hospital water as source. Potential transmission routes from contaminated breast milk, bathing, incubators. Humidifier reservoirs of incubators were filled with tap water, despite manufacturer instructions recommending distilled water. Parents cleaned reusable breast pump equipment in sinks that were also used for handwashing and other medical purposes. Organism: *Pseudomonas aeruginosa.* Transmission mode: contaminated water systems. Clinical setting: NICU, United States of America. Source: not confirmed, taps/sinks as reservoirs. Control measures: Hyperchlorination of hospital water with calcium hypochlorite at 200 parts per million (ppm) for 2 hours. Supplemental hypochlorite added at municipal water intakes yielded residual chlorine levels of 2ppm at distal sites until a monochloramine system was installed. Preparation of breast milk/infant formula outwith splash zones, bathing neonates in sterile water, following manufacturer instructions for breast pump equipment drying and incubator water. Plumbing proximal to NICU sinks was replaced. No additional cases over 1 year after implementation of recommended control measures. Limitations: Not all patient isolates were available for typing.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Decraene V, Phan HTT, George R, et al. A large, refractory nosocomial outbreak of *klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* demonstrates carbapenemase gene outbreaks involving sink sites require novel approaches to infection control. Antimicrobial Agents and Chemotherapy 2018; 62 (12).	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	23 CRE-colonised heart patients, 2 infections (UTI, SSI).	Positive samples: 850 total samples taken from sink/drain/shower/bath sites, 18 from toilets, hoppers or sluices, 33 from high-touch sites (keyboards, door handles, sponges). 85 samples positive, including shower drains, sink taps, sink drain tailpieces, sink drain strainers, sink trap water, toilet bowls.
Assessment of evidence					
Outbreak report, molecular typing confirmed link between patient cases and environment. Source not identified but sink drains identified as reservoirs, likely biofilm formation. Organism: *Klebsiella pneumoniae* Carbapenemase-Producing *Escherichia coli* (Carbapenem-resistant Enterobacteriaceae (CRE)).					

Assessment of evidence
Transmission mode: contaminated water systems. Clinical setting: Heart Centre. Manchester UK. Source: not confirmed; sink drain identified as reservoirs, likely biofilm formation. Control measures: Sink trap replacement for colonised sinks, horizontal pipework cleaning with a brush to remove biofilm. Replacement of the plumbing infrastructure back to the central drainage stacks. Replaceable sink plughole devices designed to prevent water aerosolisation in the sink U-bend and to limit biofilm formation (HygieneSiphon; Aquafree) were installed. Following patient relocation to another ward and after plumbing refurb, cases significantly decreased, suggesting the environment was responsible. However, ward utility room sinks drains were positive after plumbing refurb and prior to patient readmissions suggesting residual contamination or reintroduction.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW and Holden E. Waterborne *Pseudomonas aeruginosa* transmission in a hematology unit? American Journal of Infection Control 2018; 46: 383-386.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results (PFGE).

Assessment of evidence
Outbreak report – molecular typing conducted (PFGE). All 3 case isolates indistinguishable and identical to isolate from a water outlet in the intravenous preparation clinical room. Infusion therapy procedure trays used to carry intravenous preparations to patients on the ward were cleaned in water supplied from the contaminated outlet and left wet; environmental sampling of the trays matched the patient outlets. Water testing of the system was negative, suggesting the taps were contaminated. Active surveillance for *P. Aeruginosa* on this ward of any patient isolate was routine. Transmission of *Pseudomonas aeruginosa*; transmission route via prep trays from contaminated water outlet. Hickman lines entry route. Organism: *Pseudomonas aeruginosa* Transmission mode: contaminated water systems. Clinical setting: Haematology unit, England UK. Source: transmission route via prep trays from contaminated water outlet as reservoir. Hickman lines entry route. Control measures: POU filters were installed on all outlets in the haematology ward. Filters were already on all outlets apart from those in the intravenous prep room. Trays were cleaned with quaternary ammonium compound wipes (Clinell Universal wipes, GAMA Healthcare UK) and dried thoroughly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Wilkinson MAC, Holden KL, et al. Tap out: reducing waterborne *Pseudomonas*	Before and after study	**Level 3**	Installation of new tap outlets (the impact of installation of new tap outlets on the number of outlets	Standard Rada therm 3 (Rada, UK) tap outlets installed at the time of construction.	Total viable counts of test tap samples (cfu) *P. aeruginosa* cfu.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa transmission in an intensive care unit. Journal of Hospital Infection 102 (2019) 75 – 81.			colonised with *P aeruginosa).*		
Assessment of evidence					
This study investigated the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa*. They also investigated wither *P. aeruginosa* could be removed from contaminated tap and how often water sampling needed to be done in a setting where contamination of tap outlets with *P. aeruginosa* is high. The authors mention that there was a significant decrease in the Pa acquisition rates after the installation of new taps. However, in the same period holistic measures were also implemented. Thus, it is difficult to ascertain that such increase was due to the installation of new taps. Further studies are required to assess the effectiveness of installing new taps that can be removed for decontamination. These studies should only focus on this intervention and have a comparison group if possible. Organism: *Pseudomonas aeruginosa* Transmission mode: contaminated water outlets (water samples from taps were positive, however unclear how far back in the system this contamination went). Clinical setting: ICUs in a tertiary referral NHS teaching hospital in England, UK. Source: water system/system components. Control measures: See above.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW, Tracey J, et al. Continued transmission of *Pseudomonas aeruginosa* from a wash hand basin tap in a critical care unit. Journal of Hospital Infection 2016; 94: 8-12.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* cluster in the burns room of a critical care unit in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Clinical surveillance of *P. aeruginosa* infection took place. Water samples from all tap outlets in the unit were collected as per HTM 04-01. All isolates were typed.

Assessment of evidence

Genotyping conducted. Tap was found to be contaminated. Unable to determine the exact transmission route.

The authors state that remedial actions to decontaminate the tap as recommended by the National 04-01 addendum were insufficient.

Organism: *Pseudomonas aeruginosa*

Transmission mode: not determined exact transmission route.

Clinical setting: critical care unit (burn unit), England UK.

Source: contaminated water system. Tap was found to be contaminated.

Control measures: Control measures at UHB include disposal of waste water in the sluice where possible, and, if not, the use of absorbent gel sheets to solidify patient waste water being disposed of in a macerator.

Assessment of evidence
The new cleaning method, developed by the housekeeping staff and infection control, involves a three-cloth cleaning technique to reduce contamination.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Botana-Rial M, Leiro-Fernández V, Núñez-Delgado M, et al. A pseudo-outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* in a bronchoscopy unit. Respiration. 2016;92(4):274-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas putida* and *Stenotrophomonas maltophilia* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Pseudomonas putida* and *Stenotrophomonas maltophilia* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
From the information provided by the authors, it is not possible to conclude that the source of the outbreak were the bronchoscopes or the AERs. *Pseudomonas putida* and *Stenotrophomonas maltophilia* were also isolated from sinks, cleaning brushes and cleaning solutions. Thus, although the authors found AERs to be contaminated it is not certain that this was the source.					

Assessment of evidence
This study provides evidence that inadequate disinfection of bronchoscopes can lead to infections/colonization in patients. As the reprocessors were contaminated, the bronchocsopes became contaminated when they were being reprocessed – then when these were used on the patients, the patient samples tested positive (pseudo-outbreak, as no true colonisation/infection). Organism: *Pseudomonas putida* and *Stenotrophomonas maltophilia* Transmission mode: indirect contact (contaminated equipment) Clinical setting: bronchoscopy unit, Spain Source: contaminated water-based equipment (automated endoscope reprocessor).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kotsanas D, Wijesooriya WR, Korman TM et al. "Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. Medical Journal of Australia. 2013 Mar;198(5):267-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant Enterobacteriaceae (CRE) cluster in the ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and CRE isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE).

Assessment of evidence
Molecular typing is performed. CRE is reported from an ICU and from identical organism isolated from patients and an environmental source (sink). However, other factors (due to lack of IPC measures) might have been facilitating transmission. Organism: Carbapenem-resistant Enterobacteriaceae (CRE). Transmission mode: indirect contact. Clinical setting: ICU, Australia. Source: Sinks as a reservoir, initial source unknown however clinical waste and residual antibiotics disposed in sinks so potential patient source as CRE niche in human gut. Control measures: Cleaning and decontamination the sinks using detergents and cleaning proved unsuccessful. First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Coppry M, Leroyer C, Saly M, et al. Exogenous acquisition of *Pseudomonas aeruginosa* in intensive care units:	Surveillance study (Prospective multi-centre study)	**Level 3**	The aim of the study was to investigate the role of exogenous origin of *P. aeruginosa* in ICU patients. Exogenous acquisition was defined as	Contributions of *P. aeruginosa* exogenous acquisition by patient-to-patient transmission and	Patients were screened on admission. Number of positive samples, sample type, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
a prospective multi-centre study (DYNAPYO study). Journal of Hospital Infection. 2020 Jan 1;104(1):40-5.			colonization or infection by a strain of *P. aeruginosa* with a pulsotype previously isolated from another patient (i.e. patient-to-patient transmission) or from a tap water sample in the ICU.	from contaminated taps.	

Assessment of evidence

Typing was performed. However environmental samples only taken from tap water (free-flush), not from other water-related sources. Might be indirect transmission from contaminated environment, equipment or from the hands of healthcare workers via another colonised/infected patient.

Patient to-patient transmission was considered possible when a similar pulsotype was isolated in more than two patients hospitalized during an overlapping period without a similar pulsotype isolated from tap water. Patient-to-patient transmission in this paper only means that patients are infected with identical strains; however, it does not tell us where/how they got infected. Exogenous origin from tap water was considered possible when a similar pulsotype was isolated in a patient and at least one ICU tap water sample prior to P. aeruginosa identification in the patient.

The present study showed an exogenous origin of *P. aeruginosa* in nearly half of the patients. Patient-to-patient transmission was more frequent than acquisition from tap water.

1808 patients included, 206 excluded due to lack of screening on admission.10,402 screening samples were taken and 427 patients were positive (41 positive found on entering the study). 4946 water samples were obtained. Among the 233 taps screened, 81 (35%) were positive for *P. aeruginosa* at least once during the study, including 51 at the beginning of the study. Median duration of contamination was

Assessment of evidence
5 weeks (range 1-13 weeks). The median duration of contamination differed between electronic and conventional taps (12.6 vs 8 weeks, p=0.003). A total of 270 different pulsotypes were found in patients: 201 (74%) were sporadic, 52 were shared by patients, and 17 were shared by water and patient. **There was possible patient-to-patient transmission for 86/170 patients (50.6%) and an exogenous origin from tap water for 29 other patients (17.1%). It was not possible to draw conclusions for 55 patients from the two ICUs with the highest rates of positive tap water (ICU 5 and ICU 10) because pulsotypes were shared by many patients and tap water samples.** Organism: *P. aeruginosa* Transmission mode: tap water (contaminated water systems). Clinical setting: ICU, France Source: Potentially tap water (sinks) and/or patients. Control measures: not reported. Limitations: This study was not able to show how patients acquired infection; it showed that patients were infected by the same pulsotypes in the absence of matching samples in the water, however the limitations of the sampling methodology may have missed some positive water samples- further, the study does not track individual patients so was not able to demonstrate exactly when a patient acquired infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
outbreak attributed to contaminated rinse water. American Journal of Infection Control. 2020 Jan 1;48(1):26-32.			lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.		

Assessment of evidence

The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope.

Organism: *P. aeruginosa*

Transmission mode: indirect contact.

Clinical setting: bronchoscopy unit, China.

Source: Sink drain/sink connecting tubes. This was allowing bronchoscopes to become contaminated due to substandard manual cleaning of bronchoscopes.

Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Regev-Yochay G, Smollan G, Tal I, et al. Sink traps as the source of transmission of OXA-48–producing *Serratia marcescens* in an intensive care unit. Infection Control & Hospital Epidemiology. 2018 Nov; 39(11):1307-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *OXA-48–producing Serratia marcescens* in the ICU in Israel (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *S. marcescens* isolated from environmental/water samples were compared.	Number of patients with CPE infection/colonisation and their clinical characteristics, environmental samples (source, results and number of isolates), typing results (PFGE).
Assessment of evidence					
Extensive control measures were put in place and carried out, but contamination of sinks seemed to be recurring. Using a combined intervention (including educational component, reducing environmental contamination load) the outbreak was contained 12 months after the start of the outbreak. Organism: CPE, *S. marcescens* (OXA-48–producing *S. marcescens*). Transmission mode: indirect contact of the sinks. Clinical setting: ICU, Israel. Source: sink as reservoir and likely source.					

Assessment of evidence
Control measures: Enhanced control measures were undertaken, including increased hand hygiene observations as well as educational sessions. Thorough cleaning of all surfaces and medical devices with 1,000 PPM sodium hypochlorite and quaternary ammonium, accordingly, was carried out. After identification of the sink as the source of transmission: 2 main measures were carried out: (1) sink-trap decontamination efforts and (2) an educational intervention enhancing specific infection control measures and focusing on the sink as a source of transmission. All sink traps were replaced, water supply was treated according to Legionella protocol (heating and hyper chlorination of the main water tank and terminal points for 12 hours with free residual chlorine (20–30 mg/L).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B, et al. *Pseudomonas aeruginosa* outbreak in a neonatal intensive care unit attributed to hospital tap water. Infection control & hospital epidemiology. 2017 Jul;38(7):801-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence
PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient. Organism: *Pseudomonas aeruginosa* Transmission mode: indirect contact (however the actual transmission mode from the tap to the patient was not established). Clinical setting: Neonatal Intensive Care Unit, United States of America Source: Taps and drains contaminated - Water in the hospital remained stagnant for 3 months after completion of hospital construction, allowing ample time for biofilm formation. Although biofilm was not visualised, the authors comment that a high level of genetic diversity existed among environmental and patient isolates, which is consistent with a previous potential biofilm formation in the pipes, faucets, or drains. Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model. They were reinstated after cases appeared again. In addition, case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Watkins LK, Toews KA, Harris AM, et al. Lessons from an outbreak of	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of Legionnaires'	Clinical and environmental isolates were compared by	Number of positive samples, sample type, typing results (monoclonal

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Legionnaires' disease on a hematology-oncology unit. Infection control & hospital epidemiology. 2017 Mar; 38(3):306-13.			disease on a hematology-oncology unit (including finding the source) and to determine the impact of infection prevention and control measures.	monoclonal antibody and sequence-based typing.	antibody and sequence-based typing).

Assessment of evidence

Investigation suggests that the potable water system was the likely source of infection. Lp1 strains isolated from water on the unit were indistinguishable from all 3 clinical specimens by SBT.

Legionella spp were cultured from 21 of 30 sites (70%) sampled during the environmental investigation: legionellae were not recovered from the 2 sites that were not supplied by the second water riser. Of 10 PoU sites on the hematology-oncology unit, 9 (90%) showed Legionella, including all 4 of the case patient rooms sampled. Lp1 was identified at all sites showing Legionella growth. Sequence typing was performed on 9 Lp1 isolates from 7 sites (7 of these isolates [78%] were MAb2-positive), on the 3 Lp1 clinical isolates, and on 3 Lp1 isolates collected from the affected building prior to the investigation. All Lp1 isolates had identical sequence type results (ST36).

Further assessment of the hospital campus did not identify any nearby cooling towers, and the affected building did not contain whirlpool spas, water-birth facilities, patient bathtubs, decorative fountains, or other obvious sources of aerosolized water.

The median time between symptom onset and *Legionella* testing was 8.5 days (range, 0–65 days).

The authors suggest that a single case of LD that is definitely healthcare associated should prompt a full investigation. No further cases were identified after implementation of 0.2um point-of-use filters.

Assessment of evidence
Lessons learned from this outbreak: • Hospital had legionella water management program, however providers were not routinely notified of positive environmental testing results. Clinicians may therefore have been less likely to include diagnostic testing for LD in their initial management of patients. • Regular clinician education should be integral part of a hospitals *Legionella* water management program. • Some cases were incorrectly misclassified as community acquired rather than HAI. Organism: *Legionella* Transmission mode: indirect contact. Clinical setting: Haematology-oncology unit, United States of America. Source: contamination of the unit's potable water system (contaminated water systems). Control measures: Water restrictions (limiting contact with the affected building potable water to washing visibly soiled hands) were implements for all patients, visitors and staff. Bottled water was provided for drinking and hygiene activities, and alcohol-based hand sanitizer was provided for routine hand cleansing. Water restrictions were lifted once 0.2 um PoU filters were obtained for all sinks, shower heads, and ice machines. Remediation of the potable water system was initiated once environmental samples were obtained and consisted of superheating each of the 3 water-riser systems to 160°F, flushing, and hyperchlorination (a chlorine injection system was installed for emergency remediation). Ongoing monitoring of chlorine at points of use and follow-up sampling with subsequent remediation as needed were advised. Limitations: only confirmed cases were included in the study; potentially underestimating the actual extent of the outbreak. No control group was included. Unable to determine which of the measures was responsible for ending the outbreak as all measures were implemented simultaneously.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE).

Assessment of evidence

The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (including presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff.

Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room.

Organism: *Pantoea agglomerans.*

Transmission mode: indirect/aerosolisation.

Clinical setting: oncology clinic, United States of America.

Assessment of evidence
Source: pharmacy sink, however primary source associated with this, not identified. Control measures: Immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping. Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding. Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods. Chemotherapy preparations were moved off-site and improved the building water system. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in an intensive care burn unit. Journal of hospital infection. 2016 Sep 1;94(1):2-7.					

Assessment of evidence

Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit.

Pseudomonas aeruginosa has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: Contaminated environment; however, three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission.

Clinical setting: ICU – burn unit, Switzerland.

Source: Sink and floor drains the reservoir and likely source. Environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of *P. aeruginosa* in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain *P. aeruginosa*.

Assessment of evidence
Control measures: Corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily. Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhou Z, Hu B, Gao X, et al. Sources of sporadic *Pseudomonas aeruginosa* colonizations/infections in surgical ICUs: Association with contaminated sink trap. Journal of Infection and Chemotherapy. 2016 Jul 1;22(7):450-5.	Surveillance investigation	**Level 3**	The aim of this study was to investigate *Pseudomonas aeruginosa* colonisations/ infections in surgical ICUs and to determine the source(s). This study was a surveillance done in the absence of an outbreak.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples (all pre-flush cold tap water, tap inner surface, sink drain, counter surfaces, bed rail, bed control, equipment) were compared (PGFE) to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Genotyping was performed. 17.6% (6/3) of colonisations/infections with P. aeruginosa were most likely due to patient-to-patient transmission and 50% (17/34) from endogenous flora (diagnostic clinical sample identical to rectum and/or throat sample of the same patient). 64.7% (11/170) of exogenous sourced cases were associated with contaminated sink traps. Whereas, no strains (genotypes) recovered from tap water were identical to that from patients – this suggests that the plumbing infrastructure rather than the water was the main environmental reservoir in this setting. The percentage of carbapenem-resistant P. aeruginosa of diagnostic samples (45.7%, 16/35) was higher than that of screening samples (3.4%, 2/58) and environmental samples (15.1%, 8/53). Patient isolates associated with sink drains showed more resistance to antibiotics than patient-to-patient transmission strains (the percentage of carbapenem-resistant *P. aeruginosa*: 81.8% vs.16.7%). Organism: *Pseudomonas aeruginosa.* Transmission mode: water fitting. Clinical setting: ICU, China. Source: Contaminated sink traps – contaminated sink drains linked to 11/34 (32.4%) patients; patient-patient transmission in 17.6% (6/34) patients; 50.0% (17/34) from endogenous flora (identical to rectum and/or throat sample of the same patient).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aspelund AS, Sjöström K, Liljequist BO, et al. Acetic acid as a decontamination method for sink	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were	Positive patient samples, positive environmental samples, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
drains in a nosocomial outbreak of metallo-β-lactamase-producing *Pseudomonas aeruginosa*. Journal of Hospital Infection. 2016 Sep 1;94(1):13-20.			of infection prevention and control measures.	compared to establish a link of infection.	
Assessment of evidence					
Typing was performed. PA was found in 4/9 drainpipes that were cultured after replacement of the sinks, indicating a reservoir further down the pipes. Typing of clinical and sink drain isolates revealed identical or closely related strains. Organism: *Pseudomonas aeruginosa.* Transmission mode: Indirect contact; (likely splashing of the water in the sink or similar). Clinical setting: three different wards in a university hospital in Sweden. Source: sink drains (and further down in the pipes). Control measures: Replacement of contaminated sinks, awaiting replacement acetic acid was poured once weekly into colonised sink drains. Following this, all sinks and plumbing's were changed. Acetic acid treatment was then terminated. Hot water flushing of drainpipes, change of sink drain, siphon, and pipes to the wall were changed at the same time.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Litvinov N, da Silva MT, van der Heijden IM, et al. An outbreak of invasive fusariosis in a children's cancer hospital. Clinical Microbiology and Infection. 2015 Mar 1;21(3):268-e1	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of invasive fusariosis in Brazil and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Fusarium* spp. isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, genotyping results.

Assessment of evidence

Outbreak was only controlled 1 year after the first case, when water filters filtering 0.2 um were installed at the exit of all faucets and showers in all patient rooms (PoU).

Organism: *Fusarium.*

Clinical setting: children's cancer hospital, Brazil.

Source: Hospital water (contaminated water systems). Maintenance of the water reservoirs/tanks had been neglected since 2006 up until 2009.

Control measures:

- interruption of new admissions to the unit during 47 days
- transfer of the hospitalized patients to another unit in another building of the hospital
- renovation of rooms and bathrooms with closure of the communications between service floors and patient rooms: ceiling panels were replaced with plaster ceilings

Assessment of evidence
• disconnection of central hot water reservoir and installation of electric instant heating devices • cleaning of cold water reservoirs with chlorine and continuous chlorination of water in the reservoirs (1.5 ppm) controlled by a chlorination device • filtration of water before entry into water reservoirs (10µm filters) • 0.2-µm water filters were installed at the exit of all faucets and showers in all rooms. • prospective surveillance for new cases was maintained.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leitner E, Zarfel G, Luxner J, et al. Contaminated handwashing sinks as the source of a clonal outbreak of KPC-2-producing *Klebsiella oxytoca* on a hematology ward. Antimicrobial agents and chemotherapy. 2015 Jan 1;59(1):714-6	Outbreak investigation	**Level 3**	The aim of this study was to investigate a KPC-2-producing *Klebsiella oxytoca* clonal outbreak on a hematology ward in Austria and to determine the source.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results (MLST).

Assessment of evidence
Investigations for resistance genes and genetic relatedness of patient and environmental isolates revealed that all the isolates had the blaKPC-2 and blaTEM-1 genes and were genetically indistinguishable. Authors stated that the starting point of this outbreak was a colonised patient from the ICU who was later transferred to the haematology ward, however an environmental starting source cannot be ruled out as sinks/wet surfaces were not tested prior to transfer of this patient, and no details given regarding a look back of previous cases. It is hypothesized that KPC-2-producing *K. oxytoca* got into the sink most likely during personal hygiene activities or by disposal of contaminated body fluids, where it persisted. Authors also hypothesise that patients were contaminated by aerosols when using the sink although this is not proven from the study. Organism: *Klebsiella oxytoca.* Transmission mode: indirect/aerosolization. Clinical setting: haematology ward, Austria. Source: handwashing sink as reservoir, source not confirmed. Control measures: Reinforcement of already existing infection control measures (isolation of colonised patients, enforcement of hand hygiene, cleaning of wards particularly sinks and equipment).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al. A cluster of central line–associated bloodstream infections due to	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central line–associated nontuberculous mycobacteria bloodstream	Molecular typing results between patient strains and nontuberculous mycobacteria isolated from environmental/water	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature. Infection control & hospital epidemiology. 2015 Jan;36(1):76-80.			infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	samples were compared to establish a link of infection.	
Assessment of evidence					
The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was the shower water (mains potable water samples were negative). Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Organism: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.) Transmission mode: Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. The median time from catheter insertion to a positive blood culture was 32 days (range, 29–51 days). The median duration of bacteremia was 7 days (range, 6–10 days). Four of 5 catheter tip cultures (80%) showed mycobacterial growth.					

Assessment of evidence
Clinical setting: hematology-oncology ward, Japan. Source: contaminated shower water. Control measures: Catheter/port removal and antimicrobial therapy. Water chlorination in the main water tank at the hospital was measured daily. This hospital considered chlorine levels between 0.10 to 0.40 ppm to be adequate for maintaining sterility. During the outbreak, the chlorination level was kept at approximately 0.11 ppm. Genetic relatedness: Typing by PFGE and random amplified polymorphic DNA showed a genetic match between blood isolates of *M. mucogenicum* from 3 patients and a shower isolate. Blood isolate of *M. Canariasense* from another patient matched with isolate from a toilet. No genetic match with environmental samples was found for the isolate from the fifth patient.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wolf I, Bergervoet PW, Sebens FW, et al. The sink as a correctable source of extended-spectrum β-lactamase contamination for patients in the intensive care unit. Journal of Hospital Infection. 2014 Jun 1;87(2):126-30.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonization of extended-spectrum b-lactamase-positive bacteria (ESBLs) in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures	Molecular typing results between clinical strains and ESBLs isolated from environmental/water samples were compared to establish a link of colonization.	Number of positive samples, sample type and species, genotyping results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			(e.g. self-disinfecting siphons).		

Assessment of evidence

Patients were not infected but colonised. ESBLs originating from sinks in patient's rooms were linked to patients who stayed in ICU. Four patients (10, 12, 14, and 17) were colonised by ESBLs that had been isolated from the sink before the patients were admitted to the ICU so it was concluded that these strains had been transmitted from sink to patient.

Organism: extended-spectrum b-lactamase-positive bacteria (ESBLs).

Transmission mode: assuming indirect contact; however this is not confirmed from the study.

Clinical setting: ICU, the Netherlands.

Source: sink (contaminated water outlet).

Control measures: All 13 siphons from sinks in the ICU patient rooms and five siphons from sinks at other locations where medical workers wash their hands frequently (two toilets, the medication room, the scullery room and the staff room) were replaced.

To monitor the effect of this intervention, all 18 sinks were sampled for the presence of ESBL 1,2,3,4,6,8 months after the intervention. During month 8, samples were cultured non-selectively to determine the whole microbial flora present in the sinks.

Limitation: Positive clinical strains were only compared to isolates taken from sinks. Therefore it can be argued that the sink was the actual source, or whether it might have been the reservoir.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Knoester M, De Boer MG, Maarleveld JJ, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of multidrug	Molecular typing results between patient strains and *P.*	Number of positive samples, patient characteristics and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
An integrated approach to control a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Clinical Microbiology and Infection. 2014 Apr 1;20(4):O207-15.			resistant (MDR) *Pseudomonas aeruginosa* in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures. Patients that acquired the outbreak strain were also enrolled in a case-control study to investigate risk factors for acquiring MDR *P. aeruginosa*.	*aeruginosa* isolated from environmental/water samples were compared to establish a link of infection. For the case-control study, the exposure factors were compared between cases (ICU patients that acquired the outbreak strain) and control (ICU patient who tested at least three times negative for the outbreak strain during the follow-up period.)	exposure factors, sample type, genotyping results (AFLP).
Assessment of evidence					
Two cluster occurred during this outbreak. A common source was found for one the clusters. Two contaminated faucet aerators were identified. Cross-transmission by medical staff might have occurred as number of new cases decreased after improvement of IPC measures. Presence of drains were not evaluated; this has frequently been identified as a source of infection.					

Assessment of evidence
The case-control part of the study identified that patients who are admitted to ICU subunit I, surgery prior to or during admission and those being warmed-up with the warm-air blanker are independently associated with MDR-PA positivity. Organism: *P. aeruginosa.* Transmission mode: interpatient transmission by medical staff. (Indirect contact). Clinical setting: ICU, the Netherlands. Source: sink drain as likely reservoir, potential source. Control measures: Chlorination of sink drains (but ineffective). Audit of care-related procedures, cleaning procedures and hygiene measures on ICU. Re-education of ICU staff on hygiene protocols. Implementation of new tracheostomy care protocol. Ban on sharing equipment between patients. Standard contact isolation measures were implemented. Faucet aerators were replaced.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guyot A, Turton JF, Garner D. Outbreak of *Stenotrophomonas maltophilia* on an intensive care unit. Journal of Hospital Infection. 2013 Dec 1;85(4):303-7	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Stenotrophomonas maltophilia* outbreak (including finding the source) and to highlight the risk from contaminated devices for supply of drinking water.	Typing results of the *Stenotrophomonas maltophilia* patient strains vs *S. maltophilia* isolated from environmental/water samples.	Incidence of outbreak strains, PFGE profiles from patient's vs water strains.

Assessment of evidence
Typing was performed. A tap (in ICU kitchen) that had a water-cooler for drinking water was the source of *S. maltophilia* on ICU in a UK hospital, because a carbon filter had not only removed the disinfectant chlorine dioxide before the water-cooler, but had also accumulated organics, which serve as nutrients for bacteria facilitating the growth of biofilms on downstream tubing. On review of nursing practices, the nurses reported that they had discarded the water from tooth-brushing or patients' drinking water into handwash basins. They revealed also that they had used cooled water from the ICU kitchen from the special tap for cooled water for serving patients drinking water and mouth care. Organism: *Stenotrophomonas maltophilia.* Transmission mode: direct contact. Clinical setting: ICU, England, UK. Source: water-cooler for drinking water. Control measures: Chilling unit and tubing was removed from the tap. Since that time no more FR04 and FR06 genotypes have been found in ICU and the *Stenotrophomonas* prevalence has fallen to <2% of admissions. This chilling unit was installed in 2009 and the carbon filter had been changed quarterly, but not the tubing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schneider H, Geginat G, Hogardt M, et al. *Pseudomonas aeruginosa* outbreak in a pediatric oncology care unit	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, genotyping results (RAPD-PCR and single-nucleotide polymorphism–type

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
caused by an errant water jet into contaminated siphons. The Pediatric infectious disease journal. 2012 Jun 1;31(6):648-50.			prevention and control measures.	establish a link of infection.	*P. aeruginosa* microarray).
Assessment of evidence					
Contaminated aerosols may have emerged from the siphon at every water use. Patients could have acquired infection with the outbreak clone due to inhalation of contaminated aerosols (patients B and C), via smear infection with water drops directly from the water tap (patients B and C) or through horizontal transmission from contaminated persons such as staff or family members (patient A). Organism: *Pseudomonas aeruginosa.* Transmission mode: aerosolisation, indirect contact. Clinical setting: pediatric oncology care unit (POCU), Germany. Source:contaminated taps as reservoirs, potential sources. Control measures: New water taps were installed throughout entire POCU to avoid direct water flow into the sink. Siphons in the anterooms in isolation rooms 2 and 3 were additionally replaced. Patients and staff were obliged to rinse the water taps with running hot water preceding every water use.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lucero CA, Cohen AL, Trevino I, et al. Outbreak of *Burkholderia cepacia* complex among ventilated pediatric patients linked to hospital sinks. American journal of infection control. 2011 Nov 1;39(9):775-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* complex outbreak and to determine the source.	Molecular typing results between clinical strains and *B cenocepacia* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type and species, bionumeric analysis, genotyping results (PFGE).

Assessment of evidence

Tap water was being used for oral and tracheostomy care. The ICU contained both manual and automatic sinks, many of which had an aerator. Concerns regarding aerators were discussed, but their removal was not recommended. *B. cenocepacia* was not cultured directly from hospital water, but its recovery from drains suggest that the organism was present either in the water or in contaminated products placed in sinks.

Organism: *B cenocepacia, B. cepacia.*

Transmission mode: tap water for oral and tracheostomy care but not confirmed.

Clinical setting: ICU - ventilated paediatric patients, United States of America

Source: Sink drains as reservoir/potential source. Ventilation components also contaminated.

Control measures: Not reported.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
La Forgia C, Franke J, Hacek DM, et al. Management of a multidrug-resistant *Acinetobacter baumannii* outbreak in an intensive care unit using novel environmental disinfection: a 38-month report. American journal of infection control. 2010 May 1;38(4):259-63.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Acinetobacter baumannii* outbreak in an ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Genomic DNA of the clinical isolates were genetically analysed using restriction endonuclease analysis (REA) and compared with one another to determine whether they were genetically related.	Number of positive samples, sample type, restriction endonuclease analysis (REA).

Assessment of evidence

Organism: *Acinetobacter baumannii.*

Transmission mode: indirect transmission.

Clinical setting: ICU, United States of America.

Source: Single outbreak source was identified. Sink trap that likely represented source and reservoir.

Control measures: Contact isolation of all MDR *A baumannii*–positive patients, education of nursing staff on the epidemiology of MDR *A baumannii*, increased training on the importance of hand hygiene, introduction of alcohol-based hand hygiene solution into each patient room, and observations of environmental cleaning in the ICU.

Assessment of evidence
Bleaching protocol successfully decontaminated the reservoir and eliminated the MDR *A baumannii* infections. Flushing regime: The sink flushing protocol was devised as follows. Once per day for the first week, and then once per week thereafter until October 2008 (when the ICU was demolished for remodelling), 10 gallons of water were first run into each plugged sink in every location in the ICU, including in each patient room and the family waiting area. This was followed by slowly pouring 1 gallon of bleach into the water, avoiding splashing. Health care workers performing this task wore protective goggles as well as rubber gloves. Once all of the sinks were filled, the plugs of all sinks were pulled simultaneously, thereby flushing the sink drain piping with the bleach solution. This protocol was continued throughout the observation period. Subsequently, 5 additional cultures of the involved sink were negative over the next 30 days, as well as 6 months later. Early after initiation of the bleaching protocol, from March 2005 to September 2005, only 2 patients were culture-positive for *A baumannii*. One of these patients was colonised with an unrelated clone and the other was colonised with the epidemic clone. The patient with the epidemic clone had been hospitalized in the ICU before initiation of the bleaching protocol. Before this intervention, 18 patients over 10 months were infected or colonised with *A baumannii*. After the intervention, this decreased to 19 patients over 28 months, a statistically significant difference in rate (P<0.01).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Rogues AM, Boulestreau H, Lashéras A, et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit.	Prospective surveillance study	**Level 3**	The aim of this study was to investigate colonisation of *Pseudomonas aeruginosa* in a French ICU (including finding the source) and to determine the impact of infection	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples (pre-flush tap samples) were compared to	Number of positive samples, sample type, genotyping results (PFGE). Exogenous colonisation was defined as colonisation by a strain of P. aeruginosa with a

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2007 Sep 1;67(1):72-8.			prevention and control measures.	establish a link of colonisation.	pulsotype previously isolated from another patient, a HCW's hand or tap water.

Assessment of evidence

Pseudomonas aeruginosa was found in tap water samples in patients' rooms more than in other tap water in the unit. Chronological epidemiological analysis and PFGE results suggested transmission from tap water to patient in 7 cases of the 15 strains (roughly half) identified 72 h after patient's admission. Six patients had a strain undetected in water but found in at least one other patient during the same stay suggesting cross-transmission. Six out of the 153 patients were identified as carriers on admission.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: carriage by patients (indirect transmission) and from water source.

Clinical setting: ICU, France.

Source: contaminated water systems (taps) and colonised patients.

Control measures: Twice monthly disinfection. An aqueous solution (4.5%) of sodium hypochlorite (diluted household bleach) was injected into taps with a 60 mL syringe for 15 min. Aerators were removed every two weeks, immersed, and brushed in a detergent-disinfectant solution. *P. aeruginosa* was found in 34 out of 180 (18.8%) samples before and in 22 of 288 (7.6%) after disinfection was implemented ($P < 0.01$). Hand disinfection with an alcohol-based solution was required between patient contacts. Only bottled water was used for enteral nutrition and to administer drugs through gastric tubes. Bottled water is not sterile but analyses performed every year on bottles used for immunocompromised patients in another unit were always satisfactory. Sterile water was used for mouth care.

A defective flexible bronchoscope was contaminated and then later removed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence

Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient.

Organism: *Mycobacterium mucogenicum.*

Transmission mode: indirect/aerosolisation

Clinical setting: University-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients, United States of America.

Source: water contamination of central venous catheters (CVCs) during bathing.

Assessment of evidence
Control measures: • replace showerheads and hoses on the BMT inpatient units. Optimal frequency of showerhead and hose replacement is undetermined • allow shower hoses to hang straight with no dependent loops when not in use to decrease the risk of bacteria multiplying to higher levels in stagnant water • educate all direct care providers, patients, and family members on the risks of water contamination of CVCs during bathing and on prevention methods to use during bathing to minimize water contact • disconnect IV catheters prior to bathing when possible • if catheters cannot be disconnected, then cover connections with waterproof materials

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pena C, Dominguez MA, Pujol M, et al. An outbreak of carbapenem-resistant *Pseudomonas aeruginosa* in a urology ward. Clinical microbiology and infection. 2003 Sep;9(9):938-43.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and Carbapenem-resistant *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
				establish a link of infection.	
Assessment of evidence					
PFGE analysis showed the CRPA isolates from patients and the environment had the same PFGE pattern and belonged to a single clone. The outbreak ended when the drain was sealed. Organism: Carbapenem-resistant *Pseudomonas aeruginosa.* Transmission mode: indirect contact. Clinical setting: cystoscopy room, Spain. Source: unsealed drain, possibly colonised patients. Control measures: Strict adherence to disinfection protocol. Examination of cystoscopy room and repairs were undertaken. Surgical drape should only be used once, and the open drainage of the floor should be provisionally closed.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al. Analysis of transmission pathways of *Pseudomonas aeruginosa* between	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between *Pseudomonas aeruginosa* infection and faucet contamination in a surgical ICU.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish	Number of positive samples, sample type, relationship between genotypes (RAPD).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.				transmission pathways.	

Assessment of evidence

The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed.

Tap water isolate: PA found in 150/259 (58%) tap water samples taken from patient rooms in 13 different wards. PA was not found from samples from the central outlets of the supplying mains at different time points.

Relationship between genotypes: 18 different genotypes were identified in patient isolates and 17 different genotypes were identified in tap water isolates. 31 patients were positive in the SICU for *P. aeruginosa* over the study period of 40 wks. The patient's genotype also was found in tap water in the SICU in 17 cases.

In 10 cases (32%) a tap water isolate from the room was shown to be of the same genotype as the patient isolate. Water-to-patient transmission in the same room was likely in 7 cases and patient-to-water transmission was likely 3 cases.

6 patients were possibly colonised through contaminated water from neighbouring rooms. 2/10 patients from peripheral surgical wards to SICU and were shown to be positive for the same strain of PA before and after the transfer. Neither the faucets in the SICU nor the faucets in the prior rooms were shown to be contaminated with the patient strain. 7 patients in surgical wards other than SICU were found to carry the same genotype as found in tap water in their room.

Organism: *Pseudomonas aeruginosa*

Transmission mode: indirect (potentially hands of HCWs, transfer of colonised patients between wards, splashing of water around the washbasin).

Assessment of evidence
Clinical setting: SICU and other surgical wards, Germany. Source: individual faucets (possibly colonised patients as source). Control measures: An intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention. Infections caused by PA: Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonised with *P. aeruginosa* were wounds and the pharynx.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
El Sahly HM, Septimus E, Soini H, et al. *Mycobacterium simiae* pseudo-outbreak resulting from a contaminated hospital water supply in Houston, Texas. Clinical infectious diseases. 2002 Oct 1;35(7):802-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium simiae* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Mycobacterium simiae* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Environmental investigation: • cultures of water samples obtained from the municipal water supply, ground well, and the EDB did not yield *M. simiae* • pipes connecting the energy distribution building to the hospital building and PB1, and culture specimens obtained from heat exchangers, sinks, drinking fountains, and ice machines in hospital building and PB1, were positive. Samples from PB 2 were all negative Molecular characterization: 44 isolates (37 isolates from 33 patients and 7 environmental, including hospital water, drinking fountain and ice machine). Thirty one environmental and human outbreak–related M. simiae isolates had indistinguishable or closely related patterns on pulsed-field gel electrophoresis and were considered clonal. Results of genotyping showed that this nosocomial *M. simiae* pseudo-outbreak was caused by contaminated hospital water supply. None of the patients received specific antimicrobial treatment for *M. simiae* infection, and isolation of *M. simiae* was unrelated to the clinical presentation of the patients. Organism: *Mycobacterium simiae.* Transmission mode: not discussed. Clinical setting: hospital setting, United States of America. Source: contaminated water supply. Control measures: Chlorination increased from <1ppm to 1 ppm, this resulted in a transient decrease in number of isolates recovered.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bukholm G, Tannæs T, Kjelsberg AB, et al. An outbreak of multidrug-resistant	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak	DNA fingerprinting results (AFLP) between clinical strains and *Pseudomonas*	Number of positive samples, sample type, DNA fingerprinting results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa associated with increased risk of patient death in an intensive care unit. Infection Control & Hospital Epidemiology. 2002 Aug;23(8):441-6.			in Norway (including finding the source) and to determine the impact of infection prevention and control measures.	*aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	
Assessment of evidence					
Outbreak eventually stopped after implementation of the pasteurization procedure for water taps and use of sterile water for drugs and food. Organism: *Pseudomonas aeruginosa* Transmission mode: indirect transmission/direct transmission (ingestion). Clinical setting: ICU, Norway Source: contaminated taps/tap water. Control measures: Contact isolation regimens were implemented in rooms with contaminated patients, change of AB policy. Pasteurization of the water taps was implemented. Use of sterile water for drugs and food.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients. American Journal of Kidney Diseases. 2019 Nov 1;74(5):610-9.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (for example age and comorbid conditions). The second investigation looked at factors specific to a patient during a particular treatment.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection. Risk factors for becoming a case are investigated using case-control study designs (2x).	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence

In this study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of BSIs.

The most predominant organisms were *Serratia marcescens* (n = 21) and *Pseudomonas aeruginosa* (n = 12). Gram-negative bacteria were found in multiple environmental sources, including tap water, sinks, and surfaces. Notably, all wall box samples grew at least 1 of the 3 most common outbreak pathogens, S marcescens, P aeruginosa, and E cloacae. These organisms were infrequently isolated from sinks, water, or other surfaces at the facilities. *S. marcescens* isolates from a wall box and a patient at Facility C were indistinguishable. Analysis from *S. marcescens* coming from the wallboxes and patient from the other facility were unrelated.

Assessment of evidence
Organism: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae.* Transmission mode: indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes). Clinical setting: outpatient haemodialysis facilities, United States of America. Source: dialysis station wall boxes (contaminated water-based equipment). Control measures: Implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Amoureux L, Riedweg K, Chapuis A, et al. Nosocomial Infections with IMP-19− Producing *Pseudomonas aeruginosa* Linked to Contaminated Sinks, France.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a IMP-19-producing *Pseudomonas aeruginosa* outbreak in France and to find the source.	Molecular genotyping results between clinical strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, genotyping results (pulsotypes by PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Emerging Infectious Diseases. 2017 Feb;23(2):304.					
Assessment of evidence					
An environmental investigation was carried out in a hospital. >100 environmental samples were collected. Water samples were collected from different faucets (nursing room, medication preparation rooms, and rooms of some patients). Sink and shower drains were also sampled as well as toilets. The 7 clinical isolates belonged to 3 distinct genotypes A, B, and C. Of the 7 environmental isolates of *P. aeruginosa* we identified, 6 belonged to the same genotype as clinical isolates (genotype A). The diversity of species found and genetic structures involved with *bla*IMP-19 indicated that the environmental contamination occurred a long time ago. Organism: *P. aeruginosa.* Clinical setting: haematology department, France. Source: contaminated sinks.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bédard E, Lévesque S, Martin P, et al. Energy conservation and the promotion of *Legionella pneumophila* growth: the probable role of heat exchangers in a	Outbreak investigation	**Level 3**	The role of heat exchangers as potential sources of contamination for *L. pneumophila.*	Sequence-Based Typing (SBT) results of *Legionella pneumophila* outbreak strain vs *L. pneumophila* isolated from environmental samples.	Number of samples, number of positive samples, colony forming units/L (CFU/L), Pulsed-field gel electrophoresis (PFGE) patterns and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
nosocomial outbreak. Infection control & hospital epidemiology. 2016 Dec;37(12):1475-80.					sequence-based typing (SBT) types.

Assessment of evidence

Positive water samples from hot water taps (88% in wing A, 56% in wing B), but cold water coming into the hospital was negative. Swabs from the inner surface of the heat exchanger were positive. Temperatures within the heat exchangers ranged from 9C to 46C and prolonged stagnation was observed during the night with no flow at some points. Up to 48% of the recirculated water did not transit through the flash water heater. Hot water coming into the distribution systems was below 55'C at the time of the outbreak.

A copper-silver ionization treatment was present on both hot water systems at the time of the outbreak.

This study provides evidence on the impact or association between heat exchangers and water contamination with *Legionella pneumophila*.

Organism: *Legionella pneumophila.*

Clinical setting: Tertiary Care University Hospital, Canada.

Source: contaminated water system.

Genotyping revealed that all isolated environmental strains harboured the same related PFGE pattern.

This study provides evidence on the impact or association between heat exchangers and water contamination with Lp.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Umezawa K, Asai S, Ohshima T, et al. Outbreak of drug-resistant *Acinetobacter baumannii* ST219 caused by oral care using tap water from contaminated hand hygiene sinks as a reservoir. American Journal of Infection Control. 2015 Nov 1;43(11):1249-51.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a drug-resistant *Acinetobacter baumannii* outbreak in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, genotyping results (rep-PCR and MLST).

Assessment of evidence

Not clear how contamination occurred. It is possible that it happened from HCW. Also by amplification in outlet. Authors suggest oral care using contaminated tap water as the transmission route.

Organism: *Acinetobacter baumannii.*

Transmission mode: unknown.

Clinical setting: emergency intensive care unit, Japan.

Source: Colonization in water systems. Reservoir in tap system – Pseudo-outbreak.

Assessment of evidence
Control measures: Use of all 10 hand hygiene water sinks was prohibited. The sinks, automatic taps, tubes, and hot and cold water mixture unit were replaced. Cleaning of the water tap was added to the daily sink cleaning routine. On day 26, the method of oral care was changed to a waterless technique, performed by wiping the teeth and gingiva with a swab after moistening the tissue with sterile water (dry oral care) under the guidance of a dental hygienist. Up to that time, conventional oral care had been performed by nurses using a toothbrush, toothpaste, and tap water while suctioning (wet oral care). The outbreak was successfully controlled after replacement of the water system and implementation as of daily cleaning of water taps and oral care with a dry method. Limitation: Combined control measures were implemented, therefor not able to pinpoint which of those was responsible for the control of the outbreak.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Starlander G, Melhus Å. Minor outbreak of extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* in an intensive care unit due to a contaminated sink.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* outbreak in Sweden (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumoniae* isolated from plughole samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of hospital infection. 2012 Oct 1;82(2):122-4.					
Assessment of evidence					
The cultures from the plughole showed growth of an ESBL-producing *K. pneumoniae*, exhibiting a DNA pattern identical to that of the patient isolates. Organism: *Klebsiella pneumoniae.* Transmission mode: unknown. Clinical setting: neurosurgical intensive care unit, Sweden. Source: contaminated sink. Control measures: By replacing the sink and its plumbing and improving routines regarding sink practices, the outbreak was successfully controlled. Limitation: Only samples from the sink whole were collected.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Conger NG, O'Connell RJ, Laurel VL, et al. *Mycobacterium simiae* outbreak associated with a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium simiae* outbreak and to find the source.	Molecular genotyping results between respiratory culture strains and *Mycobacterium simiae* isolated from environmental/water	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1050-5.				samples were compared to establish link of infection.	
Assessment of evidence					
22 patients with respiratory cultures positive *for M. simiae* were identified in the study period, of which 19 isolates were available for strain typing. 3 patients had pulmonary infection – 2 matched to the tap water. In hospital, 8/23 (34.8%) water samples from patient rooms and 2/22 (9%) from non-patient rooms were positive. Total of 12 samples from the environment were positive. 11/12 environmental cultures from hospital and military base belonged to the S clone. These were found sporadically throughout the hot water recirculation system within the hospital, and at water faucets delivering water to individual patient rooms. Results of this study suggests that the tap water (both inside as outside the hospital) act as an important reservoir. 11/12 environmental cultures from hospital and military base belonged to the S clone. These were found sporadically throughout the hot water recirculation system within the hospital, and at water faucets delivering water to individual patient rooms. 14/19 patient isolates belonged to S clone and 15/19 patients had hospital exposure before their isolate was obtained. Organism: *Mycobacterium simiae.* Transmission mode: unknown. Clinical setting: military treatment facility, United States of America. Source: tap water.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aumeran C, Paillard C, Robin F, et al. *Pseudomonas aeruginosa* and *Pseudomonas putida* outbreak associated with contaminated water outlets in an oncohaematology paediatric unit. Journal of Hospital Infection. 2007 Jan 1;65(1):47-53.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* and *Pseudomonas putida* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* and *P. putida* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antibiogram and genotyping results.

Assessment of evidence

No further cases were identified after implementation of control measures.

Organism: *Pseudomonas aeruginosa* and *Pseudomonas putida*

Transmission mode: not confirmed.

Clinical setting: haematology paediatric unit, France.

Source: contaminated water system.

Control measures: Water network was chlorinated, and disposable seven-day filters were fitted on all taps and showers. Due to the deleterious effects of chlorination on the water network and the cost of the weekly filter change, a water loop producing microbiologically controlled water was installed. In addition, the concentration of the detergent disinfectant was increased (from 0.25% to 0.5%) and

Assessment of evidence
refillable sprayers were replaced with ready-to-use detergent disinfectant solution for the disinfection of infusate bottles and laminar flow hoods. The outbreak ceased after these measures. Limitation: control measures were part of a bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hota S, Hirji Z, Stockton K, et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. Infection Control & Hospital Epidemiology. 2009 Jan;30(1):25-33.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
Typing was performed using PFGE. This study shows the importance of proper designs of sinks as well as room designs. Transmission of outbreak organism to patients by means of fluorescent marker testing was visually demonstrated.					

Assessment of evidence
Organism: *Pseudomonas aeruginosa.* Transmission mode: Probably through contamination of the area where sterile procedures and medication preparation were performed through the splash of drain contents. Clinical setting: intensive care unit or transplant units of a tertiary care hospital, Canada. Source: hand hygiene sink drains. Control measures: The use of contact precautions (wearing of gowns and gloves by healthcare workers and single room isolation of the patient) for all colonised or infected cases; staff education; enhanced environmental cleaning; disinfection of hand hygiene sink drains; closure of hand hygiene sinks; and renovation of hand hygiene sinks to prevent splashing of drain contents. The outbreak was halted through simple sink and room design modifications to prevent splashing, without actually eradicating the organism or moving the sinks. Limitation: Control measures part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tosh PK, Disbot M, Duffy JM, et al. Outbreak of *Pseudomonas aeruginosa* surgical site infections after arthroscopic procedures: Texas, 2009.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/surgical equipment samples were compared to	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection Control & Hospital Epidemiology. 2011 Dec;32(12):1179-86.				establish link of infection.	

Assessment of evidence

Evidence from the investigation suggests that this outbreak was most likely the result of inadequate instrument reprocessing that led to retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: direct insertion of contaminated instruments or by infusion of fluid through the contaminated lumen.

Clinical setting: ORs, United States of America.

Source: Retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel. (Contaminated instruments)

Control measures: Closing the OR pod where the majority of arthroscopic procedures were performed, replacing the arthroscopic instruments, returning to use of more rigid suction tubing for arthroscopy, and changing the instrument reprocessing protocols. Instrument reprocessing protocols were adjusted. The gross decontamination room was redesigned to improve workflow, instrument reprocessing staff received annual training and certification, and tracking of the individual instruments used in each surgery was initiated.

Limitation: even though statistics are explained in methods, p-values etc are not provided. IPC measures are part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al. Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. Infection control and hospital epidemiology. 2004 Mar 1;25(3):231-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon *(*including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, DNA fingerprinting results (PCR-RFLP).

Assessment of evidence

Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections.

Many episodes (411) of *B. cepacia* bloodstream infection occurred among 361 patients. Cases were noted to occur in spurts. Environmental investigations were focussed on insertion techniques. Cultures of hospital water supply showed no growth of *B. cepacia.* Water cultures from taps on different wards, on nursing stations, in the operating room, and on the dialysis unit and from plastic squirt bottles were also negative. *B. cepacia* with an antimicrobial susceptibility pattern of the epidemic strain was isolated from water obtained from 1 pharmacy tap. All 4 isolates (2x clinical, 1x pharmacy water, 1x pharmacy alcohol) were identical on restricting certain enzymes and indicated strain homogeneity among the bacterial isolates.

Organism: *Burkholderia cepacia.*

Assessment of evidence
Transmission mode: contaminated tap water that contaminated alcohol-based products. Clinical setting: hospital, Lebanon. Source: Contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with *B. cepacia*). Control measures: Once organisms were cultured from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards. Type of infection: bloodstream infections. Limitation: Only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Walker JT, Jhutty A, Parks S, et al. Investigation of healthcare-acquired infections associated with *Pseudomonas aeruginosa* biofilms in taps in neonatal units in Northern Ireland.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in Northern Ireland *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, antimicrobial susceptibility, genotyping results (VNTR).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2014 Jan 1;86(1):16-23.				establish link of infection.	

Assessment of evidence

The study investigated if taps within the neonatal units were linked to the outbreak.

Thirty (30) taps and 8 flow straighteners from 7 hospitals were categorized and dismantled into 494 components. Sensor taps accounted for 73% of taps. Sensor taps had significantly greater odds of having at least one component positive for *P. aeruginosa* compared with non-sensor taps. ($P < 0.05$)

Non-sensor taps components yielded lower median counts of *P. aeruginosa* (1440 CFU) than sensor tap components (23, 400 CFU). Aerobic colony counts were significantly higher for the integrated mixer and solenoid of automatic taps than other components. Representative *P. aeruginosa* tap isolates from two hospital neonatal units had VNTR profiles consistent with strains from the tap water and infected neonates.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: not confirmed.

Clinical setting: neonatal units, Northern Ireland.

Source: biofilms in flow straighteners and associated components in the tap outlets.

Control measures: taps were replaced with new, less complex ones.

The study identified that plastic flow straighteners, metal support collars and tap bodies surrounding these components supported the highest *P. aeruginosa* colony counts from the automatic taps assessed. Complex flow straighteners had significantly higher *P. aeruginosa* counts that other types of flow straighteners ($P < 0.05$). The integrated mixers and solenoids were associated with highest aerobic colony counts. (P,0.05) There was no strong correlation between aerobic colony counts and *P. aeruginosa* counts.

Assessment of evidence
The VNTR patterns form isolates from taps form two hospitals were consistent with strains from tap water and infected neonates. The complex low straighteners were only present in sensor taps, so unable to confirm if effect due to design or another attribute of sensor taps. Therefore, biofilms can be associated with the complex flow straighteners within automatic taps, and aerobic bacteria associated with other components (solenoid and integrated mixer) within these units. However, as complex flow straighteners were only found in sensor taps, it is unclear whether higher rates in sensor taps is due to design of flow straighteners or another factor due to sensor taps. Authors encouraged manufacturers to design taps that would not be able to become contaminated or were easily decontaminated.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster et al. Centers for Disease Control and Prevention (2003) Guidelines for environmental IC in healthcare facilities Last updated: July 2019	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This international guideline from the CDC (US based) is a compilation of recommendations for the prevention and control of infectious diseases that are associated with healthcare environments. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The following sections are relevant for the research question regarding which waterborne organisms are responsible for colonisation/infection in healthcare settings.					

Assessment of evidence
"Other gram-negative bacteria present in potable water also can cause health-care associated infections. Clinically important, opportunistic organisms in tap water include *Pseudomonas aeruginosa, Pseudomonas spp., Burkholderia cepacia, Ralstonia pickettii, Stenotrophomonas maltophilia, and Sphingomonas spp*. Immunocompromised patients are at greatest risk of developing infection. Medical conditions associated with these bacterial agents range from colonization of the respiratory and urinary tracts to deep, disseminated infections that can result in pneumonia and bloodstream bacteremia. Colonization by any of these organisms often precedes the development of infection. The use of tap water in medical care (e.g., in direct patient care, as a diluent for solutions, as a water source for medical instruments and equipment, and during the final stages of instrument disinfection) therefore presents a potential risk for exposure. colonised patients also can serve as a source of contamination, particularly for moist environments of medical equipment (e.g., ventilators). In addition to *Legionella spp., Pseudomonas aeruginosa and Pseudomonas spp*. are among the most clinically relevant, gram-negative, health-care associated pathogens identified from water. These and other gram-negative, non-fermentative bacteria have minimal nutritional requirements (i.e., these organisms can grow in distilled water) and can tolerate a variety of physical conditions. These attributes are critical to the success of these organisms as health-care associated pathogens. Measures to prevent the spread of these organisms and other waterborne, gram-negative bacteria include hand hygiene, glove use, barrier precautions, and eliminating potentially contaminated environmental reservoirs." "NTM pseudo-outbreaks of *Mycobacterium chelonae, M. gordonae, and M. xenopi* have been associated with both bronchoscopy and gastrointestinal endoscopy when a. tap water is used to provide irrigation to the site or to rinse off the viewing tip in situ or b. the instruments are inappropriately reprocessed with tap water in the final steps." Limitations: The vast majority of references cited in this guidance are from pre-2000. There is therefore a risk that newer healthcare practices and the water risks related to these, have not been adequately captured in this guidance.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence

Organism: *Mycobacterium mucogenicum.*

Source: Contaminated automatic sensor water tap.

Clinical setting: paediatric haemato-oncology in a Medical Centre, Israel.

Transmission mode: water to patient likely entry via CVC lines. No evidence of patient-to-patient transmission.

Control measures: automatic taps were replaced with new manual taps and surveillance cultures taken one month and six months later were negative; chlorine levels measured periodically from two to six months later were in the normal range.

Four patients had fever, and one had signs of an exit-site infection. In one, mycobacterial infection was an incidental finding. None of the patients had signs of disseminated NTM infection on imaging studies.

Assessment of evidence
Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet. Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a haemato-oncology unit. Journal of Hospital Infection, 79; 339-343. 2011.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in Edinburgh and to determine the impact of infection prevention and control measures.	N/A	Number of positive samples, sample type and species.

Assessment of evidence
Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.) Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs). Clinical setting: haemato-oncology unit, Scotland. Source: showers but exact source within the water system unknown, assumed to be further back. Control measures: Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering; this practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. All showerheads and hoses were replaced, shower curtains removed permanently. Regular 12 weekly cleaning and chlorination of the hose, showerhead, washbasins and drain taps implemented, and flushing of showers for 2 mins before every use. The cold-water storage tanks supplying transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. No further cases identified in the 12 months following. Limitations: Similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Infections Associated with Heater Cooler Units Used in	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cardiopulmonary Bypass and ECMO - Information for healthcare providers in the UK Version 2. 2017.					

Assessment of evidence

This English document “includes a revised risk assessment and a new instruction for patient notification to facilitate early diagnosis of M. chimaera infection”. The following section(s) are relevant for the research question regarding which waterborne organisms are responsible for colonisation/infection in healthcare settings.

“During 2014-15, PHE were made aware of cases of Mycobacterium chimaera endocarditis or deep infection following cardiac surgery in Switzerland, Germany and The Netherlands. M. chimaera is a recently described species within the Mycobacterium avium complex, a group of environmental organisms usually associated with lung infections, or systemic infections in the immunocompromised host. A Swiss investigation implicated the Sorin (now LivaNova) 3T heater cooler unit (HCU) of the cardiopulmonary bypass equipment, with the transmission of bacteria to the surgical site by aerosolisation of contaminated water from within the unit. The LivaNova device is widely used in the UK and internationally. Maquet, another manufacturer of devices used in the UK, has also indicated that M. chimaera has been identified in its HCU water tanks and issued advice to manage any associated risk.”

Transmission mode: aerosolisation of M. chimaera from the contaminated water heater cooler unit.

Clinical settings: cardiac surgery, England UK.

Source: contaminated water heater cooler units.

Control measures: replacement of units.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Summary of Incident and Findings of the NHS Greater Glasgow and Clyde: Queen Elizabeth University Hospital/Royal Hospital for Children water contamination incident and recommendations for NHSScotland. Final V2. 2018.	Incident report	**Level 4**	N/A	N/A	N/A

Assessment of evidence

Between the period of 29th January and 26th September 2018, 23 cases of blood stream infections (11 different organisms) with organisms potentially linked to water contamination were identified. As a result, further testing of the water supply was undertaken across both hospital sites early in the investigation. This testing identified widespread contamination of the water system.

Organism(s): *Cupriavidus pauculus* (1), *Pseudomonas fluorescens* (1), *Pseudomonas aeruginosa* (3), *Stenotrophomonas maltophilia* (12), *Acinetobacter ursingii* (2), *Enterobacter cloacae* (7), *Klebsiella oxytoca* (1), *Serratia marcescens* (1), *Pseudomonas putida* (1), *Pantoea* sp (1), *Klebsiella pneumonia* (1), *Chryseomonas indologenes*(1)

Transmission mode: contaminated water system.

Assessment of evidence
Clinical setting: paediatric haemato-oncology unit, Scotland. Source: drain - contaminated water system. Control measures: Control measures implemented included sanitisation of the water supply to ward 2A, installation of the use of point of use filters in wash hand basins and showers in ward 2A/B and other areas where patients were considered high risk. Drain decontamination was undertaken and on 26th September 2018 wards 2A/B were closed and patients decanted to ward 6A QEUH and 4B QEUH.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.

Assessment of evidence
Organism: *M. abscessus.* Transmission mode: Tap water to patient. Possibly cardiac heater cooler units in cardiac patients. Clinical setting: Acute hospital – ICU/ OR, North Carolina, United States of America. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease Source: Water system. Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kizny Gordon A. E., Mathers A. J., Cheong E. Y. L., et al. The Hospital Water Environment as a Reservoir for Carbapenem-Resistant Organisms Causing Hospital-Acquired Infections - A Systematic Review of the Literature Clinical Infectious Diseases 2017:64	Systematic review	**Level 2+**	N/A	N/A	N/A

Assessment of evidence

The aim of this systematic literature review was to summarise studies identifying common CROs in the hospital water environment, the evidence for CRO transmission between this environment and patients, and successful IC interventions to terminate outbreaks and eliminate CROs from this environment.

Organism(s): 13 studies (32 studies in total)) reported *Pseudomonas aeruginosa* (n=13), Other *Pseudomonas* spp. (n=2), *Acinetobacter baumannii* (n=5), *Klebsiella pneumoiae* (n=7), *Klebsiella oxytoca* (n=3), *Enterobacter* spp (n=5), E. coli (n=3), *Serratia marcescens* (n=3), Other (*Leclercia* spp., *Pantoea* spp., *Citrobacter freundii, Raoutella planticola, Escherichia hermannii*, *Aeromonas hydrophilia*, *Proteus mirabilis* or not specified) (n=4).

Assessment of evidence
Clinical setting(s): Intensive Care Unit, High-risk (Hematology, Nephrology, Burns Unit), Multiple Wards. Transmission mode(s): various (not specified per study). Cause(s): “Nine studies reported IC breaches that probably contributed to outbreaks. These included poor sink design, use of sinks for contaminated clinical waste disposal, storage of clean patient materials around sinks/sluices, reuse of nonsterile surgical drapes and open drainage in the cystoscopy room, use of a single brush to clean sinks without between-site disinfection, blocked sewage pipes and waste pipe leaks, and failure to clean shower drains.” Source(s): Drains/drainage systems, sink surfaces, faucets, water, inflatable hair wash basin, sensor mixer taps, water/tea dispenser, shower/shower equipment, toilet bowl/brush. Control measures that were considered successful by the authors of that study (see suppl table 1 of this review): “Interventions successful at disinfecting water reservoirs included cleaning of sinks and taps (details not given), daily cleaning of sink surfaces with 0.1% sodium hypochlorite, weekly cleaning of sinks and plumbing with acetic acid/ hot water, transferring all patients to a dedicated isolation unit and hydrogen peroxide vapor disinfection, replacing nontouch sensor taps with conventional taps, and replacing sinks or drainage systems.” Additional control measures: “Twenty-two studies reported enhancing general IC measures, including contact isolation, strict hand hygiene, active surveillance, reinforcement of cleaning and disinfection procedures, audits, and education sessions.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gbaguidi-Haore H, Varin A, Cholley P, et al. A Bundle of Measures to Control an Outbreak of *Pseudomonas*	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in France including finding the source	Molecular typing of ESBL- or MBL-producing isolates (patient vs environmental isolates) using pulsed-field gel	Incident rate, infected/colonised patient characteristics, positive cultures (patient and environmental),

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa Associated with P-Trap Contamination. Infect Control Hosp Epidemiol. 2018;39(2):164-169. doi:10.1017/ice.2017.304			and to report on the bundle of control measures.	electrophoresis (PFGE) and multilocus sequence typing (MLST).	molecular genotyping.

Assessment of evidence

Overall, 11 patients were colonised or infected with ST235 and 10 patients with ST111.

Organism: *Pseudomonas aeruginosa.*

Clinical setting: haematology unit, France.

Source: Likely reservoir of the outbreak organism were the P-traps and lower plumbing. Acquisition of the 2 outbreak strains was mainly associated with 2 specific rooms where the environment was contaminated.

Control measures: Included (1) a global clinical audit and a reminder on recommendations of hand disinfection opportunities, (2) excreta management, (3) use of gloves, (4) recall of cleaning practices, (5) discontinuation of faeces discharge in the toilets, and (6) removal of hand showers for rinsing the toilets. After the first results of environmental sampling, all taps and all drains of sinks and toilets were replaced. New water outlets were equipped with lockable P-traps and disposable point-of-use water filters that were changed monthly. A bleach solution (water with 2.6% active chlorine) as poured twice weekly into the blocked P-traps to allow a contact time of 15 minutes before rinsing with water. An additional measure was implemented in April 2014: P-traps were changed at patient discharge whenever a patient stay exceeded 1 week. However, the effect of these measures is not included in the study, these are just mentioned in the discussion section. Authors witnessed a recolonization of the new P-traps in rooms hosting patients who were not colonised by the epidemic strains, suggesting that *P. aeruginosa* stayed in the main pipe and recontaminated the P-traps. This explains how the pathogen contaminated new P-traps and drains of rooms hosting patients negative for *P. aeruginosa.*

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Wafer T, et al. Investigation and control of an outbreak due to a contaminated hospital water system, identified following a rare case of *Cupriavidus pauculus* bacteraemia. J Hosp Infect. 2021;111:53-64. doi:10.1016/j.jhin.2021.02.001	Outbreak investigation	**Level 3**	The aim of this study was to investigate rare case of *Cupriavidus pauculus* bloodstream infection (including finding the source) which led to the investigation and control of a contaminated water system in a new build hospital due to another 22 patients infected with waterborne pathogens in the following few months.	N/A	Water/Environmental contamination - The unit undertook frequent water testing and had prior agreed cut-off levels of <10 cfu/mL at 37°C and, <100 cfu/mL at 22°C.
Assessment of evidence					
This study initially investigated a *Cupriavidus pauculus* bloodstream infection in an immunosuppressed patient which turned into the investigation and control of a contaminated water system in a new build hospital due to another 22 patients infected with waterborne pathogens in the following few months.					

Assessment of evidence
Organism (infections): Patients were infected with either *Cupriavidus pauculus* (phase 1), *Enterobacter cloacae, Stenotrophomonas maltophilia, Pseudomonas putida, P. aeruginosa, P. fluorescens, Klebsiella pneumoniae, Pantoea agglomerans and Acinetobacter ursingii* (Phase 2) *Serratia marsescens* and *Klebsiella oxytoca* (Phase 3). Source: contaminated water system and components. Clinical setting/Patient population at risk: haemato-oncology ward, Scotland. All patients were paediatric haemato-oncology patients with either underlying haematological or solid tumor malignancy. All patients had Hickman lines in situ and required treatment with intravenous antibiotics and in most cases line removal. Only sporadic cases of infection were found in the adult population, and this might be due to behavioural factors of children such as splashing while washing (hands) and small toys pushed down drains. Due to their smaller appearance, the central line sites are closer to outlets, drains and toilets. Limitations: • described as one incident categorised in 3 phases which were all separate outbreaks (different organisms) – this makes it slightly unclear • not all water samples were sent for typing. Neither were multiple colonies selected from each agar plate for typing. Therefore, it is not clear what the exact source was of the patient infections • combination of control measures makes it difficult to determine which part was responsible for the impact

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Halstead F. D., Niebel M., Garvey M., et al. *Pseudomonas aeruginosa* infection	Surveillance study	**Level 3**	This study aimed to investigate the transmission of *P. aeruginosa* from water to adults in a	Phylogenetic relatedness between clinical and environmental samples.	Number of outlets sampled, number of positive outlets per sampling period (beginning, middle,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in augmented care: the molecular ecology and transmission dynamics in four large UK hospitals. Journal of Hospital Infection 111 (2021) 162e168			non-outbreak augmented care setting.		end), phylogenetic relatedness between clinical and environmental samples.
Assessment of evidence					
In this study of four anonymized UK hospitals, 881 water outlet samples were taken from 774 taps and 107 showers and the genetic relatedness was compared to 120 clinical *P. aeruginosa* samples to investigate the transmission of *P. aeruginosa* from the water outlet to the adult patients in the 23 augmented care units. Organism: *P. aeruginosa.* Transmission mode: direct/indirect from taps and showers. Exact mode not proven. Clinical setting: augmented care units, England, UK. Source: tap water positive from taps and showers (unclear if this outlet contamination or water contamination) but a likely reservoir. Limitations: Patients were not screened on admission, so endogenous carriage not assessed.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D., Vanstokstraeten R., Crombe F., et al. Sink drains as reservoirs of VIM-2 metallo-b-lactamase producing *Pseudomonas aeruginosa* in a Belgian intensive care unit: relation to patients investigated by whole-genome sequencing. Journal of Hospital Infection 115 (2021) 75e82	Surveillance study	**Level 3**	This study aimed to verify whether patients could be colonised/infected by micro-organisms present in the sink drains and to investigate whether high-risk clones of *P. aeruginosa* are present in the ICU.	Molecular genotyping results (WGS) between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish link of colonisation/infection .	*P. aeruginosa* growth from clinical and environmental samples, genetic profiles, phenotypic resistance profiles, antibiotic resistance and virulence gene profiles.
Assessment of evidence					
This surveillance study sampled all 36 sinks in the four different ICU of the University hospital Brussels and compared the genetic profiles to the clinical isolated that were retrieved during screening (stored at -80C). In total, 11 distinct STs were identified among the sink drain isolates of which 7 were also identified in the clinical isolates. No single link was seen between environmental isolates and non-ICU clinical samples. Organism*: P. aeruginosa.*					

Assessment of evidence
Transmission mode: not reported. Clinical setting: ICUs, Belgium. Source: sink drains. Limitations: No other samples were taken other than the sinks. Authors state that it was not always clear whether the sink drains were contaminated by the patients or the other way around.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jolivet S, Couturier J, Vuillemin X et al. Outbreak of OXA-48-producing Enterobacterales in a haematological ward associated with an uncommon environmental reservoir, France, 2016 to 2019. Euro Surveill. 2021;26(21):pii=2000118	Outbreak investigation (including case-control element)	**Level 3**	The study reports the epidemiological and microbiological investigations carried out to control a large and protracted outbreak caused by OXA-48 CPE, mostly *Citrobacter freundii.*	Phylogenetic properties of isolates and epidemiologic links between patients and environmental sources.	Number of clinical cases with OXA-48-producing Enterobacterales infection or colonisation in the haematological ward. Contamination/ growth of CPE in environmental samples. Antimicrobial resistance and typing.

Assessment of evidence
37 patients cases (**31 acquired**, 6 imported); 21 developed infection. 7 toilets positive plus one sink drain. Water samples not taken. The only factor significantly associated with CPE acquisition was hospitalisation in a room with a toilet that was positive for OXA-48 CPE (odds ratio = 6.2; 95% CI:2.0–19.6; p=0.002). Organism: A total of 78 OXA-48 CPE were detected including 22 *C. freundii*, 19 *E. coli*, 15 *K. pneumoniae*, seven *Klebsiella oxytoca*, six *Enterobacter cloacae*, two *Citrobacter koseri*, two *Enterobacter aerogenes*, one *Hafnia alvei*, one *Kluyvera cryocrescens*, one *Citrobacter amalonaticus*, one *Morganella morganii*, and one *Raoultella ornithinolytica.* 18 patients had at least 2 different CPE. Transmission mode: unconfirmed, however likely a mixture of indirect, direct, patient-patient. Clinical setting: haematological ward, France. Source: toilets and sink drains a likely reservoir and potential source; patients also the source for some transmissions. Control measures: “Following the identification of the toilets as a potential source of the outbreak, intensive toilet cleaning with descaling and bleaching (initially daily, then weekly) was implemented. Afterwards, 23 environmental samples were taken (including 21 toilet rims and two drains), and only one toilet remained positive for OXA-48-producing *C. freundii*. This toilet was successfully re-decontaminated by performing a single additional cleaning and bleaching. In August 2018, all toilets bowls and tanks in two units with environmental CPE-positive samples were replaced by rimless toilets. Rimless toilets are easier to clean and reduce the risk of limescale deposits. After implementation of the environmental measures, the incidence of new CPE cases declined, and only two unrelated CPE cases”. Limitations: water samples not taken.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler M. A., Osman F., Marx J. J., et al. Hospital-acquired *Legionella*	Outbreak investigation (including case-control element)	**Level 3**	An epidemiological and laboratory investigation of a hospital-acquired *Legionella*	Molecular genotyping results (WGS) between patient strains and *L. pneumonia* isolated	Case-control study: ICU admission, 30-day mortality and 90-day mortality, Demographic data

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
pneumonia outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020			*pneumonia* outbreak at of The University of Wisconsin Hospital. Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia.*	from environmental/water samples were compared to establish link of colonisation/infection .	and patient factors, pertinent exposures Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of *Legionella* in environmental samples taken from patient rooms and clinical units, molecular type of isolates found.
Assessment of evidence					
This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the implementation of changes to the water treatment strategy and it is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters were applied. Organism: *Legionella pneumonia.*					

Assessment of evidence
Transmission mode: direct (from water system). Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients. United States of America. The case-control study showed that being a current smoker, having showered during admission and being on prescribed steroids prior to admission were the strongest predictors for acquiring Legionella disease during the outbreak. Source: hospital water circuit. Control measures: Showering activities were promptly restricted, the hot potable water distribution system was hyperchlorinated with 50-200 ppm free chlorine overnight, and sections were sequentially flushed to remove excess chlorine. The silver-copper ionization system was then returned to its original configuration. Nine days later, point of use filters were installed on showerheads and faucets in the inpatient unit with most cases. Other interventions included removal of the old water heaters and associated dead end water pipes. Despite continued monitoring, no additional cases were identified more than 1 year since the last case. Limitations: case-control element only had 13 cases which is very low to make proper statements on risk factors. Note: Legionella testing of the water system was not in place prior to the outbreak (silver-copper levels measured instead).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary bypass since reports	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and presentation,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42			from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of heater-cooler units (HCUs) used during bypass.		outcome. Growth/ contamination of air/environmental samples, whole-genome sequencing data (phylogenetic relatedness).

Assessment of evidence

This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year.

Organism: *Mycobacterium chimaera.*

Transmission mode: indirect contact/aerosolization.

Clinical setting: cardiothoracic surgery, England, UK.

Source: cardiopulmonary bypass heater-cooler units.

Limitations: a 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sax H., Bloemberg G., Hasse B., et al. Prolonged Outbreak of *Mycobacterium chimaera* Infection After Open-Chest Heart Surgery. Clinical Infectious Diseases 2015;61(1):67–75	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chimaera* outbreak in Switzerland (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of probable cases including surgery type, type of implant, latency, positive cultures. Growth/ contamination of air/environmental/water samples, genotype, outbreak management.

Assessment of evidence

This outbreak investigation started after 2 patients were found to have *Mycobacterium chimaera* infection and an in-depth outbreak investigation was done to detect the source, including retrospective case detection, prospective surveillance, on-site observations, and targeted microbiological sampling of patients and the hospital environment. In total, 6 patients met the case definition; All patients had undergone open-chest heart surgery involving implants and the use of heater-cooler units at the University Hospital of Zurich between 2008 and 2012. *Mycobacterium chimaera* was cultured from 5 heater-cooler units and an air sample. Latency between surgery and manifest infection ranged between 1.5 and 3.6 years.

Organism: *Mycobacterium chimaera* (NTM).

Transmission mode: indirect contact/aerosolization.

Clinical setting: open-chest heart surgery patients, Switzerland.

Source: heater-cooler unit reservoirs.

Assessment of evidence
Control measures: Not under control when published (Only used factory-new heater-cooler units with daily water changes and POU filters, however there was another positive sample in Sept 2014 from 1 heater-cooler unit. At the time of writing (Dec 2014), the construction of custom-built containers with high-efficiency particulate air filters to house heater-cooler units that cannot be placed outside the operating room is under way.) Incubation time: latency between surgery and manifest infection ranged between 1.5 and 3.6 years. Limitations: • no genotypic link between patients and environmental samples • all drinking water fountains in the hospital ICUs tested positive, so cannot rule out that this was another potential source

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Seagar AL, et al. Investigation of two cases of *Mycobacterium chelonae* infection in haemato-oncology patients using whole-genome sequencing and a potential link to the hospital water supply.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chelonae* cluster in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	WGS results between patient strains and *Mycobacterium chelonae* isolated from environmental samples were compared to establish link of infection.	Number of positive samples, sample type, WGS results (relatedness by using single-nucleotide polymorphisms SNPs).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
J Hosp Infect. 2021;114:111-116. doi:10.1016/j.jhin.2021.04.028					

Assessment of evidence

Outbreak report of 2 haemato-oncology patients at the Queen Elizabeth University Hospital. WGS of patient samples were done to check for patient-patient transmission as well as water testing was performed and WGS on positive *M. chelonae* samples to check for relatedness and identify potential sources. The results showed that the patient strains were unrelated to each other, but that the isolate from one patient was closely related to environmental samples from water outlets, supporting nosocomial acquisition.

147 unfiltered water samples were tested, 68 (46%) water samples from outlets tested positive, with 34 of 68 (50%) having counts >100 colony-forming units/mL. WGS was undertaken on 31 isolates as well as the two patient isolates for comparison to identify the source/relatedness.

Organism: *Mycobacterium chelonae*

Transmission mode: not confirmed.

Clinical setting: haemato-oncology inpatient wards, Scotland, UK.

Source: water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ito K, Honda H, Yoshida M, et al. A metallo-beta-lactamase producing	Outbreak report	**Level 3**	This study reported the investigation of an outbreak of metallo-beta-	Molecular typing result between patient strains and environmental strain	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Enterobacteriaceae outbreak from a contaminated tea dispenser at a children's hospital in Japan. Infection Control & Hospital Epidemiology (2019), 40, 217–220			lactamase producing Enterobacteriaceae in a pediatric ward at a Children's medical center in Japan.	isolated from environmental/water samples were compared to establish a link of infection.	Genetic relatedness.

Assessment of evidence

Five patient cases. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). K. pneumoniae strains isolated from the clinical and environmental samples all harbored the blaIMP-1 gene. A core-genome single nucleotide polymorphism (SNP)–based phylogenetic analysis revealed that 33 of the blaIMP-1-positive K. pneumoniae strains had a common ancestor.

No water contamination in any other areas of hospital.

Organism: MBL-producing Enterobacteriaceae (Klebsiella pneumoniae).

Transmission mode: potentially direct (ingestion of contaminated tea) and indirect (from environment/hands/equipment).

Clinical setting: paediatric cardiology/ophthalmology ward, Japan.

Source: tea dispenser identified as a potential reservoir along with 2 sinks.

Control measures: Banning of use of public areas such as playroom and dining hall, reinforcement of appropriate standard and contact precautions, increase of routine cleaning of sinks and frequently touched areas using 0.1% hypochlorite from 1 to 3 times daily. The tea dispenser was also removed. Noted that domestic staff were not adequately educated/trained on hand hygiene.

Assessment of evidence
Outcome: “No MBL-producing Enterobacteriaceae were isolated from patients admitted to the ward or occupying the ward environment after banning the use of the tea dispenser.” Limitations: no details given on whether the sinks remained contaminated after the tea dispenser was removed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ambrogi V, Cavalie L, Mantion B, et al. Transmission of metallo-b-lactamase-producing *Pseudomonas aeruginosa* in a nephrology-transplant intensive care unit with potential link to the environment. Journal of Hospital Infection 92 (2016) 27-29	Outbreak report	**Level 3**	This study reports on a cluster of five cases of infection with metallo-beta-lactamase producing *P. aeruginosa* in a nephrology-transplant ICU in France.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates. Genetic relatedness.
Assessment of evidence					
5 patient cases. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). No water contamination in any other areas of hospital.					

Assessment of evidence
Organism: *Pseudomonas aeruginosa.* Clinical setting: nephrology transplant ICU, France. Transmission mode: unknown (authors hypothesised that HCWs touching taps when washing hands may have cross-transferred from patients). Source: sinks as reservoirs and potential source. Control measures: Replacement of sinks/taps with ones that have a larger space between the tap and the basin. ABHR use reinforced and flushing of outlets instigated (presumably had not been happening before). Genetic relatedness: All 5 clinical strains showed the same antibiotype (sensitive only to colistin), possessed bla_{vim-2} genes expressing VIM-2 carbapenemase and were genetically indistinguishable.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wong V, Levi K, Baddal B, et al. Spread of Pseudomonas fluorescens Due to Contaminated Drinking Water in a Bone Marrow Transplant Unit.	Outbreak study	**Level 3**	This study reports the findings of the epidemiological and microbiological investigation of a *Pseudomonas fluorescens* outbreak.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Clinical Microbiology 2011, 49(6), 2093-2096.					

Assessment of evidence

Nine patient cases, 6 of this developed febrile neutropenia. All had positive pharyngeal samples. Water sample from a water dispenser in the unit tested positive and genetically matched the patient isolates. All other environmental samples were negative.

Organism: *Pseudomonas fluorescens.*

Clinical setting: bone marrow transplant unit, England, UK.

Transmission mode: direct (ingestion).

Source: chilled water dispenser as reservoir, unclear how it became contaminated (authors theorised that the nozzle may have been touched by contaminated hands).

Control measures: Removal of the contaminated chilled water dispenser (the remaining one was kept). The long-term plan for the unit is to install filtered plumbed-in main water dispensers and to implement regular qualitative and quantitative water assessments.

Genetic relatedness: All nine patient isolates and the one environmental isolate were identified as being Pseudomonas fluorescens. “The isolate from the water dispenser was found to be genotypically identical to the patients’ isolates: all isolates of P. fluorescens produced identical RAPD patterns (type b pattern), and typing by PFGE revealed that all isolates recovered were indistinguishable, with a designated profile of NOTT PF1.”

Limitations: Water was sampled via the nozzle of the chiller unit and not directly from the bottle before or after installation, so unclear where the contamination originated from.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Snitkin ES, Zelazny AM, Thomas PJ, et al. Tracking a Hospital Outbreak of Carbapenem-Resistant Klebsiella pneumoniae with Whole-Genome Sequencing. Sci Transl Med. 2012 August 22; 4(148)	Outbreak report	**Level 3**	This paper describes the application of whole-genome sequencing (WGS) to track an outbreak of carbapenem-resistant *K. pneumoniae* at Clinical center in the United States.	Molecular typing results between patient strains and *K. pneumoniae* isolated from environmental/water samples were compared.	Genetic relatedness.

Assessment of evidence

18 colonised patients, 11 died. Whole genome sequencing established links between patients and environmental samples (6 drains, a ventilator and another patient room (specific location in room not stated)).

Authors focused on genetic linkage to assess patient to patient transmission, only a brief mention of genetically matched positive cultures from environmental sources but no clear acknowledgement of a transmission route from these sources/reservoirs.

Organism: *Klebsiella pneumoniae*

Clinical setting: ICU, United States of America.

Source: unconfirmed, found in 6 sink drains and 1 ventilator.

Transmission mode: possible patient-patient and environment to patient.

Control measures: extensive cleaning and contact precautions but no details of drain cleaning.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leung GHY, Gray TJ, Cheong EYL, et al. Persistence of related bla-IMP-4 metallo-beta-lactamase producing Enterobacteriaceae from clinical and environmental specimens within a burns unit in Australia - a six-year retrospective study. Antimicrobial Resistance and Infection Control 2013, 2:35	Outbreak report	**Level 3**	This paper describes the investigation undertaken in a six - year persistent bla-IMP-4 metallo-beta-lactamase (MBL) producing Enterobacteriaceae within a separately confined hospital burns unit in a tertiary hospital in Australia.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates.

Assessment of evidence

23 patients, with clinical infection in 7 (2 bacteremias, 2 CVC tip infections, 3 wound infections).

Assessment of evidence: the only environment shared between patients was the shower and bathroom facilities.

Organism: *Enterobacter clocae* (most commonly detected organism), *Klebsiella pneumoniae, Enterobacter aerogenes, Klebsiella oxytoca.*

Clinical setting: burns unit, Australia.

Assessment of evidence
Source: Sink and shower drains identified as reservoirs and potential source for some transmissions. Patients may have been initial source. Transmission: Unclear, however likely both direct and indirect. Control measures: Monthly and then bi-monthly environmental sampling (bathroom facilities and plumbing including shower drains, ensuite room sink drains). Regular physical cleaning of drains to remove biofilm and additional cleaning with double-strength phenolic disinfectant (Phensol), later changed to chlorine-based product (Chlor-clean). Despite both regular environmental surveillance and disinfection, environmental reservoirs remained.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wendel AF, Kolbe-Busch S, Ressina S et al. Detection and termination of an extended low-frequency hospital outbreak of GIM-1-producing *Pseudomonas aeruginosa* ST111 in Germany.	Outbreak report	**Level 3**	This paper describes an outbreak of an extensively drug-resistant GIM-1-carrying *Pseudomonas aeruginosa* Strain in a tertiary care hospital in Germany from 2002-2013.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
American Journal of Infection Control 43 (2015) 635-9					
Assessment of evidence					
A total of 199 environmental specimens were collected (pre+post flush water samples, reusable hair washbasins, sink drains, sink basins, sink counter – all taken before cleaning). The outbreak strain was detected in 6 sink drains (5 patients rooms, 1 service room) and 1 inflatable hair washbasin. Not found in tap water. Five out of 24 patients had a clinical infection, remainder were colonised. Organism: *Pseudomonas aeruginosa*. Setting: ICU, Germany. Transmission mode: likely indirect and direct, however cannot rule out patient-patient transmission. Source: sink drains as a reservoir; cannot rule out patient-patient transmission. Control measures: Use of water from patient room sinks for patient-related procedures was forbidden. Reusable hair washbasins removed. Clean materials not stored near sinks. Sink drains replaced. No further detections in the year after.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hong KB, Oh HS, Song JS et al. Investigation and Control of an Outbreak of Imipenem-resistant *Acinetobacter*	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of imipenem-resistant *Acinetobacter baumanii* in a pediatric ICU in a	Molecular typing results (multilocus sequence typing) between patient strains and environmental strains isolated from	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
baumannii Infection in a Pediatric Intensive Care Unit. Pediatr Infect Dis J 2012;31: 685–690.			Children hospital in Korea.	environmental/water samples were compared to establish a link of infection.	
Assessment of evidence					
Environmental samples were obtained from mechanical ventilator devices, respiratory equipment, bed rails, side tables, blood pressure cuffs, door handles, intravenous stands, keyboards, water taps and sinks. Contaminated shallow sink with high water pressure created splashing onto surrounding areas; staff were using towels to soak this up. Organism: *Acinetobacter baumannii.* Setting: paediatric ICU, Korea. Transmission route: unknown. Source: sink drain a reservoir, cannot rule out patient-patient transmission (patient as a source). Control measures: patient and nurse cohorting, active surveillance on admission, contaminated sink was replaced; following this the rate of colonisation decreased. Genetic relatedness: multilocus sequence typing analysis linked environmental samples from sink drain and that sink tap water to patient cases.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tofteland S, Naseer U, Lislevand JH et al. A Long-Term Low-Frequency Hospital Outbreak of KPC-Producing *Klebsiella pneumoniae* Involving Intergenus Plasmid Diffusion and a Persisting Environmental Reservoir. PLoS ONE 8(3): e59015	Outbreak report	**Level 3**	This paper reports the investigation of the molecular characteristics of a long-term, low frequency outbreak of blakpc-2 in a hospital in Norway.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness Antimicrobial susceptibility.

Assessment of evidence

Sink drains and taps supplying water to dialysis machines were sampled. PGFE/MLST analysis of isolates were carried out. KPC-producing bacteria were detected in 4/19 environmental locations in the ICU-A (sink drains in room 5, 6, 9, and the rinsing room).

Organism*: K. pneumoniae* ST258.

Clinical setting: surgical/medical ICU, Norway.

Transmission: Patient negative on admission because positive 5 days post admission, was admitted to room vacated by positive patient; room sink drain was positive. Matching pulsotypes for all these isolates.

Source: Environmental reservoir (sink drains) and patients

Assessment of evidence
Control measures: Active surveillance on admission. The sinks and sink traps were decommissioned and the connecting pipe elbows were disinfected using a chlorine disinfectant before new sinks and sink traps were installed. Monthly environmental screening of these positive locations was then undertaken. Several sinks continued to be positive, but no further patient cases. Genetic relatedness: “PFGE and MLST typing revealed that 14 K. pneumoniae isolates from both patients and the environment, including the three bla$_{KPC}$-negative *K. pneumoniae* UTI-isolates, belonged to two clonally related pulsotypes (A1 and A2), that by MLST were typed to ST258”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Vergara-Lopez S, Dominguez MC, Conejo MC et al. Wastewater drainage system as an occult reservoir in a protracted clonal outbreak due to metallo-b-lactamase-producing *Klebsiella oxytoca.* Clin Microbiol Infect 2013; 19: E490–E498	Outbreak report	**Level 3**	This paper describes the investigation of a protracted nosocomial clonal outbreak of a multidrug resistant IMP-8 producing *Klebsiella oxytoca* (MDRKO) in a Spanish Hospital.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence
42 patients colonised (n=28) or infected (n=14). The average time between admission and acquisition of MDRKO was 8 days (IQR,6-37), 16 days (12-17) and 14 (9–40) days in waves 1, 2, and 3, respectively (p 0.22). A urinary catheter removed from a colonised patient and a stethoscope used with that patient yielded MDRKO. Sampling of sinks, drainpipes and traps, was carried out. Samples from room S6 were positive: MDRKO cultured from every pipe, trap and drainage grille sample taken; samples from the faucet or overflow grille were negative. Samples from the pipe connecting S6 and S7 were also positive. Organism: Klebsiella oxytoca. Setting: surgical/medical ICU, Spain. Transmission: unconfirmed. Source: sink drains/drainage pipes as reservoir, patients also a source. Control measures: Chemical dosing of the whole water system (a standard annual practice) did not eradicate the outbreak. Sink 6 and its drain system were permanently removed and the drain system of S7 was replaced. Then, a decision to isolate wastepipe 5, which S5 and S7 still drained into. Thus, the complete horizontal drainage system of S5 and S7 was replaced and connected up to wastepipe 4. Shut-off valves were also installed to each sink drainage system. Since then, a disinfection of the drainage system was performed twice a week using ‘Biguanid’ (quaternary ammonium compound) at 1.6% for 30 min (through closing the valves), followed by opening the valves and running hot water (70°C) for 5 min. No new cases in follow up to publication. Genetic relatedness: Selected isolates from waves 3 and 4 and all the environmental samples were studied for the presence of blaIMP-8 and molecular relatedness by PFGE profile. Every strain studied carried blaIMP-8 and they showed the same PFGE profile as previous isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Seara N, Oteo J, Carrillo R et al. Interhospital spread of NDM-7-producing Klebsiella pneumoniae belonging to ST437 in Spain. International Journal of Antimicrobial Agents 46 (2015) 169–173	Outbreak report	**Level 3**	This paper describes an interhospital spread of carbapenem-resistant Klebsiella pneumoniae (CRKP) producing NDM-7 carbapenemase across three hospitals in Spain.	Molecular typing result between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

A total of 7 cases across 3 different hospitals (4 infected, 3 colonised) were categorised as HAI according to CDC definition (supported by admission screening). The median duration from admission to detection of CRKP in these 7 patients was 32 days (range, 21–44 days). Presence of NDM-7 producing *K. pneumoniae* in the traps of the shower and sink.

Organism: Klebsiella pneumoniae.

Setting: 3 different hospitals (An acute tertiary hospital, an acute rehabilitation care hospital and a secondary center that provides medical and surgery support to all other hospitals in the Madrid hospital network), Spain.

Transmission: unconfirmed.

Source: sink/shower drain as reservoir for some cases.

Control measures: Active surveillance at admission following first case. cleaning of the sink and shower with sodium hypochlorite, vaporisation of the inner trap with a steam cleaner for 1 min, and pouring 0.1% sodium hypochlorite, 0.1% sodium hydroxide and 0.1%

Assessment of evidence
C12–C16 alkyl dimethyl amine oxide down the drain. 2 months later NDM-producing *K. pneumoniae* was still present in the sink trap and consequently the trap was replaced. Genetic relatedness: PFGE indicated that all CRKP isolates were closely related; MLST showed that all of the isolates belonged to ST437, a single-locus variant of ST11. 5 patients had no overlap of stay but had stayed in same room – this room had colonised sink and shower traps.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lalande V, Barbut F, Varnerot M et al. Pseudo-outbreak of *Mycobacterium gordonae* associated with water from refrigerated fountains. Journal of Hospital Infection (2001) 48: 76–79	Outbreak report	**Level 3**	This paper describes the investigation of a pseudo-outbreak of *M. gordonae* in the chest medicine department of a hospital in France.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.
Assessment of evidence					
5 cases pseudo-outbreak (contaminated sputum samples, no infection). In total, 129 environmental samples were collected from tap water from patients' rooms (73) nurses' offices (36) and from refrigerated fountains (20). Contamination with *M. gordonae* was observed in 38.4%, 5.6%, and 25% of tap water from patients' rooms, nurses' offices and refrigerated fountains, respectively. Counts were generally low (<10 cfu/150 ml) but the refrigerated fountain counts were high (>500 cfu/150ml).					

Assessment of evidence
Organism: *Mycobacterium gordonae.* Clinical setting: chest medicine, France. Transmission mode: direct (ingestion of water). Source: refrigerated water fountain (supported by fact that none of the cases had bronchoscopy examination before the smear-positive specimen and that sputum induction was performed without rinsing their mouth with water, using single-use disposable equipment, and all lab reagents were negative). Control measures: rubber pipes in water fountains changed -no further cases in following 6 months. Genetic relatedness: “Pulsed field gel electrophoresis showed an identical pattern for strains isolated from the four patients and for strain isolated from the refrigerated water of the chest unit. Strains from other sources were unique and differed from the epidemic strain.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Brulet A, Nicolle M, Giard M et al. Fatal nosocomial *Legionella pneumophila* infection due to exposure to contaminated water from a washbasin in a hematology unit.	Case report	**Level 3**	This paper describes a case of fatal nosocomial legionellosis after documented washbasin water contamination in a hospital in France.	Molecular typing results (PFGE) between patient isolates and *L. pneumophila* isolated from water samples were compared.	Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infect Control Hosp Epidemiol 2008; 29:1091.					

Assessment of evidence

Comparison of patient isolate (2 cases) and water samples by PFGE. High levels of L. pneumophila serogroup 5 and serogroup 1 were detected in the potable hot water of every shower sample, ranging from 350 to 165,000 colony-forming units (cfu)/L. The unit's wing inlet and outlet (ie, the places from where the water starts and returns, respectively) were also contaminated (900 and 3,400 cfu/L, respectively). Tap water in patient room had 1,500 cfu/L.

Organism: *Legionella pneumophila* serogroup 5.

Setting: haemato-oncology unit, France.

Transmission mode: (unclear, possibly direct ingestion and/or aspiration).

Source: water system.

Control measures: Flexible shower hoses removed. Hot water reheated to 58'C and hyperchlorinated twice a week, monthly Legionella screening instituted, filters on all outlets. Taps changed to simple mixer valves that did not have volumes of standing water. The hyperchlorination and water reheating alone were unsuccessful. No organisms found in water once filters were installed.

Genetic relatedness: "*L. pneumophila* serogroup 5 isolates from the cold wash-basin water matched the patient's isolate and the isolate from an earlier case by genotyping with pulsed-field gel electrophoresis (PFGE)"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Durojaiye OC, Carbarns N, Murray S et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 78 (2011) 152–159.	Outbreak report	**Level 3**	This paper reports a nosocomial outbreak of MDR strains of *P. aeruginosa* among 10 patients in a renovated adult ICU in a hospital in the United Kingdom.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

All the 10 samples collected from the taps, water outlets and water supply to the sinks in the unit grew 300 cfu/100 mL of multidrug-resistant *P. aeruginosa*.

Organism: *Pseudomonas aeruginosa.*

Clinical setting: ICU, Wales.

Transmission mode: unknown. Possible patient-patient indirect transmission as well as environmental.

Source: contaminated taps (newly installed sensor taps).

Control measures: All sinks in the unit decommissioned and portable sinks using bottled water were arranged. All sensor taps in the unit were replaced with conventional non-sensor mixer taps – repeated sampling showed no further contamination and no more cases. Monthly water sampling continued.

Limitations: No details of time from admission to positive test.

Assessment of evidence
Genetic relatedness: Isolates from the water samples showed three different strains of *P. aeruginosa*, two of which matched the strains isolated from patients (variable number tandem repeat).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Engelhart S, Krizek L, Glasmacher A et al. *Pseudomonas aeruginosa* outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment. Journal of Hospital Infection (2002) 52: 93-98	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *P. aeruginosa* associated with contamination of surface cleaning equipment in a hematology-oncology unit in a hospital in Germany.	Molecular typing (PFGE) result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 6 Cases identified as nosocomial infection as per CDC guidance. *P. aeruginosa* was isolated from six of 133 (4.5%) `sanitary equipment' samples (taps, 2; washbasin drains, 2; shower water, 1; tap water, 1), and from eight of 40 (20.0%) `surface cleaning equipment' samples (cleaning cloths, 4; mops, 2; cleaning solutions, 2) from both cleaning trolleys. None of 36 samples from dry environmental surfaces yielded *P. aeruginosa.* All water samples were pre-flush.

Assessment of evidence
The environmental isolates (11) belonged to seven different PFGE types, two of which (i.e., PFGE types A and C) were identical with the PFGE types of the clinical isolates. Organism: *Pseudomonas aeruginosa.* Clinical setting: haemato-oncology unit, Germany. Transmission mode: unconfirmed (cleaning equipment may have been a vehicle for environmental transmission in the unit). Source: sinks/taps/showers as reservoirs (and potential source) but cannot rule out patient as source for transmission. Control measures: Filters fitted to showers and taps, regular disinfection of sink drains using peroxide disinfectant, re-adoption of disinfectants rather than detergents for patients immediate environment. One further case in the following 6 month period. Genetic relatedness: “Genotypic analysis by pulsed-field gel electrophoresis showed different patterns for all (N = 6) of the patient isolates, however, two of the patient isolates were identical in comparison with environmental isolates from cleaning equipment (four samples) and sanitary equipment (one sample).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Carbonne A, Brossier F, Arnaud I et al. Outbreak of Nontuberculous Mycobacterial Subcutaneous Infections Related to Multiple	Outbreak report	**Level 3**	This paper describes an outbreak of severe subcutaneous infection due to NTM following mesotherapy in a clinic in France.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to	Number of positive environmental and clinical isolates. Odds ratios. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Mesotherapy Injections. Journal of Clinical Microbiology 47(6); 1961-4, 2009.				establish a link of infection.	
Assessment of evidence					
A total of 16 cases (12 certain, 4 probable) of NTM skin infection. Tap water samples from the room where mesotherapy had been performed showed 2,400 CFU/litre of *M. chelonae.* Organism: *Mycobacterium chelonae.* Setting: private mesotherapy clinic, France. Transmission route: direct (injection). Source: tap water (via inappropriately decontaminated injector device). Control measures: not described. Genetic relatedness: "The PFGE patterns of *M. chelonae* isolates from 11 mesotherapy patients and from tap water in the medical examination room showed 100% similarity indexes by Dice analyses and were considered indistinguishable"					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chroneou A, Zimmerman SK, Cook S et al.	Outbreak report	**Level 3**	This paper describes a pseudo-outbreak of *M. chelonae* in bronchoalveolar	Molecular typing result (REP-PCR) between patient strains and	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Molecular typing of *Mycobacterium chelonae* isolates from a pseudo-outbreak involving an automated bronchoscope washer. Infect Control Hosp Epidemiol 2008; 29:1088-90			lavage fluid from 9 patients traced to a contaminated automated bronchoscope washer in a medical center in the United States of America.	environmental strain isolated from environmental/water samples were compared to establish a link of infection.	

Assessment of evidence

A total of 9 patients with positive bronchoalveolar lavage fluid speimens. None had symptoms or infection (Pseudo-outbreak). Incoming water supply and a bowl drain from the automated washer matched the 9 patient isolates (>90% similarity with REP-PCR).

Organism: *Mycobacterium chelonae.*

Clinical setting: bronchoscopy, United States of America.

Transmission mode: from water supply via contaminated automated washer.

Control measures: automated washer removed from service, and new one purchased. Responsibility for changing filters assigned to biomedical staff and changed every month rather than twice per year. Authors state this eliminated the strain but not clear how this was known.

Genetic relatedness: “REP-PCR findings demonstrated a greater than 90% similarity among the isolates associated with the 9 patients…, the 2 environmental isolates recovered from the drain bowl…, and the isolate recovered from the incoming water supply/”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Vijayaraghavan R, Chabdrashekhar R, Sujatha A et al. Hospital outbreak of atypical mycobacterial infection of port sites after laparoscopic surgery. Journal of Hospital Infection (2006) 64, 344-347	Outbreak report	**Level 3**	This paper describes an outbreak of atypical mycobacterial infections (AMI) in 35 patients following laparoscopy over a six-week period in a hospital in India.	N/A	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

A total of 35 patients infected out of 156 subjected to laparoscopy over a 6-month period, all surgery by same team. Water samples taken from the scrub area, water used for the manual cleaning of instruments, and rinsing water (obtained from the hospital water supply system, boiled and cooled, and subsequently stored in autoclaved glass bottles) used for rinsing instruments taken out of the chemical disinfectant trays. Swabs taken from chemical disinfectant and prepping solutions, vapour sterilisation chambers, OR tables, theatre lights, walls/floors of OR, reusable sleeves of laparoscopy instruments, suture mesh samples, valves of CO2 cylinders/insufflator. Scrapings taken from biofilm layers from the bottom of chemical disinfectant trays, the water supply pipes and water baths for boiling rinsing water.

The chemically disinfected laparoscopy instruments were rinsed with the boiled-cooled, autoclaved water prior to the operative procedure; this prepared water was contaminated with NTM (unclear how it because contaminated as NTM are likely to be killed by boiling temperatures). The mains water supply was negative. Organisms thriving within biofilm in the bottom of the disinfectant trays (which were positive) likely also re-contaminated the freshly prepared disinfectant.

Assessment of evidence
Organism: *Mycobacterium chelonae.* Clinical setting: OR (laparoscopy), India. Transmission mode: indirect. Source: contaminated water-based equipment. Control measures: Contaminated water samples and glutaraldehyde solutions were re-autoclaved and placed in formaldehyde vapour sterilization chambers overnight; AFB were identified in all samples. Since the organism survived autoclaving, formaldehyde vapour sterilization and chemical disinfection with glutaraldehyde, ethylene gas oxide sterilization was used; following this, no viable organisms were identifiable. Limitations: While it is stated that 'similar isolates' [to the patient ones] were recovered from the environmental samples, typing was not conducted to confirm an exact match. However, the epi evidence is strong enough to implicate the contaminated equipment as the source.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gebo KA, Srinivasan A, Perl TM et al. Pseudo-outbreak of *Mycobacterium fortuitum* on a Human Immunodeficiency Virus Ward: Transient Respiratory Tract Colonization from a	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *M. fortuitum* recovered from the respiratory tract of hospitalized patients on an HIV ward in a tertiary hospital in the United States.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Contaminated Ice Machine. Clinical Infectious Diseases 2002; 35:32–8					
Assessment of evidence					
40 patient's respiratory samples tested positive – no infection (colonisation, not a pseudo-outbreak). Water and ice samples taken from 4 different floors in the hospital and from 6 other buildings (cold water supply on entry to ice machine, from the filter, reservoir etc), taps in sputum induction room and patient rooms, mains supply. Water samples from ice machine tested positive. Mains water negative. Case-control added evidence to the ice machine being the likely source of colonisation for these patients. Organism: *Mycobacterium fortuitum.* Clinical setting: HIV ward, United States of America. Transmission mode: direct (ingestion of ice). Source: contaminated ice machine. Outbreak report: filters added to ice machines – no further cases detected following this. Genetic relatedness: "Environmental investigation demonstrated that the *M. fortuitum* isolated from patients was identical to the ice machine isolates by pulsed-field gel electrophoresis." Limitations: Although there are no details given regarding date of positivity since admission (to rule out acquisition outwith the care setting), the epidemiological evidence supports the ice machine as the likely source.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lowe C, Willey B, O'Shaughnessy A et al. Outbreak of Extended-Spectrum β-Lactamase–producing *Klebsiella oxytoca* infections associated with contaminated handwashing sinks. Emerging infectious diseases 18.8 (2012): 1242.	Outbreak investigation	**Level 3**	This paper describes a retrospective review and investigation of a *K. oxytoca* outbreak in an ICU of an acute tertiary care hospital in Canada.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

Among 27 patients, 24 patients had 25 hospital-acquired infections (9 UTI, 4 of them bacteremic; 8 asymptomatic bacteriurias; 4 soft tissue infections, 1 of them bacteremic; 3 primary bacteraemia's; and 1 pneumonia with bacteraemia).

In 11 cases, clinical cultures were preceded by identified rectal colonization; median time to first identification of a clinical isolate after recognition of colonization was 10 days (mean 12.5 days, range 1–31 days). Isolates were considered hospital acquired if the first specimen (clinical culture or rectal swab) yielding resistant *K. oxytoca* was obtained >3 days after the admission date or if the specimen was obtained <3 days after admission in a patient who had been hospitalized at the outbreak hospital within the previous 3 months.

Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Assessment of evidence
Organism: Extended-spectrum b-lactamase-producing *Klebsiella oxytoca.*
Clinical setting: ICU, Canada.
Transmission mode: unconfirmed.
Source: sink drains as reservoir.
Control measures: Although intended only for hand hygiene, foot-operated sinks were also used for disposal of fluids, including body fluids. When sinks were identified as a potential reservoir, use of the sinks for hand hygiene only was reinforced. Attempts were made to reduce or eradicate K. oxytoca contamination by cleaning sinks and leaving them unused for 48 hours with disinfectant standing in traps. When this process failed, routine daily sink disinfection was initiated; sink surfaces, including taps, rims of sinks, and basins, were cleaned with a 1:16 dilution of Virox and ≈250 mL of the diluted solution was poured down the drain. Neither this daily cleaning, nor month-long trials of cleaning with bleach and with a foaming hydrogen peroxide product, resulted in reduced sink colonization rates. Sink cleaning was increased to 2×/ day in late 2007 and 3×/day in August 2008 but compliance was poor. The average rate of sink contamination during the outbreak period was 16.4% (149/910). After implementation of 3×/day cleaning/disinfection of sinks (October–December 2008), the sink colonization rate decreased to 3.9% (3/77) during the quarter; the rate increased to 16.7% (71/424) the following quarter (January–March, 2009), when adherence to routine sink cleaning was noted to have decreased. During February–June 2010, all drains were changed, eliminating the connection with the overflow drain; the overflow holes were decommissioned; the strainers in the sink basin were replaced by strainers containing a larger number of smaller holes to reduce backsplash; and sink traps were replaced. These modifications were temporally associated with persistent declines in the rate of clinical infections.
Genetic relatedness: Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Davis RJ, Jensen SO, Van Hal S et al. Whole Genome Sequencing in Real-Time Investigation and Management of a *Pseudomonas aeruginosa* Outbreak on a Neonatal Intensive Care Unit. Infect. Control Hosp. Epidemiol. 2015;36(9):1058–1064	Outbreak report	**Level 3**	This paper describes the use of whole genome sequencing (WGS) to investigate the likely origin of an outbreak of *P. aeruginosa* in a neonatal unit in a hospital in Australia.	Molecular typing result (WGS) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

P. aeruginosa was isolated from 8 sinks, including 4 sink drains and 5 sink splashbacks; genetic match to 6 patients. There were 6 patient colonisations and 1 infection.

The diversity in the environmental isolates indicated a large diverse bioburden with the NICU. As neonates do not bring in community acquisition, it is probable that environmental reservoirs were responsible for the colonisations (6 patients WGS was identical).

Organism: *Pseudomonas aeruginosa.*

Clinical setting: NICU, Australia.

Transmission mode: unconfirmed.

Assessment of evidence
Source: sink drains as reservoir. Control measures: Sinks replaced along with splashbacks that were in one piece and easier to clean. In the following 6 months, only 2 infants were found to be colonised with *P. aeruginosa*, and one of these had an organism that differed phenotypically from the outbreak isolate. Prior to sink replacement, aerators were changed on all taps, sinks cleaned daily with bleach and weekly screening of all babies was initiated. Limitation: no mention of the water itself being tested at any point.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chapuis A, Amoureux L, Bador J et al. Outbreak of Extended-Spectrum Beta-Lactamase Producing *Enterobacter cloacae* with High MICs of Quaternary Ammonium Compounds in a Hematology Ward Associated with Contaminated Sinks.	Outbreak report	**Level 3**	This paper describes an investigation of an outbreak of extended-spectrum beta-lactamase (ESBL) producing Enterobacter cloacae in the hematology ward of a University Hospital in France.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Front. Microbiol. 7:1070, 2016.					

Assessment of evidence

A total of 43 patients (10 infected (urine, wound, blood) and 33 colonised).

Positive samples in patient shower drains, sink drains; 6 were identical to patient isolates. Biofilm was visible in drains and there were no positive water samples.

Organism: *Enterobacter cloacae.*

Clinical setting: haematology unit, France.

Transmission mode: unconfirmed, possible direct contact with water from drain/spray/splash as correlation between contaminated sink and subsequent acquisition in same room

Source: sink/shower drains as reservoir, however patient seeding environment not considered

Control measures: Prior to outbreak, QAC-based disinfectant poured daily into all sinks. Following environmental investigation, a bleach-based disinfection programme was implemented. Biofilm was removed on one occasion from all drains (sinks, showers) but no details given as to method (sinks had to be completely dismantled) – this did not completely eradicate the biofilm as more grew. Possible that below-concentration disinfection (as no contact time with sides of pipes) influenced the decreased susceptibility to QAC disinfectant.

Genetic relatedness: “Among the 17 environmental ESBL-producing E. cloacae there were 9 distinct pulsotypes and 7 STs. Among the 9 pulsotypes, 6 were identical to those of patients isolates.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bousquet A, Van der Mee-Marquet N, Dubost C et al. Outbreak of CTX-M-15–producing Enterobacter cloacae associated with therapeutic beds and syphons in an intensive care unit. American Journal of Infection Control 45 (2017) 1160-4.	Outbreak report	**Level 3**	This paper describes the investigation of a 4-month outbreak of extended-spectrum β-lactamase-producing *E. cloacae* between July and November 2013 in an ICU in military teaching hospital in France.	Molecular typing result (RAPD) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

Total of 18 ICU patients affected (8 infected, 10 colonised).

Sinks and drains tested positive.

Single sink in patient room used for both handwashing and disposal of body fluids, and distance between sink and patient was <1 metre. Hand hygiene with water still being preferred over alcohol gel even when not indicated.

Organism: ESBL-*Enterobacter cloacae.*

Clinical setting: ICU, France.

Transmission mode: unconfirmed.

Source: sink drains as reservoir (patients likely the original source).

Assessment of evidence
Control measures: Replacement of all sinks in rooms, and of contaminated mattresses (patients decanted for this). Genetic relatedness: Molecular typing of the ESBL-ECL isolates using RAPD revealed that all clinical and environmental isolates except 1 had the same RAPD profile and therefore were considered likely clonally related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrobial Resistance and Infection Control (2017) 6:24	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a teaching hospital in Belgium.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.
Assessment of evidence					
A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission).					

Assessment of evidence
Sink drain in this room was positive, as was every other isolation room on the unit. Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc). Organism: Enterobacteriaceae. Clinical setting: ICU, Belgium. Transmission mode: unconfirmed. Source: sink drain as reservoir (and likely source for some patients). Control measures: daily disinfection of the sinks with Incidin® Plus (a glucoprotamine product) was implemented; sinks were dedicated to 'clean work' (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere. Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kossow A, Kampmeier S, Willems S et al. Control of Multidrug-Resistant *Pseudomonas aeruginosa* in Allogeneic	Prospective outbreak investigation	**Level 3**	This paper describes the study of microbiological surveillance data on *MDRPa* for 3 years during the reconstruction of a Bone marrow	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hematopoietic Stem Cell Transplant Recipients by a Novel Bundle Including Remodeling of Sanitary and Water Supply Systems. Clinical Infectious Diseases, 65(6); 935-942, 2017			transplantation center in Germany.	establish a link of infection.	

Assessment of evidence

The number of nosocomially-infected patients decreased from 31 in 2012-13 (9.17%) to 3 (1.68%) in 2014 ($p<0.001$).

In 2012-13, 18.94% of toilet samples were positive, 8.11% of shower samples were positive. This decreased to 6.13% of toilets and 2.96% showers in 2014 (both statistically significant reductions). During follow up, 4% of toilets and 5.59% of showers were positive. Sinks tested positive in 0.93% samples in 2012-13 and in zero samples in 2014.

Patients screened on admission and weekly thereafter. WGS indicated a close relationship between patient and environmental isolates however unable to determine exact transmission pathways.

Organism: Multi-drug resistant *Pseudomonas aeruginosa.*

Clinical setting: haematopoietic stem cell transplant unit, Germany.

Transmission mode: unconfirmed.

Assessment of evidence
Source: Shower drains and toilets as potential reservoirs, unable to determine exact modes of transmission however this study provides evidence that patients acquired infection likely from an environmental source. Control measures: New shower drains installed (easy to clean/disinfect) with covers (disinfected weekly) to prevent removal by patients. Shower heads and taps fitted with point of use filters. Biorec disinfection units installed underneath all sinks (these use UV light, vibration (50-200 Hz), temperature (85'C) and have an antibacterial coating to prevent biofilm formation. Toilets replaced with rimless toilets and an automatic disinfectant flush (0.5% glucoprotamin). Limitations: some patients not screened weekly due to their clinical situation. Culture method may not have maximised growth of admission screening samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard A M et al. Investigation of an Enterobacter hormaechei OXA-436 carbapenemase outbreak: when everything goes down the drain. Infection Prevention in Practice, 4, 2022	Outbreak report	**Level 3**	Environmental screening included shower drains, floor drains below sinks, sinks and bedpan boilers/ instrument washers. Water testing not conducted.	Whole genome sequencing of patient and environmental isolates.	Positive sample in 2 patient bathroom shower drains. The 2 drain isolates were closely related (between 0 and 11 SNPs) to the 7 patient blaOXA-436 - positive isolates.

Assessment of evidence
Both shower drains tended to become partly blocked resulting in regular overflow while patients were showering. No overlap of patients in time on the unit. Organism: *Enterobacter hormaechei* (CPE). Clinical setting: cardiology department, Denmark. Transmission mode: unconfirmed. Source: shower drains identified as reservoir/ongoing source. Control measures: Drains fixed to prevent overflow. The floor grate and traps of showers were changed and fixed to the drain, so that they could not be removed and contaminate other rooms. Shower heads were relocated so patients didn't have to stand on top of the drain while showering and the water jet didn't hit the drain directly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jaubert J, Mougari F, Picot S P, et al. A case of postoperative breast infection by *Mycobacterium fortuitum*. American Journal of Infection Control. 2015 43: 406-408.	Case report	**Level 3**	The aim of this study was to investigate a single case of postoperative breast infection.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence
Chlorine and all other control measures for the hospital water supply were within normal ranges in the 6 months prior to the infection. Rep-PCR match between the patient and water samples taken from taps in multiple locations including outwith the gynaecology department. Organism: *Mycobacterium fortuitum*. Transmission mode: unconfirmed, likely direct. Clinical setting: surgical patient ward, France. Source: hospital water supply. Control measures: Staff education, use of sterile water for wound cleaning, avoidance of showers postoperatively. Unclear if point of use filters were installed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ashraf M S, Swinker M, Augustino K L, et al. Outbreak of *Mycobacterium mucogenicum* bloodstream infections among patients with sickle cell disease in an outpatient setting.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 4 cases of M. mucogenicum bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection Control and Hospital Epidemiology. 2012 35 (11): 1132-1136.					

Assessment of evidence

All 4 patients had ports for intravenous medication. Tap water from 2 taps grew *Mycobacterium* species including *M. gordonae*, *M. szulgai*, *M, mucogenicum*, *M. kansasii*). Rep-PCR typing; isolate from tap water from tap with an aerator matched the patient ATCC strains for *M. mucogenicum* with more than 93% similarity.

Organism: *Mycobacterium mucogenicum.*

Transmission mode: intravenous flushes performed on the sink counter from a saline bag that was hanging throughout the day over the sink, instead of using prefilled saline flushes; this is a non-sterile field. The same sink also used for handwashing.

Clinical setting: outpatient haematology clinic, United States of America.

Source: hospital water supply.

Control measures: All aerators removed from taps, staff educated on aseptic procedures away from sinks and need for prefilled saline flushes. No mention of chlorination/other control methods of the actual water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum*	Molecular typing result between patient strains and environmental strain isolated from	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium phocaicum* associated with an outbreak of bacteremias at a Texas hospital. Applied Environmental Microbiology. 2008. Apr; 74(8): 2480-2487.			bloodstream infection.	environmental/water samples were compared to establish a link of infection.	
Assessment of evidence					
Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present. Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework. Organism: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* Transmission mode: unconfirmed but all patients had CVCs.					

Assessment of evidence
Clinical setting: oncology department, United States of America. Source: hospital water supply. Control measures: not described.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cadot L., Bruguière H., Jumas-Bilak E., et al. Extended spectrum beta-lactamase-producing *Klebsiella pneumonia* outbreak reveals incubators as pathogen reservoir in neonatal care centre. European Journal of paediatrics, 178: 505-513, 2019.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a beta-lactamase-producing *Klebsiella pneumonia* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumonia* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).
Assessment of evidence					
Setting: neonatal ICU, France. Organism: ESBL *Klebsiella pneumonia*.					

Assessment of evidence
Transmission route: not confirmed, however multiple environmental contamination identified and incubators and incubator mattresses found to be contaminated. Source: unconfirmed, but incubator mattresses found to be a reservoir, supported by steam water. Provides evidence that mattresses and incubators can remain contaminated and may pose a reservoir for infection even after decontamination. Steam cleaning may not be suitable for mattresses as residual moisture can support grown of organisms.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Wilson G, Black J, et al. *Cupriavidus* spp. and other waterborne organisms in healthcare water systems across the UK. J Hosp Infect. 2022;123:80-86. doi:10.1016/j.jhin.2022.02.003	Surveillance study	**Level 3**	The aim of this study was to determine the presence of *Cupriavidus* spp. and other waterborne organisms in healthcare water systems across the UK.	N/A	Sample location (geographically and within healthcare water system), number of positive outlet samples, presence of gram-negative organisms.
Assessment of evidence					
In this study *Cupriavidus* spp isolates were identified from multiple outlets and one expansion vessel from four different hospital in the UK. In total, 10 hospitals provided system-wide pre-flush samples (sample sites included water storage tanks, expansion vessels and outlets (a maximum of 15 samples per hospital) and also a range of gram-negative organisms were found within those samples.					

Assessment of evidence
Setting: 10 healthcare facilities across the UK. Organism: *Cupriavidus* spp. – also range of gram-negative bacteria found including *Pseudomonas* spp., *Sphingomonas* spp. and *Brevunidimonas* spp. Source: multiple outlets and one expansion vessel. No link was made between environmental and clinical isolates and therefore it is not clear what the clinical risk is of these organisms.

Question 2: How do healthcare water system-associated organisms survive in the environment?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Takajo I, Iwao C, Aratake M, et al. Pseudo-outbreak of *Mycobacterium paragordonae* in a hospital: possible role of the aerator/rectifier connected to the faucet of the water supply system. Journal of Hospital Infection 2020; 104: 545-551.	Outbreak investigation	**Level 3**	An increase in the rate of *M. paragordonae* positive clinical samples was observed following hospital renovation; aerators/rectifiers were fitted to most taps of the water supply system in the hospital.	N/A	Positive patient samples. Positive environmental sampling. Molecular typing.
Assessment of evidence					
No patients were infected; positive samples were obtained from 15 patients however it was not possible to determine if patients were colonised or if the clinical samples were contaminated (i.e. patient may have gargled tap water prior to sputum collection, and the bowel prep was mixed with tap water taken from aerator-fitted taps). Additional isolates were from gastrointestinal samples (3 via intestinal lavage via colonoscopy, 1 stool sample). Environmental sampling identified *M. paragordonae* from tap water from taps with aerators, from tap water from taps without aerators, and from endoscope-cleaning and disinfecting devices.					

Assessment of evidence
Aerators were tested separately; small particles i.e. plastic pieces were trapped due to the mesh structure possibly indicative of biofilm; samples were positive. This Japanese study serves as evidence that NTM can survive in hospital water systems even when ongoing chemical treatment is within recommended limits. Rates of positive clinical isolates following the control measures were statistically significantly lower than pre-control measures ((19% vs. 3.1%, P=0.026). Organism: *Mycobacterium paragordonae.* Transmission mode: contaminated water systems. Clinical setting: multiple wards. Source: Tap water from taps with aerators, from tap water from taps without aerators, and from endoscope-cleaning and disinfecting devices. Aerators were tested separately; small particles, i.e. plastic pieces, were trapped due to the mesh structure possibly indicative of biofilm – these tested positive. Control measures: Patients (particularly immunocompromised) instructed not to drink tap water unless it was first boiled, not to gargle with tap water prior to providing sputum samples. Bottled water was used for colon cleaning prior to colonosocopy. Aerators were removed from taps. Limitations: Although rates of positive clinical samples were lower following control measures, water testing was not conducted to determine the level of contamination. Limited information regarding specific water testing (i.e. if it was pre or post flush), and actions related to endoscope decontamination. No follow-up water testing was conducted to determine if the measures were successful.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Decraene V, Phan HTT, George R, et al. A large, refractory nosocomial outbreak of *klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* demonstrates carbapenemase gene outbreaks involving sink sites require novel approaches to infection control. Antimicrobial Agents and Chemotherapy 2018; 62 (12).	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	23 CRE-colonised heart patients, 2 infections (UTI, SSI).	Positive samples: 850 total samples taken from sink/drain/shower/ bath sites, 18 from toilets, hoppers or sluices, 33 from high-touch sites (keyboards, door handles, sponges). 85 samples positive, including shower drains, sink taps, sink drain tailpieces, sink drain strainers, sink trap water, toilet bowls.
Assessment of evidence					
Outbreak report, molecular typing confirmed link between patient cases and environment. Source not identified but sink drains identified as reservoirs, likely biofilm formation.					

Assessment of evidence
The authors state: “Current guidelines do not address the control of large persistent outbreaks or provide advice on the sampling and management of environmental reservoirs, and there is limited evidence in support of any given measure.” Organism: *Klebsiella pneumoniae* Carbapenemase-Producing *Escherichia coli.* (Carbapenem-resistant Enterobacteriaceae (CRE)) Transmission mode: contaminated water systems. Clinical setting: Heart Centre. Manchester. Source: not confirmed, sink drain identified as reservoirs, likely biofilm formation. Control measures: Sink trap replacement for colonised sinks, horizontal pipework cleaning with a brush to remove biofilm. Replacement of the plumbing infrastructure back to the central drainage stacks. Replaceable sink plughole devices designed to prevent water aerosolisation in the sink U-bend and to limit biofilm formation (HygieneSiphon; Aquafree) were installed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	N/A	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of hospital infection. 2016 Sep 1;94(1):2-7.					

Assessment of evidence

Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit.

Pseudomonas aeruginosa has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: contaminated environment; however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission.

Clinical setting: ICU – burn unit.

Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa.

Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily.

Assessment of evidence
Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bédard E, Lévesque S, Martin P, et al. Energy conservation and the promotion of *Legionella pneumophila* growth: the probable role of heat exchangers in a nosocomial outbreak. Infection control & hospital epidemiology. 2016 Dec;37(12):1475-80.	Outbreak investigation	**Level 3**	The role of heat exchangers as potential sources of contamination for *L. pneumophila.*	Sequence-Based Typing (SBT) results of *Legionella pneumophila* outbreak strain vs *L. pneumophila* isolated from environmental samples.	Number of samples, number of positive samples, colony forming units/L (CFU/L), Pulsed-field gel electrophoresis (PFGE) patterns and sequence-based typing (SBT) types.

Assessment of evidence
The authors state that although an infectious dose has not been determined, several countries have established action levels between 1,000 and 10,000 colony-forming units (CFU)/L, and a concentration higher than 10,000 CFU/L requires immediate corrective actions. “A copper-silver ionization treatment was present on both hot water systems at the time of the outbreak”.

Assessment of evidence
Water heater exchangers are installed to increased energy efficiency; however these can provide optimal environmental conditions for *L. pneumophila*. The researchers found that "temperatures within the heat exchangers ranged from 9C to 46C" and they reported that "prolonged stagnation was observed during the night". This study derived from Canada provides evidence on the impact or association between heat exchangers and water contamination with *L. pneumophila* showing that temperature fluctuations/increases can favour *L. pneumophila* growth.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster et al. Centers for Disease Control and Prevention (2003) Guidelines for environmental IC in healthcare facilities Last updated: July 2019	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This international guideline from the CDC (US based) is a compilation of recommendations for the prevention and control of infectious diseases that are associated with healthcare environments. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The following sections are relevant for the research question regarding survival of waterborne organisms in the environment:					

Assessment of evidence
"Some NTM species (e.g., *Mycobacterium xenopi*) can survive in water at 113°F (45°C), and can be isolated from hot water taps, which can pose a problem for hospitals that lower the temperature of their hot water systems. Other NTM (e.g., *Mycobacterium kansasii, M. gordonae, M. fortuitum, and M. chelonae*) cannot tolerate high temperatures and are associated more often with cold water lines and taps. NTM have a high resistance to chlorine; they can tolerate free chlorine concentrations of 0.05–0.2 mg/L (0.05–0.2 ppm) found at the tap. They are 20–100 times more resistant to chlorine compared with coliforms; slow-growing strains of NTM (e.g., *Mycobacterium avium and M. kanasii*) appear to be more resistant to chorine inactivation compared to fast-growing NTM. Slow-growing NTM species have also demonstrated some resistance to formaldehyde and glutaraldehyde, which has posed problems for reuse of hemodialyzers. The ability of NTM to form biofilms at fluid-surface interfaces (e.g., interior surfaces of water pipes) contributes to the organisms' resistance to chemical inactivation and provides a microenvironment for growth and proliferation. *Pseudomonas* spp. and other gram-negative, non-fermentative bacteria have minimal nutritional requirements (i.e., these organisms can grow in distilled water) and can tolerate a variety of physical conditions. These attributes are critical to the success of these organisms as health-care associated pathogens. Colonized patients also can serve as a source of contamination, particularly for moist environments of medical equipment (e.g., ventilators) – Patients and health-care workers contribute significantly to the environmental contamination of surfaces and equipment with Acinetobacter spp. and Enterobacter spp., especially in intensive care areas, because of the nature of the medical equipment (e.g., ventilators) and the moisture associated with this equipment. This suggests that survival of waterborne pathogens in water systems is also promoted by having a patient reservoir, allowing re-seeding of environmental sources – relevant for 'sources' research question. Water borne microorganisms can survive and persist in biofilms. Colonization of the reservoirs and water lines (if proper cleaning is not carried out). About Legionella: The bacteria multiply within single-cell protozoa in the environment and within alveolar macrophages in humans. presence of certain free-living aquatic amoebae that can support intracellular growth of legionellae

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Falkinham, J.O. Surrounded by mycobacteria: nontuberculous mycobacteria in the human environment. Applied Microbiology, 2008.	Non-systematic literature review (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This non-systematic literature review on NTMs summarises their pathogenicity and how they survive, persist and grow in drinking water distribution systems. The following sections are relevant for this research question on survival of waterborne organisms:

“NTMs are oligotrophs and able to grow on a variety of organic compounds including some found in water and soil. The major determinant of NTM ecology and epidemiology is the presence of a lipid-rich outer membrane. The outer membrane’s long chain mycolic acids contribute to the hydrophobicity, impermeability, and slow growth of both slowly and rapidly growing mycobacteria. Those features, in turn, lead to the preferential attachment to surfaces and resistance to disinfectants and antibiotics. “

“Cell surface hydrophobicity is a major determinant of the presence of NTM in drinking water distribution systems and household plumbing. Both rapidly and slowly growing NTM colonize drinking water systems via their attachment to particulates that enter the treatment plant and to the formation of biofilms in the distribution system. In a number of instances (i.e. drinking water distribution systems), human intervention (e.g. disinfection) contributes to selection for proliferation and persistence of NTM. Disinfection kills off competitors, consequently selecting for the oligotrophic NTM that can grow on the low levels of nutrient. Biofilm formation results in increased disinfectant resistance of *M. avium* and *M. intracellulare* and *Mycobacterium* phlei cells. All those factors likely contributed to the increase in *M. avium* numbers in drinking water distribution systems, the further the distance from the treatment plant. Further, it is likely that both rapidly and slowly growing NTM can survive in hot water heaters and hot water pipes because they survive temperatures of

Assessment of evidence
between 50 and 55 C. Unless hot water heater temperatures are maintained above 50 C, NTM may proliferate in household hot waters. Effective chlorine disinfection for *M. avium* and *M. intracellulare* requires exposures of greater than 1 mg L-1 for longer than 2 hours." "Water filtration has been shown to reduce NTM numbers, but without changing the filter regularly (<3 weeks), the filter can become a source. Filters provide an ideal habitat for NTM; they attach and can grow on the filter material on the organic compounds collected and concentrated on the filters, even if the filter is impregnated with an antimicrobial agent. NTM numbers in drinking water distribution systems are higher in systems with higher turbidity, likely because of the hydrophobicity-driven adherence of NTM to soil particulates. Thus, reduction of water turbidity would be expected to reduce NTM numbers in both water treatment systems and households." "Intracellular growth of M. avium strains in either macrophages or amoebae results in increased virulence and antibiotic resistance."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Heireman L, Hamerlinck H, Vandendriessche S, et al. Toilet drain water as a potential source of hospital room-to-room transmission of carbapenemase-producing *Klebsiella pneumoniae*.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* outbreak (including finding the source) and to determine the impact of infection prevention and control measures	Whole genome sequencing results of the *Klebsiella pneumoniae* patient strains vs *K. pneumoniae* isolated from environmental samples. Comparison was also made between daily disinfection type (bleach vs acetic acid) of toilets	Number of environmental samples, number of positive samples, colony forming units/L (CFU/L), wgMLST analysis.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection 2020; 106: 232-239.				positive for *K. pneumoniae*.	

Assessment of evidence

OXA-48-producing *Klebsiella pneumoniae* was detected in toilet water in four out of six rooms and drain water between two rooms during an outbreak of *K. pneumonia* in a Belgium hospital. The strain persisted in two out of six rooms after two months of daily disinfection with bleach. All outbreak isolates belonged to sequence type (ST) 15 and showed isogenicity (<15 allele differences). The common strain found in all outbreak isolates suggests that the strain may have spread between rooms by drain water - during the outbreak period, several drain pipe obstructions were reported in the burn centre resulting in water reflux to the different toilets. Every room has its own healthcare supplies as well as cleaning material and toilet brush (which is replaced after patient discharge).

Organism: OXA-48-producing *Klebsiella pneumonia.*

Transmission mode: contaminated water systems.

Clinical setting: burn unit of University hospital.

Source: toilet drain water.

Control measures: bleach added to daily toilet cleaning regime, sampling of toilet water (even though did not completely prevent the presence of carbapenemase-producing *K. pneumonia*. One week after the last application of acetic acid, the water of all three toilets screened positive for carbapenemase-producing *K. pneumoniae*. By contrast, all the toilets disinfected with bleach tested negative for carbapenemase-producing *K. pneumoniae*. Neither disinfectant prevented recolonization after discontinuation - the effect of disinfectants is only temporary since biofilms are not disrupted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guyot A, Turton JF, Garner D. Outbreak of *Stenotrophomonas maltophilia* on an intensive care unit. Journal of Hospital Infection. 2013 Dec 1;85(4):303-7	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Stenotrophomonas maltophilia* outbreak (including finding the source) and to highlight the risk from contaminated devices for supply of drinking water.	Typing results of the *Stenotrophomonas maltophilia* patient strains vs *S. maltophilia* isolated from environmental/water samples.	Incidence of outbreak strains, PFGE profiles from patient's vs water strains

Assessment of evidence

Typing was performed. A tap (in ICU kitchen) that had a water-cooler for drinking water was the source of *S. maltophilia* on ICU in a UK hospital, because a carbon filter had not only removed the disinfectant chlorine dioxide before the water-cooler, but had also accumulated organics, which serve as nutrients for bacteria facilitating the growth of biofilms on downstream tubing.

On review of nursing practices, the nurses reported that they had discarded the water from tooth-brushing or patients' drinking water into handwash basins. They revealed also that they had used cooled water from the ICU kitchen from the special tap for cooled water for serving patients drinking water and mouth care.

Organism: *Stenotrophomonas maltophilia*

Transmission mode: direct contact.

Clinical setting: ICU.

Source: water-cooler for drinking water.

Assessment of evidence
Control measures: Chilling unit and tubing was removed from the tap. Since that time no more FR04 and FR06 genotypes have been found in ICU and the *stenotrophomonas* prevalence has fallen to <2% of admissions. This chilling unit was installed in 2009 and the carbon filter had been changed quarterly, but not the tubing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hota S, Hirji Z, Stockton K, et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. Infection Control & Hospital Epidemiology. 2009 Jan;30(1):25-33.	Outbreak investigation	**Level 3**	An epidemiologic investigation was carried out to search for potential case-case links or case-common environmental source links. PFGE was used to determine genetic relatedness. Drain plugs from 3 sink traps were examined. Sink drain contents were investigated for dispersion onto surfaces.	Association between clinical and environmental samples through PFGE typing.	Number of positive cultures, phenotype results, PFGE types.

Assessment of evidence
Typing was performed using PFGE. This study shows the importance of proper designs of sinks as well as room designs. Transmission of outbreak organism to patients by means of fluorescent marker testing was visually demonstrated. Organism: *Pseudomonas aeruginosa.* Transmission mode: Probably through contamination of the area where sterile procedures and medication preparation were performed through the splash of drain contents. In combination with high water pressure and a very shallow sink bowl, this created a means by which Pseudomonas biofilms within the drains could be disrupted, thereby transferring the viable organism to surrounding surfaces or, potentially, to the hands of healthcare workers. Clinical setting: intensive care unit or transplant units of a tertiary care hospital. Source: hand hygiene sink drains. Control measures: the use of contact precautions (wearing of gowns and gloves by healthcare workers and single room isolation of the patient) for all colonized or infected cases; staff education; enhanced environmental cleaning; disinfection of hand hygiene sink drains; closure of hand hygiene sinks; and renovation of hand hygiene sinks to prevent splashing of drain contents. The outbreak was halted through simple sink and room design modifications to prevent splashing, without actually eradicating the organism or moving the sinks. Replacing sinks and exposed piping may not eradicate biofilm that is more distal within the plumbing system; presumably this biofilm would simply recolonize new plumbing over time. Limitation: control measures part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental	Incident rate, positive cultures, molecular fingerprinting.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.			(including finding the source) and to determine the impact of infection prevention and control measures.	isolates of *Mycobacterium abscessus.*	

Assessment of evidence

Organism: *M. abscessus.*

Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients.

Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease.

Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favourable for *M. abscessus* growth.

Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU

Assessment of evidence
exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Health Technical Memorandum 04-01 Water safety for healthcare premises Part B: Operational management	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following sections are relevant for this research question on survival of waterborne organisms: “The following conditions have been found to influence the colonisation and growth rate of Legionella: water temperature between 20°C and 45°C is the range in which *Legionella* will proliferate most rapidly. The optimum laboratory temperature for the growth of the organism is 37°C. *Legionella* are killed within a few minutes at temperatures above 60°C.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Denoncourt Alix M., Paquet Valérie E., Charette Steve J. Potential role of bacteria packaging by protozoa in the persistence and transmission of pathogenic bacteria Frontiers in Microbiology. 2014	Non-systematic literature review (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
Review summarising the role of protozoa in bacteria and their survival, including survival in water and therefore protecting against disinfection strategies. “In addition to *L. pneumophila* and *Mycobacterium* spp., a large number of bacterial species can withstand predation by protozoa and can persist and/or grow in them. A summary of the outcomes reported in the literature for pathogenic bacteria that interact with various protozoa is presented in Table 1.”					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). Legionella and the prevention of legionellosis. ISBN 92 4 156297 8 (NLM classification: WC 200) © World Health Organization 2007	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following sections are relevant for this research question on survival of waterborne organisms:

“Legionellae can multiply in 14 species of protozoa, including:

• Acanthamoeba, Naegleria and *Hartmanella* spp.

• the ciliates *Tetrahymena pyriformis, Tetrahymena vorax*

• one species of slime mould

Protozoa are an important vector for the survival and growth of Legionella within natural and artificial environments, and have been detected in environments implicated as sources of legionellosis.

Protozoa help to protect Legionella from the effects of biocides and thermal disinfection. Legionellae can survive in encysted amoebal cells and it has been postulated that this can be a mechanism by which *L. pneumophila* is able to survive adverse environmental conditions and survive within airborne aerosols.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakade J, Nakamura Y, Katayama Y, et al. Systematic active environmental surveillance successfully identified and controlled the *Legionella* contamination in the hospital. J Infect Chemother. 2023;29(1):43-47. doi:10.1016/j.jiac.2022.09.010	Surveillance study	**3**	This surveillance study was performed after a patient acquired *Legionella* infection to identify and control the *Legionella* contamination. Resampling was done 1, 2 and 3 months after implementation of control measures (disinfecting by increasing heat, increasing chlorine and increasing water pressure) and results were negative.	N/A	Sample location, water temperature (°C), chlorine concentration(ppm), *Legionella* counts (CFU/100ml).
Assessment of evidence					
This surveillance study was performed after a patient acquired *Legionella* infection. The authors state that the patient infection must be nosocomial as on day 18 high fever started and *Legionella* was confirmed 28 days after admission. Samples were taken from the bathrooms of the patient as well as bathrooms on different floors that connected to the same plumbing, in total 47 water samples were taken and *Legionella* was confirmed in 16 of the 47 samples (3/5 from patient bathroom and 13/42 from connected bathrooms).					

Assessment of evidence
However, it is not confirmed by genotyping/serotyping that the strains found in water samples were matching the patient strains and thus it could be possible that *Legionella* was acquired elsewhere (in rare cases the incubation period can take up to 20 days according to ECDC). Organism: *Legionella.* Transmission mode: not confirmed. Source: not confirmed (either faucets/shower heads or inside the plumbing of the circulation). Control measures: Increase of water temperature (from 65C to 70C), increase of chlorine concentrations, increase of water pressure. Legionella-positive water tap was replaced with a new one. For the parts those are difficult for being replaced, such as water plumbing around bathtub for the accessible bathing, plumbing was flushed by hot water of 45C Celsius for 15 min followed by 60C Celsius for 3 min for 3 consecutive days. In addition, water taps and plumbing were flushed more than 15 min once a week on a regular basis after cleaning and disinfecting. Limitations: • no genotyping performed, thus not known whether the isolates (patient and all environmental isolates) were identical strains • not confirmed if case was nosocomial. Patient used bathroom on 5th floor and 7th floor, and both were positive for *Legionella* afterwards, but not known if the patient was the source or if the water was the source • single patient case • not clear whether *Legionella* was contaminated only in faucets/shower heads or inside the plumbing of the circulation

Question 3: What are the causes/sources of environmental contamination with healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and environmental microbiology 2019; 85.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing.	Sample type, amount of positive samples, CFU counts, MIC, PFGE type.
Assessment of evidence					
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca.*					

Assessment of evidence
Transmission mode: contaminated water-based equipment. Clinical setting: perinatal setting/childrens hospital. Source: isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Control measures: Environmental monitoring, admission screening, IPC training HCWs, renovation/contamination sinks, etc. All garments worn by newborns and children were laundered by professionally service. The washing machine was removed. The use of professional washing machines and routine checking with a temperature logger are urgent requirements.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Campos-Gutierrez S, Ramos-Real MJ, Abreu R, et al. Pseudo-outbreak of *Mycobacterium fortuitum* in a hospital bronchoscopy unit. American Journal of Infection Control 2020; 48: 765-769.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a pseudo-outbreak of *Mycobacterium fortuitum* in Spain (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *M. fortuitum* isolated from a water sample (tap) were compared.	Number of positive samples, sample type, typing results (by restriction fragment length polymorphism and by enterobacterial repetitive intergenic consensus sequences).

Assessment of evidence
The hospital water supply showed to be contaminated with *M. fortuitum*, which is why its use in the rinsing of high-level disinfection led to a recontamination of the bronchoscopy. Organism: *Mycobacterium fortuitum.* Transmission mode: contaminated water-based equipment. Clinical setting: pneumology bronchoscopy unit. Source: the hospital water used by the bronchoscope automatic washing machine (without antibacterial filter). Control measures: Not using the washing machine without manually cleaning and disinfecting it with prefiltered water using the Pall AquaSafe Water Filter until purchasing a new washing machine. As a surveillance measure, an environmental microbiologic study of the hospital water was established every 15 days, in which, since this outbreak, an RGM study was included. Installation of filters in those taps where water is taken from to rinse invasive instruments after disinfection. The authors describe a pseudo-outbreak as real clustering of false infections or artefactual clustering of real infections, which is often identified when there is increased recovery of unusual microorganisms. They however call it a pseudo-outbreak because there was no clinical impact on patients.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Heireman L, Hamerlinck H, Vandendriessche S, et al. Toilet drain water as a potential source of hospital room-to-	Outbreak investigation	**Level 3**	The aim of this study was to investigate a OXA-48-producing *Klebsiella pneumonia* outbreak in Belgium (including finding the source) and to determine the	Molecular typing results between patient strains and *Klebsiella pneumonia* isolated from environmental/water	Number of positive samples, sample type, whole-genome sequencing results and phylogenetic analysis.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
room transmission of carbapenemase-producing *Klebsiella pneumoniae*. Journal of Hospital Infection 2020; 106: 232-239.			impact of infection prevention and control measures.	samples were compared.	
Assessment of evidence					
Toilets and drain water appeared to be the source of this outbreak. The common strain found in all outbreak isolates suggests that the strain may have spread between rooms by drain water. Organism: OXA-48-producing *Klebsiella pneumonia.* Transmission mode: contaminated water systems. Clinical setting: burn unit of University hospital. Source: toilet drain water. Control measures: bleach added to daily toilet cleaning regime, sampling of toilet water (even though did not completely prevent the presence of carbapenemase-producing *K. pneumonia*).					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Constantinides B, Chau KK, Phuong Quan T, et al.	Surveillance study	**Level 3**	The aim of this study was to investigate the prevalence of contamination of	Phylogenies of sink drain aspirates sampled over 12 weeks across three	Number of positive samples, sample type, whole-genome sequence analysis

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Genomic surveillance of *Escherichia coli* and *Klebsiella* spp. in hospital sink drains and patients. Microbial Genomics 2020; 6: 4-16.			healthcare sinks by strains of *E. coli* and *Klebsiella* spp.	wards and patient samples.	(including metagenomic sequencing).
Assessment of evidence					
In this study isolates were identified from sinks from different hospital wards and were linked retrospectively to isolate results from patients staying in the same units during the same time period. Genomic overlap with sink isolates was only identified in 1/46 of all sequenced isolates causing clinical urine-infection over the same timeframe, associated with acquisition from a sink source. Organism: Enterobacterales species (*E. coli* and *Klebsiella* spp). Transmission mode: not confirmed. Clinical setting: general medicine ward in hospital UK. Source: possibly a sink. Control measures: not documented. Even though isolates from the sinks were compared to isolates from patients' samples there was no epidemiological data used to investigate whether this correlation is actual true. Both microbiological and epi data is needed to link strains to infection. This study provides evidence that sinks can be colonised with a wide abundance of microorganisms that are associated with healthcare-associated infections, indicating a possible reservoir and risk of infection. This study provides evidence for the source of infection.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jung J, Choi HS, Lee JY, et al. Outbreak of carbapenemase-producing Enterobacteriaceae associated with a contaminated water dispenser and sink drains in the cardiology units of a Korean hospital. Journal of Hospital Infection 2020; 104: 476-483.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a carbapenemase-producing Enterobacteriaceae outbreak in Korea and to find the risk factors for acquiring CPE.	Epidemiologic links between patients and potential environmental sources.	Number of positive samples, sample type, typing (PFGE analysis)

Assessment of evidence

Sinks in patient rooms and water dispenser acted as reservoirs (PFGE confirmed).

The water dispenser for provision of water to patients was located near a handwashing sink; of note, used dialysing solution after haemodialysis was emptied into this handwashing sink.

Organism: KPC-producing *Escherichia coli*, NDM-1-producing *Citrobacter freundii*, NDM-1-producing *Enterobacter cloacae.*

Transmission mode: contaminated water system.

Clinical setting: cardiology and Cardiothoracic surgery intensive care units in a South Korean University Medical Centre.

Assessment of evidence
Source: water dispenser, sinks in the patient bathroom. Control measures: Water dispenser was removed and bottled water was provided to patients. Sink drains were treated with bleach and afterward replaced. Active surveillance tests and pre-emptive isolation were also carried out alongside “thorough daily cleaning with monitoring and deep terminal cleaning using no-touch disinfection (hydrogen peroxide vapour and ultraviolet area decontaminator)”.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M, et al. Pseudo-outbreak of *Mycobacterium chimaera* through aerators of hand-washing machines at a hematopoietic stem cell transplantation center. Infection Control and Hospital Epidemiology 2019; 40: 1433-1435.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results.
Assessment of evidence					
Outbreak investigation. A genetic relationship was found between the clinical and environmental isolates.					

Assessment of evidence
Organism: *Mycobacterium chimaera.* Transmission mode: contaminated water system. Clinical setting: 28 bed Hematopoietic stem cell transplantation (HSCT) Centre in Japan. Source: biofilm on the aerators of the handwashing machines in each patient's room. Control measures: Replacement of aerators and related part every 6 months. Communication with facilities maintenance personnel including officers and mechanics, to incorporate this replacement into routine work. Definition of pseudo-outbreak not defined. From context in paper it seems to refer to cases who do no experience clinical illness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Coppry M, Leroyer C, Saly M, et al. Exogenous acquisition of Pseudomonas aeruginosa in intensive care units: a prospective multi-centre study (DYNAPYO study). Journal of Hospital Infection. 2020 Jan 1;104(1):40-5.	Prospective multi-centre study	**Level 3**	The aim of the study was to investigate the role of exogenous origin of *P. aeruginosa* in ICU patients. Exogenous acquisition was defined as colonization or infection by a strain of *P. aeruginosa* with a pulsotype previously isolated from another patient	Contributions of *P. aeruginosa* exogenous acquisition by patient-to-patient transmission and from contaminated taps.	Number of positive samples, sample type, typing results

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			(i.e. patient-to-patient transmission) or from a tap water sample in the ICU.		

Assessment of evidence

Typing was performed. However environmental samples only taken from tap water (free-flush), not from other water-related sources. Might be indirect transmission from contaminated environment, equipment or from the hands of healthcare workers via another colonised/infected patient.

Patient to-patient transmission was considered possible when a similar pulsotype was isolated in more than two patients hospitalized during an overlapping period without a similar pulsotype isolated from tap water. Patient-to-patient transmission in this paper only means that patients are infected with identical strains; however, it does not tell us where/how they got infected. Exogenous origin from tap

water was considered possible when a similar pulsotype was isolated in a patient and at least one ICU tap water sample prior to P. aeruginosa identification in the patient.

The present study showed an exogenous origin of *P. aeruginosa* in nearly half of the patients. Patient-to-patient transmission was more frequent than acquisition from tap water.

1808 patients included, 206 excluded due to lack of screening on admission.10,402 screening samples were taken and 427 patients were positive (41 positive found on entering the study). 4946 water samples were obtained. Among the 233 taps screened, 81 (35%) were positive for *P. aeruginosa* at least once during the study, including 51 at the beginning of the study. Median duration of contamination was 5 weeks (range 1-13 weeks). The median duration of contamination differed between electronic and conventional taps (12.6 vs 8 weeks, p=0.003). A total of 270 different pulsotypes were found in patients: 201 (74%) were sporadic, 52 were shared by patients, and 17 were shared by water and patient. **There was possible patient-to-patient transmission for 86/170 patients (50.6%) and an exogenous origin from tap water for 29 other patients (17.1%). It was not possible to draw conclusions for 55 patients from the two ICUs with the highest rates of positive tap water (ICU 5 and ICU 10) because pulsotypes were shared by many patients and tap water samples.**

Assessment of evidence
Organism: *P. aeruginosa.* Transmission mode: tap water (contaminated water systems). Clinical setting: ICU, France. Source: potentially tap water (sinks) and/or patients. Control measures: not reported. Limitations: this study was not able to show how patients acquired infection; it showed that patients were infected by the same pulsotypes in the absence of matching samples in the water, however the limitations of the sampling methodology may have missed some positive water samples- further, the study does not track individual patients so was not able to demonstrate exactly when a patient acquired infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lv Y, Xiang Q, Jin YZ, et al. Faucet aerators as a reservoir for Carbapenem-resistant *Acinetobacter baumannii*: A healthcare-associated infection outbreak in a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Acinetobacter baumannii* (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
neurosurgical intensive care unit. Antimicrobial Resistance and Infection Control 2019; 8 (1) (no pagination).					
Assessment of evidence					
Typing results found that the outbreak strain was only found in the faucet aerator of the dining room, used by HCWs. The faucet aerator may have acted as a reservoir for bacteria in the outbreak, and contamination of the faucet aerator might have occurred from splashes originating from handwashing by the healthcare workers (HCWs). Organism: Carbapenem-resistant *Acinetobacter baumannii* (CRAB). Transmission mode: possible transmission from the contaminated tap to the patient via contaminated HCW hands – not confirmed. Clinical setting: neurosurgical intensive care unit (NSICU). Source: unknown (could have been municipal water, pipeline, or hands of medical staff). Faucet aerator was a likely reservoir – see limitations. Control measures: Intensive infection control measures (strengthening hand hygiene measures, isolation, fluorescent labelling to control cleaning, aerosolized hydrogen peroxide to carry out terminal disinfection, contact precautions, unnecessary transfer of patients, retraining of staff) and environmental microbial sampling were implemented immediately, but their effects were poor. Stop of use of all faucet aerators in the NSICU. Following the emergency response process, an outbreak control team was established including an infection control officer, bacteriologists, cleaning staff, NSICU doctors, and nurses.					

Assessment of evidence
Limitations: the sampling was carried out AFTER control measures were implemented, therefore may not have represented what was present at the time of infection/colonisation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
de Jonge E, de Boer MGJ, van Essen EHR, et al. Effects of a disinfection device on colonization of sink drains and patients during a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 2019; 102: 70-74	Outbreak investigation	**Level 3**	The aim of this study was to study the influence of installing disinfecting devices on sink drains on colonization of sinks and patients in a Dutch ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa.*	Isolated cultures of multidrug-resistant *P. aeruginosa.* before and after the 'intervention' (installation of disinfecting devices).	Number of positive samples, sample type.

Assessment of evidence
The study was described as a 'two-armed intervention trial' with disinfecting devices installed in sink drains in ICU A and new conventional PVC plastic siphons installed in sink drains in ICU B and described the effects on sink and patient colonisation.

Assessment of evidence
The disinfection device aims to decontaminate waste water in the siphon basin by applying repeated heating (to at least 85C) and electromechanical vibration. The study reported that installation of the devices in ICU A resulted in a decrease in colonisation of patients in the subunit from 4.8 to 2.1 per 1000 admission days while colonisation of sink "almost disappeared". Patient colonisation dropped further to between 0 and 0.2 per 1000 patient days when the devices were installed in both subunits (ICU A and B). These devices appeared to be successful at decreasing the colonisation rates of sink drains however they were not 100% effective; some sink drains occasionally tested positive for MDR-PA. This suggests that other components/distal regions of the sink plumbing remained colonised. Organism: multidrug-resistant *Pseudomonas aeruginosa.* Transmission mode: contaminated water systems. Clinical setting: ICU. Source: sink drains. Control measures: installation of disinfecting devices on sink drains.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Decraene V, Phan HTT, George R, et al. A large, refractory nosocomial outbreak of *klebsiella pneumoniae* carbapenemase-producing *Escherichia coli*	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* outbreak (including finding the source) and to determine the	23 CRE-colonised heart patients, 2 infections (UTI, SSI).	Positive samples: 850 total samples taken from sink/drain/shower/bath sites, 18 from toilets, hoppers or sluices, 33 from high-touch sites (keyboards, door handles, sponges).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
demonstrates carbapenemase gene outbreaks involving sink sites require novel approaches to infection control. Antimicrobial Agents and Chemotherapy 2018; 62 (12).			impact of infection prevention and control measures.		85 samples positive, including shower drains, sink taps, sink drain tailpieces, sink drain strainers, sink trap water, toilet bowls.

Assessment of evidence

Outbreak report, molecular typing confirmed link between patient cases and environment. Source not identified but sink drains identified as reservoirs, likely biofilm formation.

The authors state: “Current guidelines do not address the control of large persistent outbreaks or provide advice on the sampling and management of environmental reservoirs, and there is limited evidence in support of any given measure.”

Organism: *Klebsiella pneumoniae* Carbapenemase-Producing *Escherichia coli* (Carbapenem-resistant Enterobacteriaceae (CRE))

Transmission mode: contaminated water systems.

Clinical setting: Heart Centre. Manchester.

Source: not confirmed; sink drain identified as reservoirs, likely biofilm formation.

Control measures: Sink trap replacement for colonised sinks, horizontal pipework cleaning with a brush to remove biofilm. Replacement of the plumbing infrastructure back to the central drainage stacks. Replaceable sink plughole devices designed to prevent water aerosolisation in the sink U-bend and to limit biofilm formation (HygieneSiphon; Aquafree) were installed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW and Holden E. Waterborne *Pseudomonas aeruginosa* transmission in a hematology unit? American Journal of Infection Control 2018; 46: 383-386.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the UK (including finding the source) and to determine the impact of infection prevention and control measures	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results (PFGE).

Assessment of evidence

Outbreak report – molecular typing conducted (PFGE).

Transmission of *Pseudomonas aeruginosa*; transmission route via prep trays from contaminated water outlet. Hickman lines entry route.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: contaminated water systems.

Clinical setting: hematology unit, UK.

Source: transmission route via prep trays from contaminated water outlet. Hickman lines entry route.

Control measures: POU filters were installed on all outlets in the hematology ward. Filters were already on all outlets apart from those in the intravenous prep room. Trays were cleaned with quaternary ammonium compound wipes (Clinell Universal wipes, GAMA Healthcare UK) and dried thoroughly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW, Tracey J, et al. Continued transmission of *Pseudomonas aeruginosa* from a wash hand basin tap in a critical care unit. Journal of Hospital Infection 2016; 94: 8-12.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* cluster in the burns room of a critical care unit in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Clinical surveillance of *P. aeruginosa* infection took place. Water samples from all tap outlets in the unit were collected as per HTM 04-01. All isolates were typed.

Assessment of evidence

Genotyping conducted. Tap was found to be contaminated. Unable to determine the exact transmission route.

The authors state that remedial actions to decontaminate the tap as recommended by the National 04-01 addendum were insufficient.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: not determined exact transmission route.

Clinical setting: critical care unit (burn unit), UK.

Source: contaminated water system. tap was found to be contaminated.

Control measures: Control measures at UHB include disposal of waste water in the sluice where possible, and, if not, the use of absorbent gel sheets to solidify patient waste water being disposed of in a macerator.

Assessment of evidence
The new cleaning method, developed by the housekeeping staff and infection control, involves a three-cloth cleaning technique to reduce contamination.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kotsanas D, Wijesooriya WR, Korman TM et al. "Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. Medical Journal of Australia. 2013 Mar;198(5):267-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant Enterobacteriaceae (CRE) cluster in the ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and CRE isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE).

Assessment of evidence
Molecular typing is performed. CRE is reported from an ICU and from identical organism isolated from patients and an environmental source (sink). However, other factors (due to lack of IPC measures) might have been facilitating transmission. Organism: Carbapenem-resistant Enterobacteriaceae (CRE). Transmission mode: indirect contact. Clinical setting: ICU.

Assessment of evidence
Source: Uncertain, sinks drains found to be contaminated. It was reported that clinical waste and residual antibiotics were being disposed of in clinical hand wash sinks. A single brush was being used to clean down all the sink drains on the unit, without disinfection between sinks. Control measures: cleaning and decontamination the sinks using detergents and cleaning proved unsuccessful. First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-outbreak attributed to contaminated rinse water. American Journal of Infection Control.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2020 Jan 1;48(1):26-32.					

Assessment of evidence

The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope.

Organism: *P. aeruginosa.*

Transmission mode: indirect contact.

Clinical setting: bronchoscopy unit.

Source: sink connecting tube was implicated as the source of *P aeruginosa* contamination to bronchoscopes.

Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Watkins LK, Toews KA, Harris AM, et al. Lessons from an outbreak of Legionnaires'	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of Legionnaires' disease on a	Clinical and environmental isolates were compared by monoclonal antibody	Number of positive samples, sample type, typing results (monoclonal antibody and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
disease on a hematology-oncology unit. Infection control & hospital epidemiology. 2017 Mar;38(3):306-13.			hematology-oncology unit (including finding the source) and to determine the impact of infection prevention and control measures.	and sequence-based typing.	sequence-based typing).

Assessment of evidence

64 bulk water samples and biofilm swab samples were collected from 30 locations. These included point of entry of municipal water into the building, water in the central system, tabs in patient care areas. 21 of 30 locations were positive (70%). This included 9 taps tested positive including all 4 of the case patient rooms.

Investigation suggests that the potable water system was the likely source of infection. Lp1 strains isolated from water on the unit were indistinguishable from all 3 clinical specimens by SBT.

The median time between symptom onset and *Legionella* testing was 8.5 days (range, 0–65 days)

The authors suggest that a single case of LD that is definitely healthcare associated should prompt a full investigation. No further cases were identified after implementation of 0.2um point-of-use filters.

Lessons learned from this outbreak:

- hospital had legionella water management program, however providers were not routinely notified of positive environmental testing results. Clinicians may therefore have been less likely to include diagnostic testing for LD in their initial management of patients
- regular clinician education should be integral part of a hospitals *Legionella* water management program
- some cases were incorrectly misclassified as community acquired rather than HAI

Assessment of evidence
Organism: *Legionella.* Transmission mode: indirect contact. Clinical setting: hematology-oncology unit. Source: contamination of the unit's potable water system (Contaminated water systems). Control measures: water restrictions (limiting contact with the affected building potable water to washing visibly soiled hands) were implements for all patients, visitors and staff. Bottled water was provided for drinking and hygiene activities, and alcohol-based hand sanitizer was provided for routine hand cleansing. Water restrictions were lifted once 0.2 um PoU filters were obtained for all sinks, shower heads, and ice machines. Remediation of the potable water system was initiated once environmental samples were obtained and consisted of superheating each of the 3 water-riser systems to 160°F, flushing, and hyperchlorination (a chlorine injection system was installed for emergency remediation). Ongoing monitoring of chlorine at points of use and follow-up sampling with subsequent remediation as needed were advised. Limitations: only confirmed cases were included in the study; potentially underestimating the actual extent of the outbreak. No control group was included. Unable to determine which of the measures was responsible for ending the outbreak as all measures were implemented simultaneously.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (including finding	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were	Number of positive samples, sample type, typing results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.			the source) and to determine the impact of infection prevention and control measures.	compared to establish a link of infection.	

Assessment of evidence

The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (incl. presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff.

Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room

Organism: *Pantoea agglomerans.*

Transmission mode: indirect/aerosolisation.

Clinical setting: oncology clinic.

Source: pharmacy sink, however primary source associated with this, not identified.

Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping.

Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding.

Assessment of evidence
Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods. Chemotherapy preparations were moved off-site and improved the building water system. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit. Journal of hospital infection. 2016 Sep 1;94(1):2-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Assessment of evidence
Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit. *Pseudomonas aeruginosa* has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients. Organism: *Pseudomonas aeruginosa.* Transmission mode: Contaminated environment, however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission. Clinical setting: ICU – burn unit. Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa. Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily. Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhou Z, Hu B, Gao X, et al. Sources of sporadic *Pseudomonas aeruginosa* colonizations/infections in surgical ICUs: Association with contaminated sink trap. Journal of Infection and Chemotherapy. 2016 Jul 1;22(7):450-5.	Outbreak investigation	**Level 3**	The aim of this study was to investigate *Pseudomonas aeruginosa* colonisations/infections in surgical ICUs and to determine the source(s). This study was a surveillance done in the absence of an outbreak.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence

Genotyping was performed.

17.6% (6/3) of colonisations/infections with P. aeruginosa were most likely due to patient-to-patient transmission and 50% (17/34) from endogenous flora (diagnostic clinical sample identical to rectum and/or throat sample of the same patient). 64.7% (11/170) of exogenous sourced cases were associated with contaminated sink traps. Whereas, no strains (genotypes) recovered from tap water were identical to that from patients – this suggests that the plumbing infrastructure rather than the water was the main environmental reservoir in this setting.

Assessment of evidence
The percentage of carbapenem-resistant P. aeruginosa of diagnostic samples (45.7%, 16/35) was higher than that of screening samples (3.4%, 2/58) and environmental samples (15.1%, 8/53). Patient isolates associated with sink drains showed more resistance to antibiotics than patient-to-patient transmission strains (the percentage of carbapenem-resistant *P. aeruginosa*: 81.8% vs.16.7%). Organism: *Pseudomonas aeruginosa.* Transmission mode: water fitting. Clinical setting: ICU, China. Source: Contaminated sink traps – contaminated sink drains linked to 11/34 (32.4%) patients; patient-patient transmission in 17.6% (6/34) patients; 50.0% (17/34) from endogenous flora (identical to rectum and/or throat sample of the same patient).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aspelund AS, Sjöström K, Liljequist BO, et al. Acetic acid as a decontamination method for sink drains in a nosocomial outbreak of metallo-β-lactamase-producing *Pseudomonas aeruginosa*.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2016 Sep 1;94(1):13-20.					
Assessment of evidence					
Typing was performed. PA was found in 4/9 drainpipes that were cultured after replacement of the sinks, indicating a reservoir further down the pipes. Typing of clinical and sink drain isolates revealed identical or closely related strains. Organism: *Pseudomonas aeruginosa.* Transmission mode: indirect contact; (likely splashing of the water in the sink or similar). Clinical setting: three different wards in University hospital in Sweden. Source: sink drains (and further down in the pipes). Control measures: Replacement of contaminated sinks, awaiting replacement acetic acid was poured once weekly into colonised sink drains. Following this, all sinks and plumbing's were changed. Acetic acid treatment was then terminated. Hot water flushing of drainpipes, change of sink drain, siphon, and pipes to the wall were changed at the same time.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leitner E, Zarfel G, Luxner J, et al. Contaminated handwashing sinks as the source of a clonal outbreak of	Outbreak investigation	**Level 3**	The aim of this study was to investigate a KPC-2-producing *Klebsiella oxytoca* clonal outbreak on a hematology ward in Austria and to	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were	Number of positive samples, sample type, genotyping results (MLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
KPC-2-producing *Klebsiella oxytoca* on a hematology ward. Antimicrobial agents and chemotherapy. 2015 Jan 1;59(1):714-6			determine the source.	compared to establish a link of infection.	

Assessment of evidence

The starting point of this outbreak started with a colonised patient from the ICU who was later transferred to the hematology ward.

It is hypothesized that KPC-2-producing *K. oxytoca* got into the sink most likely during personal hygiene activities or by disposal of contaminated body fluids, where it persisted. Authors also hypothesise that patients were contaminated by aerosols when using the sink although this is not proven from the study.

Organism: *Klebsiella oxytoca.*

Transmission mode: indirect/aerosolization.

Clinical setting: hematology ward.

Source: handwashing sink.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central line–associated	Molecular typing results between patient strains and nontuberculous	Number of positive samples, sample

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
A cluster of central line–associated bloodstream infections due to rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature. Infection control & hospital epidemiology. 2015 Jan;36(1):76-80.			nontuberculous mycobacteria bloodstream infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	mycobacteria isolated from environmental/water samples were compared to establish a link of infection.	type, genotyping results.
Assessment of evidence					
The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was shower water (mains potable water samples were negative). Submersion of CVC during bathing, showering or toileting seemed to be the port of entry.					

Assessment of evidence
Organism: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.)
Transmission mode: submersion of CVC during bathing, showering or toileting seemed to be the port of entry.
Clinical setting: hematology-oncology ward.
Source: contaminated shower water.
Control measures: catheter/port removal and antimicrobial therapy.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wolf I, Bergervoet PW, Sebens FW, et al. The sink as a correctable source of extended-spectrum β-lactamase contamination for patients in the intensive care unit. Journal of Hospital Infection. 2014 Jun 1;87(2):126-30.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonization of extended-spectrum b-lactamase-positive bacteria (ESBLs) in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures (for example self-disinfecting siphons).	Molecular typing results between clinical strains and ESBLs isolated from environmental/water samples were compared to establish a link of colonization.	Number of positive samples, sample type and species, genotyping results (AFLP).

Assessment of evidence
Patients were not infected but colonised. ESBLs originating from sinks in patient's rooms were linked to patients who stayed in ICU. Organism: extended-spectrum b-lactamase-positive bacteria (ESBLs). Transmission mode: assuming indirect contact; however this is not confirmed from the study. Clinical setting: ICU. Source: sink (contaminated water systems). Control measures: All 13 siphons from sinks in the ICU patient rooms and five siphons from sinks at other locations where medical workers wash their hands frequently (two toilets, the medication room, the scullery room and the staff room) were replaced. To monitor the effect of this intervention, all 18 sinks were sampled for the presence of ESBL 1,2,3,4,6,8 months after the intervention. During month 8, samples were cultured non-selectively to determine the whole microbial flora present in the sinks. Limitation: positive clinical strains were only compared to isolates taken from sinks. Therefore it can be argued that the sink was the actual source, or whether it might have been the reservoir.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guyot A, Turton JF, Garner D. Outbreak of *Stenotrophomonas maltophilia* on an intensive care unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Stenotrophomonas maltophilia* outbreak (including finding the source) and to highlight the risk from contaminated	Typing results of the *Stenotrophomonas maltophilia* patient strains vs \ *S. maltophilia* isolated from environmental/water samples.	Incidence of outbreak strains, PFGE profiles from patient's vs water strains.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2013 Dec 1;85(4):303-7			devices for supply of drinking water.		
Assessment of evidence					
Typing was performed. A tap (in ICU kitchen) that had a water-cooler for drinking water was the source of *S. maltophilia* on ICU in a UK hospital, because a carbon filter had not only removed the disinfectant chlorine dioxide before the water-cooler, but had also accumulated organics, which serve as nutrients for bacteria facilitating the growth of biofilms on downstream tubing. On review of nursing practices, the nurses reported that they had discarded the water from tooth-brushing or patients' drinking water into handwash basins. They revealed also that they had used cooled water from the ICU kitchen from the special tap for cooled water for serving patients drinking water and mouth care. Organism: *Stenotrophomonas maltophilia.* Transmission mode: direct contact. Clinical setting: ICU. Source: water-cooler for drinking water. Control measures: Chilling unit and tubing was removed from the tap. Since that time no more FR04 and FR06 genotypes have been found in ICU and the *Stenotrophomonas* prevalence has fallen to <2% of admissions. This chilling unit was installed in 2009 and the carbon filter had been changed quarterly, but not the tubing.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schneider H, Geginat G, Hogardt M, et al. *Pseudomonas aeruginosa* outbreak in a pediatric oncology care unit caused by an errant water jet into contaminated siphons. The Pediatric infectious disease journal. 2012 Jun 1;31(6):648-50.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results (RAPD-PCR and single-nucleotide polymorphism–type *P. aeruginosa* microarray).

Assessment of evidence

Contaminated aerosols may have emerged from the siphon at every water use. Patients could have acquired infection with the outbreak clone due to inhalation of contaminated aerosols (patients B and C), via smear infection with water drops directly from the water tap (patients B and C) or through horizontal transmission from contaminated persons such as staff or family members (patient A).

Organism: *Pseudomonas aeruginosa.*

Transmission mode: aerosolisation, indirect contact.

Clinical setting: pediatric oncology care unit (POCU).

Source: contaminated siphons.

Assessment of evidence
Control measures: new water taps were installed throughout entire POCU to avoid direct water flow into the sink.Siphons in the anterooms in isolation rooms 2 and 3 were additionally replaced. Patients and staff were obliged to rinse the water taps with running hot water preceding every water use.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lucero CA, Cohen AL, Trevino I, et al. Outbreak of *Burkholderia cepacia* complex among ventilated pediatric patients linked to hospital sinks. American journal of infection control. 2011 Nov 1;39(9):775-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* complex outbreak and to determine the source.	Molecular typing results between clinical strains and *B cenocepacia* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type and species, bionumeric analysis, genotyping results (PFGE).

Assessment of evidence
B. cenocepacia was not cultured directly from hospital water, but its recovery from drains suggest that the organism was present either in the water or in contaminated products placed in sinks. Organism: *B cenocepacia.* Transmission mode: Indirect contact.

Assessment of evidence
Clinical setting: ICU - ventilated paediatric patients. Source: sink drains and ventilation components. Control measures: not reported.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
La Forgia C, Franke J, Hacek DM, et al. Management of a multidrug-resistant *Acinetobacter baumannii* outbreak in an intensive care unit using novel environmental disinfection: a 38-month report. American journal of infection control. 2010 May 1;38(4):259-63.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Acinetobacter baumannii* outbreak in an ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Genomic DNA of the clinical isolates were genetically analysed using restriction endonuclease analysis (REA) and compared with one another to determine whether they were genetically related.	Number of positive samples, sample type, restriction endonuclease analysis (REA).

Assessment of evidence
Organism: *Acinetobacter baumannii*

Assessment of evidence
Transmission mode: indirect transmission. Clinical setting: ICU. Source: Single outbreak source was identified. sink trap that likely represented contamination of the entire horizontal drainage system. Control measures: contact isolation of all MDR *A baumannii*–positive patients, education of nursing staff on the epidemiology of MDR *A baumannii*, increased training on the importance of hand hygiene, introduction of alcohol-based hand hygiene solution into each patient room, and observations of environmental cleaning in the ICU. Bleaching protocol successfully decontaminated the reservoir and eliminated the MDR *A baumannii* infections. Flushing regime: The sink flushing protocol was devised as follows. Once per day for the first week, and then once per week thereafter until October 2008 (when the ICU was demolished for remodelling), 10 gallons of water were first run into each plugged sink in every location in the ICU, including in each patient room and the family waiting area. This was followed by slowly pouring 1 gallon of bleach into the water, avoiding splashing. Health care workers performing this task wore protective goggles as well as rubber gloves. Once all of the sinks were filled, the plugs of all sinks were pulled simultaneously, thereby flushing the sink drain piping with the bleach solution. This protocol was continued throughout the observation period.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Rogues AM, Boulestreau H, Lashéras A, et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonisation of *Pseudomonas aeruginosa* in a French ICU (including finding the source) and to	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
medical intensive care unit. Journal of Hospital Infection. 2007 Sep 1;67(1):72-8.			determine the impact of infection prevention and control measures.	establish a link of colonisation.	

Assessment of evidence

Pseudomonas aeruginosa was found in cold tap water samples (pre-flush) in patients' rooms more than in other tap water in the unit. Aerators were swabbed and the swab broken into the water samples.

Half of the environmental isolates of *P. aeruginosa* derived from colonised patients and did not stem from a central source in the supply mains. Carriage happened by patients (source). Both water-related and non-water related strains appeared to have spread in half of the instances.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: carriage by patients (indirect transmission).

Clinical setting: ICU.

Source: contaminated tap water.

Control measures: twice monthly disinfection. An aqueous solution (4.5%) of sodium hypochlorite (diluted household bleach) was injected into taps with a 60 mL syringe for 15 min. Aerators were removed every two weeks, immersed and brushed in a detergent-disinfectant solution. The disinfection programme was instituted. Hand disinfection with an alcohol-based solution was required between patient contacts. Only bottled water was used for enteral nutrition and to administer drugs through gastric tubes. Bottled water is not sterile but analyses performed every year on bottles used for immunocompromised patients in another unit were always satisfactory. Sterile water was used for mouth care.

A defective flexible bronchoscope was contaminated and then later removed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence

Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient. *M. mucogenicum* also found in the hot water source in the main hospital, and the city water source for the hospital.

Organism: *Mycobacterium mucogenicum.*

Transmission mode: indirect/aerosolisation.

Clinical setting: university-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients.

Source: water contamination of central venous catheters (CVCs) during bathing.

Control measures: the following control measures were recommended and implemented:

- showerheads and hoses on the Bone marrow transplant (BMT) units were replaced

Assessment of evidence
• shower hoses were allowed to hang straight with no dependent loops when not in use to reduce the risk of bacteria multiplying to higher levels in stagnant water • direct care providers, patients and family members were educated on the risks of water contamination of central venous catheters (CVC) during bathing and on prevention methods to minimize water contact during bathing • IV catheters were disconnected before bathing when possible • catheter connections were covered with waterproof material if they could not be disconnected

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pena C, Dominguez MA, Pujol M, et al. An outbreak of carbapenem-resistant *Pseudomonas aeruginosa* in a urology ward. Clinical microbiology and infection. 2003 Sep;9(9):938-43.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and Carbapenem-resistant *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Typing indicated that the CRPA outbreak resulted from the contamination of the cystoscopy room via an unsealed drain. The outbreak ended when the drain was sealed. Organism: Carbapenem-resistant *Pseudomonas aeruginosa.* Transmission mode: indirect contact Clinical setting: cystoscopy room. Source: unsealed drain. Control measures: Strict adherence to disinfection protocol. Examination of cystoscopy room and repairs were undertaken. Surgical drape should only be used once, and the open drainage of the floor should be provisionally closed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al. Analysis of transmission pathways of *Pseudomonas aeruginosa* between patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between *Pseudomonas aeruginosa* infection and faucet contamination in a surgical ICU.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish transmission pathways.	Number of positive samples, sample type, relationship between genotypes (RAPD).

Assessment of evidence
The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed. Tap water isolate: PA found in 150/259 (58%) tap water samples taken from patient rooms in 13 different wards. PA was not found from samples from the central outlets of the supplying mains at different time points. Relationship between genotypes: 18 different genotypes were identified in patient isolates and 17 different genotypes were identified in tap water isolates. 31 patients were positive in the SICU for *P. aeruginosa* over the study period of 40 wks. The patient's genotype also was found in tap water in the SICU in 17 cases. In 10 cases (32%) a tap water isolate from the room was shown to be of the same genotype as the patient isolate. Water-to-patient transmission in the same room was likely in 7 cases and patient-to-water transmission was likely 3 cases. 6 patients were possibly colonised through contaminated water from neighbouring rooms. 2/10 patients from peripheral surgical wards to SICU and were shown to be positive for the same strain of PA before and after the transfer. Neither the faucets in the SICU nor the faucets in the prior rooms were shown to be contaminated with the patient strain. 7 patients in surgical wards other than SICU were found to carry the same genotype as found in tap water in their room. Organism: *Pseudomonas aeruginosa.* Transmission mode: indirect (potentially hands of HCWs, transfer of colonised patients between wards, splashing of water around the washbasin). Clinical setting: SICU and other surgical wards, Germany. Source: individual faucets (possibly colonised patients as source). Control measures: An intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention. Infections caused by PA: Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonised with *P. aeruginosa* were wounds and the pharynx.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
El Sahly HM, Septimus E, Soini H, et al. *Mycobacterium simiae* pseudo-outbreak resulting from a contaminated hospital water supply in Houston, Texas. Clinical infectious diseases. 2002 Oct 1;35(7):802-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium simiae* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Mycobacterium simiae* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results.

Assessment of evidence

Environmental investigation:

- cultures of water samples obtained from the municipal water supply, ground well, and the EDB did not yield *M. simiae*
- pipes connecting the energy distribution building to the hospital building and PB1, and culture specimens obtained from heat exchangers, sinks, drinking fountains, and ice machines in hospital building and PB1, were positive. Samples from PB 2 were all negative

Molecular characterization: 44 isolates (37 isolates from 33 patients and 7 environmental, including hospital water, drinking fountain and ice machine). Thirty one environmental and human outbreak–related M. simiae isolates had indistinguishable or closely related patterns on pulsed-field gel electrophoresis and were considered clonal. Results of genotyping showed that this nosocomial *M. simiae* pseudo-outbreak was caused by contaminated hospital water supply. None of the patients received specific antimicrobial treatment for *M. simiae* infection, and isolation of *M. simiae* was unrelated to the clinical presentation of the patients.

Assessment of evidence
Organism: *Mycobacterium simiae.* Transmission mode: not discussed. Clinical setting: hospital setting, United States of America. Source: contaminated water supply. Control measures: Chlorination increased from <1ppm to 1 ppm, this resulted in a transient decrease in number of isolates recovered.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bukholm G, Tannæs T, Kjelsberg AB, et al. An outbreak of multidrug-resistant *Pseudomonas aeruginosa* associated with increased risk of patient death in an intensive care unit. Infection Control & Hospital Epidemiology. 2002 Aug;23(8):441-6.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in Norway (including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results (AFLP) between clinical strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, DNA fingerprinting results (AFLP).

Assessment of evidence
Positive samples found on sinks and from on and inside the sink taps in patient rooms. Organism: *Pseudomonas aeruginosa.* Transmission mode: indirect transmission. Clinical setting: ICU. Source: tap water. Control measures: Contact isolation regimens were implemented in rooms with contaminated patients, change of AB policy. Pasteurization of the water taps was implemented; all taps heated to 75'C for 60 minutes once a week. Outbreak eventually stopped after implementation of the pasteurization procedure for water taps and use of sterile water for drugs and food.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Amoureux L, Riedweg K, Chapuis A, et al. Nosocomial Infections with IMP-19− Producing *Pseudomonas aeruginosa* Linked to Contaminated Sinks, France.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a IMP-19-producing *Pseudomonas aeruginosa* outbreak in France and to find the source.	Molecular genotyping results between clinical strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, genotyping results (pulsotypes by PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Emerging Infectious Diseases. 2017 Feb;23(2):304.					
Assessment of evidence					
An environmental investigation was carried out in a hospital. >100 environmental samples were collected. Water samples were collected from different faucets (nursing room, medication preparation rooms, and rooms of some patients). Sink and shower drains were also sampled as well as toilets. The 7 clinical isolates belonged to 3 distinct genotypes A, B, and C. Of the 7 environmental isolates of P. aeruginosa we identified, 6 belonged to the same genotype as clinical isolates (genotype A). The diversity of species found and genetic structures involved with *bla*IMP-19 indicated that the environmental contamination occurred a long time ago. Organism: *P. aeruginosa.* Clinical setting: hematology department. Source: contaminated sink and shower drains, and toilet bowls.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bédard E, Lévesque S, Martin P, et al. Energy conservation and the promotion of *Legionella pneumophila* growth: the probable role of heat exchangers in a	Outbreak investigation	**Level 3**	The role of heat exchangers as potential sources of contamination for *L. pneumophila.*	Sequence-Based Typing (SBT) results of *Legionella pneumophila* outbreak strain vs *L. pneumophila* isolated from environmental samples.	Number of samples, number of positive samples, colony forming units/L (CFU/L), Pulsed-field gel electrophoresis (PFGE) patterns and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
nosocomial outbreak. Infection control & hospital epidemiology. 2016 Dec;37(12):1475-80.					sequence-based typing (SBT) types.

Assessment of evidence

The authors state that although an infectious dose has not been determined, several countries have established action levels between 1,000 and 10,000 colony-forming units (CFU)/L, and a concentration higher than 10,000 CFU/L requires immediate corrective actions.

“A copper-silver ionization treatment was present on both hot water systems at the time of the outbreak”.

Water heater exchangers are installed to increased energy efficiency; however these can provide optimal environmental conditions for Lp. The researchers found that “temperatures within the heat exchangers ranged from 9C to 46c” and they reported that “prolonged stagnation was observed during the night”.

It is important to highlight this note from the researchers: “The heat exchanger from wing A was fed by a combination of cold makeup water and recirculated hot water depending on demand, and up to 48% of the recirculated water did not transit through the flash water heater. The risk of Lp proliferation in heat exchangers is exacerbated by (1) the prevailing environmental conditions (e.g, temperature, surface area, surface-to-volume ratio, materials); (2) operational conditions (e.g, low flow, stagnation); and (3) the microbial load and presence of Lp in the feed water, which was the case in wing A for the recirculated water feed”.

This study provides evidence on the impact or association between heat exchangers and water contamination with *Legionella pneumophila*.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Umezawa K, Asai S, Ohshima T, et al. Outbreak of drug-resistant *Acinetobacter baumannii* ST219 caused by oral care using tap water from contaminated hand hygiene sinks as a reservoir. American Journal of Infection Control. 2015 Nov 1;43(11):1249-51.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a drug-resistant *Acinetobacter baumannii* outbreak in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, genotyping results (rep-PCR and MLST).

Assessment of evidence

Not clear how contamination occurred. It is possible that it happened from HCW. Also by amplification in outlet. Authors suggest oral care using contaminated tap water as the transmission route.

Organism: *Acinetobacter baumannii.*

Transmission mode: unknown.

Clinical setting: emergency intensive care unit.

Source: colonisation in water systems.

Assessment of evidence
Control measures: use of all 10 hand hygiene water sinks was prohibited. The sinks, automatic taps, tubes, and hot and cold water mixture unit were replaced. Cleaning of the water tap was added to the daily sink cleaning routine. On day 26, the method of oral care was changed to a waterless technique, performed by wiping the teeth and gingiva with a swab after moistening the tissue with sterile water (dry oral care) under the guidance of a dental hygienist. Up to that time, conventional oral care had been performed by nurses using a toothbrush, toothpaste, and tap water while suctioning (wet oral care). The outbreak was successfully controlled after replacement of the water system and implementation as of daily cleaning of water taps and oral care with a dry method. Limitation: combined control measures were implemented, therefore not able to pinpoint which of those was responsible for the control of the outbreak.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Starlander G, Melhus Å. Minor outbreak of extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* in an intensive care unit due to a contaminated sink.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* outbreak in Sweden (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumoniae* isolated from plughole samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of hospital infection. 2012 Oct 1;82(2):122-4.					
Assessment of evidence					
The cultures from the plughole showed growth of an ESBL-producing *K. pneumoniae*, exhibiting a DNA pattern identical to that of the patient isolates. Organism: *Klebsiella pneumoniae.* Transmission mode: unknown. Clinical setting: neurosurgical intensive care unit. Source: contaminated sink. Control measures: by replacing the sink and its plumbing and improving routines regarding sink practices, the outbreak was successfully controlled. Limitation: only samples from the sink hole were collected.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Conger NG, O'Connell RJ, Laurel VL, et al. *Mycobacterium simiae* outbreak associated with a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium simiae* outbreak and to find the source.	Molecular genotyping results between respiratory culture strains and *Mycobacterium simiae* isolated from environmental/water	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1050-5.				samples were compared to establish link of infection.	
Assessment of evidence					
Results of this study suggests that the tap water (both inside as outside the hospital) act as an important reservoir. 11/12 environmental cultures from hospital and military base belonged to the S clone. These were found sporadically throughout the hot water recirculation system within the hospital, and at water faucets delivering water to individual patient rooms. 14/19 patient isolates belonged to S clone and 15/19 patients had hospital exposure before their isolate was obtained. Organism: Mycobacterium simiae. Transmission mode: unknown. Clinical setting:military treatment facility. Source: tap water.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aumeran C, Paillard C, Robin F, et al. *Pseudomonas aeruginosa* and *Pseudomonas putida*	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* and *Pseudomonas putida*	Molecular genotyping results between patient strains and *P. aeruginosa* and *P.*	Number of positive samples, sample type, antibiogram and genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
outbreak associated with contaminated water outlets in an oncohaematology paediatric unit. Journal of Hospital Infection. 2007 Jan 1;65(1):47-53.			outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	*putida* isolated from environmental/water samples were compared to establish link of infection.	
Assessment of evidence					
Tap water and shower water samples taken; positive results returned from both sites. No further cases were identified after implementation of control measures. Organism: *Pseudomonas aeruginosa* and *Pseudomonas putida.* Transmission mode: not confirmed. Clinical setting: haematology paediatric unit. Source: contaminated water outlets. Control measures: water network was chlorinated, and disposable seven-day filters were fitted on all taps and showers. Due to the deleterious effects of chlorination on the water network and the cost of the weekly filter change, a water loop producing microbiologically controlled water was installed. In addition, the concentration of the detergent disinfectant was increased and refillable sprayers were replaced with ready-to-use detergent disinfectant solution for high-risk areas.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hota S, Hirji Z, Stockton K, et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. Infection Control & Hospital Epidemiology. 2009 Jan;30(1):25-33.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence

Typing was performed using PFGE. This study shows the importance of proper designs of sinks as well as room designs.

Transmission of outbreak organism to patients by means of fluorescent marker testing was visually demonstrated.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: probably through contamination of the area where sterile procedures and medication preparation were performed through the splash of drain contents.

Clinical setting: intensive care unit or transplant units of a tertiary care hospital.

Assessment of evidence
Source: hand hygiene sink drains. Control measures: The use of contact precautions (wearing of gowns and gloves by healthcare workers and single room isolation of the patient) for all colonised or infected cases: staff education; enhanced environmental cleaning; disinfection of hand hygiene sink drains; closure of hand hygiene sinks; and renovation of hand hygiene sinks to prevent splashing of drain contents. Limitation: control measures part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tosh PK, Disbot M, Duffy JM, et al. Outbreak of *Pseudomonas aeruginosa* surgical site infections after arthroscopic procedures: Texas, 2009. Infection Control & Hospital Epidemiology. 2011 Dec;32(12):1179-86.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/surgical equipment samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
Evidence from the investigation suggests that this outbreak was most likely the result of inadequate instrument reprocessing that led to retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel.					

Assessment of evidence
Organism: *Pseudomonas aeruginosa.* Transmission mode: direct insertion of contaminated instruments or by infusion of fluid through the contaminated lumen. Clinical setting: ORs. Source: retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel. (contaminated instruments). Control measures: closing the OR pod where the majority of arthroscopic procedures were performed, replacing the arthroscopic instruments, returning to use of more rigid suction tubing for arthroscopy, and changing the instrument reprocessing protocols. Instrument reprocessing protocols were adjusted. The gross decontamination room was redesigned to improve workflow, instrument reprocessing staff received annual training and certification, and tracking of the individual instruments used in each surgery was initiated. Limitation: even though statistics are explained in methods, p-values etc are not provided. IPC measures are part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al. Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon *(*including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, DNA fingerprinting results (PCR-RFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
alcohol skin antiseptic. Infection control and hospital epidemiology. 2004 Mar 1;25(3):231-9.					
Assessment of evidence					
Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections. Tap water and swab from inside tab were positive. Organism: *Burkholderia cepacia.* Transmission mode: contaminated tap water that contaminated alcohol-based products. Clinical setting: hospital. Source: contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with *B. cepacia*). Control measures: once organisms were cultures from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards. Type of infection: bloodstream infections. Limitation: Only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Walker JT, Jhutty A, Parks S, et al. Investigation of healthcare-acquired infections associated with *Pseudomonas aeruginosa* biofilms in taps in neonatal units in Northern Ireland. Journal of Hospital Infection. 2014 Jan 1;86(1):16-23.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in Northern Ireland *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, genotyping results (VNTR).
Assessment of evidence					
Representative *P. aeruginosa* tap isolates from two hospital neonatal units had VNTR profiles consistent with strains from the tap water and infected neonates. Organism: *Pseudomonas aeruginosa.* Transmission mode: not confirmed. Clinical setting: neonatal units. Source: biofilms in flow straighteners and associated components in the tap outlets. Control measures: taps were replaced with new, less complex ones.					

Assessment of evidence
The study identified that plastic flow straighteners, metal support collars and tap bodies surrounding these components supported the highest *P. aeruginosa* colony counts from the automatic taps assessed. Complex flow straighteners had significantly higher *P. aeruginosa* counts that other types of flow straighteners (P < 0.05). The integrated mixers and solenoids were associated with highest aerobic colony counts. (P,0.05) There was no strong correlation between aerobic colony counts and *P. aeruginosa* counts. The VNTR patterns form isolates from taps form two hospitals were consistent with strains from tap water and infected neonates. The complex low straighteners were only present in sensor taps, so unable to confirm if effect due to design or another attribute of sensor taps. Therefore biofilms can be associated with the complex flow straighteners within automatic taps, and aerobic bacteria associated with other components (solenoid and integrated mixer) within these units. However, as complex flow straighteners were only found in sensor taps, it is unclear whether higher rates in sensor taps is due to design of flow straighteners or another factor due to sensor taps. Authors encouraged manufacturers to design taps that would not be able to become contaminated or were easily decontaminated.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a haemato-oncology unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in Edinburgh and to determine the impact of infection	N/A	Number of positive samples, sample type and species.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection, 79; 339-343. 2011.			prevention and control measures.		

Assessment of evidence

Pre and post flush samples taken from taps from sinks, baths and showers, mains water tank inlets also tested. Showers were positive as was the water tank.

Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.).

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: haemato-oncology unit.

Source: water system.

Control measures: the cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced.

Assessment of evidence
Limitations: similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence
Organism: *Mycobacterium mucogenicum.* Source: contaminated automatic water tap. Clinical setting: paediatric haemato-oncology.

Assessment of evidence
Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet. Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.
Assessment of evidence					
Organism: *M. abscessus.* Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients.					

Assessment of evidence
Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease. Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favourable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM, Chinn RYW, Arduino MJ, et al.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/American Hospital Association; 2004.					
Assessment of evidence					
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally-mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on causes/sources of environmental contamination: “Where recirculation is employed, the pipe runs should be insulated and long dead legs avoided in efforts to minimize the potential for water stagnation, which favours the proliferation of *Legionella* spp. and NTM.” See table 15 – sources and reservoirs of waterborne pathogens which include:					

Assessment of evidence
• dialysis water • automated endoscope reprocessors and rinse water • water baths (including hydrotherapy tanks and pools such as birthing tanks) • tub immersion • ice and ice machines • faucet aerators • sinks • showers • dental unit water lines • decorative fountains • eyewash stations • toilets

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kizny Gordon A. E., Mathers A. J., Cheong E. Y. L., et al. The Hospital Water Environment as a	Systematic review	**Level 2+**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reservoir for Carbapenem-Resistant Organisms Causing Hospital-Acquired Infections - A Systematic Review of the Literature Clinical Infectious Diseases 2017:64					

Assessment of evidence

The aim of this systematic literature review was to summarise studies identifying common CROs in the hospital water environment, the evidence for CRO transmission between this environment and patients, and successful IC interventions to terminate outbreaks and eliminate CROs from this environment.

Organism(s): 13 studies (32 studies in total)) reported *Pseudomonas aeruginosa* (n=13), Other *Pseudomonas* spp. (n=2), *Acinetobacter baumannii* (n=5), *Klebsiella pneumoiae* (n=7), *Klebsiella oxytoca* (n=3), *Enterobacter* spp (n=5), E. coli (n=3), *Serratia marcescens* (n=3), Other (*Leclercia* spp., *Pantoea* spp., *Citrobacter freundii, Raoutella planticola, Escherichia hermannii*, *Aeromonas hydrophilia*, *Proteus mirabilis* or not specified) (n=4).

Clinical setting(s): Intensive Care Unit, High-risk (Hematology, Nephrology, Burns Unit), Multiple Wards.

Transmission mode(s): various (not specified per study).

Cause(s): “Nine studies reported IC breaches that probably contributed to outbreaks. These included poor sink design, use of sinks for contaminated clinical waste disposal, storage of clean patient materials around sinks/sluices, reuse of nonsterile surgical drapes and open drainage in the cystoscopy room, use of a single brush to clean sinks without between-site disinfection, blocked sewage pipes and waste pipe leaks, and failure to clean shower drains.”

Assessment of evidence
Source(s): drains/drainage systems, sink surfaces, faucets, water, inflatable hair wash basin, sensor mixer taps, water/tea dispenser, shower/shower equipment, toilet bowl/brush. Control measures that were considered successful by the authors of that study (see suppl table 1 of this review): “Interventions successful at disinfecting water reservoirs included cleaning of sinks and taps (details not given), daily cleaning of sink surfaces with 0.1% sodium hypochlorite, weekly cleaning of sinks and plumbing with acetic acid/ hot water, transferring all patients to a dedicated isolation unit and hydrogen peroxide vapor disinfection, replacing nontouch sensor taps with conventional taps, and replacing sinks or drainage systems.” Additional control measures: “Twenty-two studies reported enhancing general IC measures, including contact isolation, strict hand hygiene, active surveillance, reinforcement of cleaning and disinfection procedures, audits, and education sessions.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Wafer T, et al. Investigation and control of an outbreak due to a contaminated hospital water system, identified following a rare case of *Cupriavidus pauculus* bacteraemia. J Hosp Infect. 2021;111:53-64.	Outbreak investigation	**Level 3**	The aim of this study was to investigate rare case of *Cupriavidus pauculus* bloodstream infection (including finding the source) which led to the investigation and control of a contaminated water system in a new build hospital due to	N/A	Water/Environmental contamination - The unit undertook frequent water testing and had prior agreed cut-off levels of <10 cfu/mL at 37°C and, <100 cfu/mL at 22°C.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
doi:10.1016/j.jhin.2021.02.001			another 22 patients infected with waterborne pathogens in the following few months.		

Assessment of evidence

This study initially investigated a *Cupriavidus pauculus* bloodstream infection in an immunosuppressed patient which turned into the investigation and control of a contaminated water system in a new build hospital due to another 22 patients infected with waterborne pathogens in the following few months.

Source: Outlets (taps and shower heads) were a likely source, but this was not confirmed with typing. Also expansion vessels, flow straighteners, drains, and debris and 2 sponges from the water storage tanks were tested positive for microbial load and biofilm growth. Moreover, problems arose with the build of the hospital/ at commissioning stage. This was investigated by external agencies:

Investigation by external agencies reported the following issues: elevated TVCs at the time of hospital handover, bypass of mains filtration, failure of temperature control, presence of dead legs, stagnation due to early filling of the water system, debris present in water tanks, installation of open-ended pipework, presence of flexible hoses, corrosion within the system, pressure testing of taps off site and suboptimal maintenance post-handover of the building. Components of the system were also found to be incompatible with silver/hydrogen peroxide.

Limitations:

- described as one incident categorised in 3 phases which were all separate outbreaks (different organisms) – this makes it slightly unclear
- not all water samples were sent for typing. Neither were multiple colonies selected from each agar plate for typing. Therefore, it is not clear what the exact source was of the patient infections

Assessment of evidence
• combination of control measures makes it difficult to determine which part was responsible for the impact

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Network. Guideline on the management of Legionella cases, incidents, outbreaks and clusters in the community. Health Protection Network Scottish Guidance 2 (2014 Edition). Health Protection Scotland, Glasgow, 2014.	Guidance	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance document on the management of *Legionella* spp. incidents mentions the putative sources of *Legionella* in section 4.1: “4.1.2 Potential sources					

Assessment of evidence
Any water system that has the right environmental conditions could potentially be a source for Legionella bacteria growth. There is a reasonably foreseeable Legionella risk in a water system if: • water is stored or re-circulated as part of the system; • the water temperature in all or some part of the system is between 20-45 °C; • there are deposits that can support bacterial growth, such as rust, sludge, scale and organic matter; • it is possible for aerosols to be produced and dispersed; • it is likely that employees, contractors, visitor etc. could be exposed to any contaminated aerosols “ “High risk sources for Legionella in installations were recognised as: Cooling towers/evaporative condensers/air conditioning systems and hybrid systems – associated with major community outbreaks. Hot and cold water systems (particularly in hospitals, hotels, leisure facilities and care homes to a lesser extent) – often related to showerheads. Whirlpools/spa baths (both ‘display’ and leisure)/birthing pools. Other risk sources relevant for the healthcare environment are: ‘Respiratory therapy devices’ which generate aerosols; ‘Aerosolising’ devices, contaminated hospital equipment”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Halstead F. D., Niebel M., Garvey M., et al. *Pseudomonas aeruginosa* infection in augmented care: the molecular ecology and	Surveillance study	**Level 3**	This study aimed to investigate the transmission of *P. aeruginos*a from water to adults in a non-outbreak augmented care setting.	Phylogenetic relatedness between clinical and environmental samples.	Number of outlets sampled, number of positive outlets per sampling period (beginning, middle, end), phylogenetic relatedness between clinical and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
transmission dynamics in four large UK hospitals. Journal of Hospital Infection 111 (2021) 162e168					environmental samples.
Assessment of evidence					
In this study of four anonymized UK hospitals, 881 water outlet samples were taken from 774 taps and 107 showers and the genetic relatedness was compared to 120 clinical *P. aeruginosa* samples to investigate the transmission of *P. aeruginosa* from the water outlet to the adult patients in the 23 augmented care units. Organism: *P. aeruginosa.* Transmission mode: direct/indirect from taps and showers. Exact mode not proven. Clinical setting: augmented care units. Source: water outlets (taps and showers).					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D., Vanstokstraeten R., Crombe F., et al. Sink drains as reservoirs of VIM-2 metallo-b-	Surveillance study	**Level 3**	This study aimed to verify whether patients could be colonised/infected by micro-organisms present in the sink	Molecular genotyping results (WGS) between patient strains and *P. aeruginosa* isolated from	*P. aeruginosa* growth from clinical and environmental samples, genetic profiles, phenotypic resistance profiles,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
lactamaseproducing *Pseudomonas aeruginosa* in a Belgian intensive care unit: relation to patients investigated by whole-genome sequencing. Journal of Hospital Infection 115 (2021) 75e82			drains and to investigate whether high-risk clones of *P. aeruginosa* are present in the ICU.	environmental/water samples were compared to establish link of colonisation/infection .	antibiotic resistance and virulence gene profiles.
Assessment of evidence					
This surveillance study sampled all 36 sinks in the four different ICU of the University hospital Brussels and compared the genetic profiles to the clinical isolated that were retrieved during screening (stored at -80C). In total, 11 distinct STs were identified among the sink drain isolates of which 7 were also identified in the clinical isolates. No single link was seen between environmental isolates and non-ICU clinical samples. Organism*: P. aeruginosa.* Transmission mode: not reported. Clinical setting: ICUs. Source: sink drains. Limitations: no other samples were taken other than the sinks.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jolivet S., Couturier J., Vuillemin X., et al. Outbreak of OXA-48-producing Enterobacterales in a haematological ward associated with an uncommon environmental reservoir, France, 2016 to 2019. Euro Surveill. 2021;26(21):pii=2000118	Outbreak investigation (including case-control element)	**Level 3**	The aim of this study was to investigate a OXA-48-producing Enterobacterales outbreak in France (including finding the source) and to determine the impact of infection prevention and control measures.	Phylogenetic properties of isolates and epidemiologic links between patients and environmental sources.	Number of clinical cases with OXA-48-producing Enterobacterales infection or colonisation in the haematological ward. Contamination/ growth of CPE in environmental samples. Antimicrobial resistance and typing.

Assessment of evidence

This outbreak highlights the possible role of toilets as a source of transmission of OXA-48 CPE. It was successfully controlled only after replacing all the toilets in the ward.

Organism: A total of 78 OXA-48 CPE were detected including 22 *C. freundii*, 19 *E. coli*, 15 *K. pneumoniae*, seven *Klebsiella oxytoca*, six *Enterobacter cloacae*, two *Citrobacter koseri*, two *Enterobacter aerogenes*, one *Hafnia alvei*, one *Kluyvera cryocrescens*, one *Citrobacter amalonaticus*, one *Morganella morganii*, and one *Raoultella ornithinolytica*

Transmission mode: indirect contact (toilet splashback).

Clinical setting: haematological ward of a French hospital.

Source: toilets rims.

Assessment of evidence
Control measures: Following the identification of the toilets as a potential source of the outbreak, intensive toilet cleaning with descaling and bleaching (initially daily, then weekly) was implemented. Afterwards, 23 environmental samples were taken (including 21 toilet rims and two drains), and only one toilet remained positive for OXA-48-producing *C. freundii*. This toilet was successfully re-decontaminated by performing a single additional cleaning and bleaching. In August 2018, all toilets bowls and tanks in two units with environmental CPE-positive samples were replaced by rimless toilets.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler M. A., Osman F., Marx J. J., et al. Hospital-acquired *Legionella pneumonia* outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020	Outbreak investigation (including case-control element)	**Level 3**	An epidemiological and laboratory investigation of a hospital-acquired *Legionella pneumonia* outbreak at of the University of Wisconsin Hospital. Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia.*	Molecular genotyping results (WGS) between patient strains and *L. pneumonia* isolated from environmental/water samples were compared to establish link of colonisation/infection .	Case-control study: ICU admission, 30-day mortality and 90-day mortality, Demographic data and patient factors, pertinent exposures. Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of *Legionella* in environmental samples taken from

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
					patient rooms and clinical units, molecular type of isolates found.

Assessment of evidence

This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the implementation of changes to the water treatment strategy and it is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters.

Organism: *Legionella pneumonia.*

Transmission mode: direct (from water system).

Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients.

The case-control study showed that being a current smoker, having showered during admission and being on prescribed steroids prior to admission were the strongest predictors for acquiring Legionella disease during the outbreak.

Source: hospital water circuit.

Control measures: Showering activities were promptly restricted, water distribution system was hyperchlorinated with 50-200 ppm free chlorine overnight, POU filters were installed on showerheads and faucets. Other interventions included removal of the old water heaters and associated dead end water pipes.

Limitations: case-control element only had 13 cases which is very low to make proper statements on risk factors.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary bypass since reports from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of heater-cooler units (HCUs) used during bypass.	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and presentation, outcome. Growth/ contamination of air/environmental samples, whole-genome sequencing data (phylogenetic relatedness).

Assessment of evidence

This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year.

Organism: *Mycobacterium chimaera.*

Assessment of evidence
Transmission mode: indirect contact/aerosolisation. Clinical setting: cardiothoracic surgery. Source: cardiopulmonary bypass heater-cooler units, Limitations: A 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Infections Associated with Heater Cooler Units Used in Cardiopulmonary Bypass and ECMO - Information for healthcare providers in the UK Version 2. 2017.	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
The following sections of this UK guidance document are relevant for this research question on causes/sources of environmental contamination:

Assessment of evidence
"During 2014-15, PHE were made aware of cases of *Mycobacterium chimaera* endocarditis or deep infection following cardiac surgery in Switzerland, Germany and The Netherlands. *M. chimaera* is a recently described species within the *Mycobacterium avium* complex, a group of environmental organisms usually associated with lung infections, or systemic infections in the immunocompromised host. A Swiss investigation implicated the Sorin (now LivaNova) 3T heater cooler unit (HCU) of the cardiopulmonary bypass equipment, with the transmission of bacteria to the surgical site by aerosolisation of contaminated water from within the unit. The LivaNova device is widely used in the UK and internationally. Maquet, another manufacturer of devices used in the UK, has also indicated that *M. chimaera* has been identified in its HCU water tanks and issued advice to manage any associated risk." Transmission mode: aerosolisation of *M. chimaera* from the contaminated water heater cooler unit. Clinical settings: cardiac surgery. Source: contaminated water heater cooler units. Control measures: replacement of units.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sax H., Bloemberg G., Hasse B., et al. Prolonged Outbreak of *Mycobacterium chimaera* Infection After Open-Chest Heart Surgery.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chimaera* outbreak in Switzerland (including finding the source) and to determine the impact of infection	Molecular genotyping results between patient strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared to	Clinical and patients' characteristics of probable cases include surgery type, type of implant, latency, positive cultures. Growth/ contamination of air/environmental/ water samples,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Clinical Infectious Diseases 2015;61(1):67–75			prevention and control measures.	establish link of infection.	genotype, outbreak management.

Assessment of evidence

This outbreak investigation started after 2 patients were found to have *Mycobacterium chimaera* infection and an in-depth outbreak investigation was done to detect the source, including retrospective case detection, prospective surveillance, on-site observations, and targeted microbiological sampling of patients and the hospital environment. In total, 6 patients met the case definition; All patients had undergone open-chest heart surgery involving implants and the use of heater-cooler units at the University Hospital of Zurich between 2008 and 2012. *Mycobacterium chimaera* was cultured from 5 heater-cooler units and an air sample. Latency between surgery and manifest infection ranged between 1.5 and 3.6 years.

Organism: *Mycobacterium chimaera* (NTM).

Transmission mode: indirect contact/aerosolisation.

Clinical setting: open-chest heart surgery patients.

Source: heater-cooler unit reservoirs.

Control measures: Not under control when published (Only used factory-new heater-cooler units with daily water changes and POU filters, however there was another positive sample in Sept 2014 from 1 heater-cooler unit. At the time of writing (Dec 2014), the construction of custom-built containers with high-efficiency particulate air filters to house heater-cooler units that cannot be placed outside the operating room is under way).

Incubation time: latency between surgery and manifest infection ranged between 1.5 and 3.6 years.

Limitations:

- no genotypic link between patients and environmental samples
- all drinking water fountains in the hospital ICUs tested positive, so cannot rule out that this was another potential source

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Summary of Incident and Findings of the NHS Greater Glasgow and Clyde: Queen Elizabeth University Hospital/Royal Hospital for Children water contamination incident and recommendations for NHSScotland. Final V2. 2018.	Incident report	**Level 4**	N/A	N/A	N/A

Assessment of evidence

Between the period of 29th January and 26th September 2018, 23 cases of blood stream infections (11 different organisms) with organisms potentially linked to water contamination were identified. As a result, further testing of the water supply was undertaken across both hospital sites early in the investigation. This testing identified widespread contamination of the water system.

Organism(s): *Cupriavidus pauculus* (1), *Pseudomonas fluorescens* (1), *Pseudomonas aeruginosa* (3), *Stenotrophomonas maltophilia* (12), *Acinetobacter ursingii* (2), *Enterobacter cloacae* (7), *Klebsiella oxytoca* (1), *Serratia marcescens* (1), *Pseudomonas putida* (1), *Pantoea* sp (1), *Klebsiella pneumonia* (1), *Chryseomonas indologenes*(1)

Transmission mode: contaminated water system.

Assessment of evidence
Clinical setting: paediatric haemato-oncology unit. Source: wash hand basin, drain - contaminated water system. Control measures: Control measures implemented included sanitisation of the water supply to ward 2A, installation of the use of point of use filters in wash hand basins and showers in ward 2A/B and other areas where patients were considered high risk. Drain decontamination was undertaken and on 26th September 2018 wards 2A/B were closed and patients decanted to ward 6A QEUH and 4B QEUH. The following sections of this guidance document are relevant for this research question on causes/sources of environmental contamination: “widespread contamination of the water system that serves both QEUH and RHC. Further testing across the site provided confirmation of this, with positive samples being identified in a number of areas across both sites at both outlet level and within the water system in the basement level (risers). Within the same timeframe staff within wards 2A/B also reported they had witnessed “black effluent” around the rim of the drain in some wash hand basins. Following visual inspection and laboratory testing, this was considered to be biofilm and sampling identified significant contamination of the drains with microorganisms and fungi. Drain contamination is not unexpected however the level of biofilm evident was not in keeping with a water system of less than four years old.” “Causes could be relating to the design and installation of taps and clinical wash hand basins. Flow regulators were used as the design was commissioned in 2009; however, revised SHTM 04-01 guidance no longer supports the use of flow regulators in clinical wash hand basins since they have a number of components and could create ideal conditions for biofilm development which was confirmed by testing of the flow regulators. 50% showed high level of contamination incl biofilm formation. “ “Taps were also non compatible with silver hydrogen peroxide, therefore it could have been degraded. Taps that were sent off for testing exhibited contamination. Moreover, the presence of high levels of gram negative bacteria and fungus in the water system may indicate that temperature control required has not always been achieved.”

Assessment of evidence
"A small low level number of micro-organisms may have been present in the water supply at the point of entry. Lack of temperature or chemical control may have enabled biofilm formation. Due to the increasing biofilm throughout the system this may have allowed any subsequent micro-organisms present at point of entry an opportunity to flourish and cause widespread contamination of the system".

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B, et al. *Pseudomonas aeruginosa* outbreak in a neonatal intensive care unit attributed to hospital tap water. Infection control & hospital epidemiology. 2017 Jul;38(7):801-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence
PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient. Organism: *Pseudomonas aeruginosa.* Transmission mode: the actual transmission mode from the tap to the patient was not established.

Assessment of evidence
Clinical setting: Neonatal Intensive Care Unit Source: tap water -Water in the hospital remained stagnant for 3 months after completion of hospital construction, allowing ample time for biofilm formation. Although biofilm was not visualised, the authors comment that a high level of genetic diversity existed among environmental and patient isolates, which is consistent with a previous potential biofilm formation in the pipes, faucets, or drains. Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model. They were reinstated after cases appeared again. In addition, case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The British Standards Institution. BS 8580-1:2019. Water quality – Risk assessments for Legionella control – Code of practice. 2019	Guidance	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on Legionella risk assessment relevant to water systems. It is applicable to any undertaking involving a work activity or premises controlled in connection with a trade, business or other undertaking where there is potential for exposure to water or when water is used or stored in circumstances that could cause a reasonably foreseeable risk of infection by Legionella and contracting legionellosis. This British Standard is applicable to risk assessments being undertaken on premises, plant and systems for the first time. It also covers reviews and reassessments where a previous assessment has been undertaken and where control measures might have been implemented. The standard mentions nutrient sources (such as dirt and food that enters the system) and poor design of the system/equipment that can cause *Legionella* growth. Stagnant or slow-flowing water increases the risk of sedimentation of particulates out of the water, which can act as a focus for growth

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cadot L., Bruguière H., Jumas-Bilak E., et al. Extended spectrum beta-lactamase-producing *Klebsiella pneumonia* outbreak reveals incubators as pathogen reservoir in neonatal care centre.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a beta-lactamase-producing *Klebsiella pneumonia* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumonia* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
European Journal of paediatrics, 178: 505-513, 2019.					
Assessment of evidence					
Setting: neonatal ICU, France. Organism: ESBL *Klebsiella pneumonia.* Transmission route: not confirmed, however multiple environmental contamination identified and incubators and incubator mattresses found to be contaminated. Source: unconfirmed, but incubator mattresses found to be a reservoir, supported by steam water. Provides evidence that mattresses and incubators can remain contaminated and may pose a reservoir for infection even after decontamination. Steam cleaning may not be suitable for mattresses as residual moisture can support grown of organisms.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (for example age and	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
American Journal of Kidney Diseases. 2019 Nov 1;74(5):610-9.			comorbid conditions). The second investigation looked at factors specific to a patient during a particular treatment.	Risk factors for becoming a case are investigated using case-control study designs (2x).	

Assessment of evidence

In this study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of BSIs.

Organism: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae.*

Transmission mode: indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes).

Clinical setting: outpatient haemodialysis facilities.

Source: dialysis station wall boxes (contaminated water-based equipment).

Control measures: implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard MM, et al. Investigation of an *Enterobacter hormaechei* OXA-436 carbapenemase outbreak: when everything goes down the drain. Infect Prev Pract. 2022;4(3):100228. Published 2022 Jun 30. doi:10.1016/j.infpip.2022.100228	Outbreak investigation	**Level 3**	The aim of the study was to investigate a *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Timeline of outbreak and overlap of patients, amount of positive environmental samples, whole genome sequencing results (MLST types).

Assessment of evidence

This study investigated an outbreak of *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene in the Cardiology department of a hospital in Denmark. Various environmental swab samples were taken (from shower drains, floor drains below sinks, sinks, bedpan boilers/instrument washers) and WGS results (MSLT types) revealed a link between patient strains and two environmental strains taken from the shower drains in the only two patient bathrooms in the unit. Staff reported that these drains had a tendency to become partly blocked resulting in regular overflow of water from the drains while patients were showering. Outbreak measures described below resolved the outbreak and no new cases nor new positive environmental samples were found after 3 years.

Organism: *Enterobacter hormaechei* OXA-436 carbapenemase.

Assessment of evidence
Clinical setting: cardiology department. Source: shower drains (overflow of water from clogged drains while showering). Control measures: Physical floor grate and traps were changed and fixed to the drain. The bathrooms were emptied and cleaned. The part of the floor drains, that wasn't possible to change were manually cleaned and afterward rinsed with vinegar. Finally the bathrooms were disinfected with vaporized hydrogen peroxide (RHEA Compact) following cleaning. The shower heads were relocated so that the water did not hit the drain directly (reducing splash risk). The waste pipes were cleaned and the function of the drains and sewer system re-established to prevent overflow. In addition to the regular cleaning of the two bathrooms, an extra daily cleaning with chlorine disinfection of all contact points was established. Limitations: • patient characteristics are not provided, only that the patients were admitted to the same department (different times 6/7).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Moghaddam S, Nojoomi F, Dabbagh Moghaddam A, et al. Isolation of nontuberculous mycobacteria species from different water sources: a study of six hospitals in Tehran, Iran.	Surveillance study	**Level 3**	This study aimed to investigate the prevalence of NTMs (and determine the species) in hospital water supplies (i.e. drink water) in Iran by taking tap water samples of various departments in 6 hospitals.	N/A	Distribution of water samples (amount and hospital), positive samples, collection sources, species identification, MIC (minimum inhibitory concentrations) values and susceptibility to

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
BMC Microbiol. 2022;22(1):261. Published 2022 Oct 29. doi:10.1186/s12866-022-02674-z					antimicrobial agents (susceptible, intermediate, resistant).

Assessment of evidence

This surveillance study showed that NTMs are ubiquitous in the water hospital supply in Iran. The most common strains identified were *M. gordonae* (24 isolates), followed by *M. kansasii* (18 isolates), *M. simiae* (18 isolates), *M. fortuitum* (12 isolates), and *M. chelonae* (4 isolates). It is however not known if the NTM dose found in the water supply will have a negative effect on patients (e.g. what is the infectious dose for infection/colonisation?) and the study did not report any patient infection/colonisation numbers of the studied wards/hospitals.

Organism: Non-Tuberculous Mycobacteria (NTM).

Clinical setting: Various (tap water from the emergency department (n = 12), women's internal medicine (n = 6), men's internal medicine (n = 6), women's surgery center (n = 18), men's surgery center (n = 6), ICU (n = 24), CCU (n = 12), operating room (n = 12), laboratory (n = 10), dentistry unit water (n = 14), department of Infectious diseases (n = 24), hemodialysis center fluid (n = 36), angiography department (n = 14), and heater-cooler devices).

Source: tap water.

Limitations:

- biochemical tests could only identify 76 (40.4%) of the 188 isolates investigated in this study. The rest of the isolates remained unidentified
- not linked to infection/colonisation. Would have been better if the study reported on the number of patients with NTM infections/colonisation in the studied wards/hospital

Assessment of evidence
• not directly applicable to Scottish health and care settings, but it does provide evidence that NTMs are ubiquitous in hospital water systems • unknown what the infectious dose of NTM is and thus more research is needed to determine whether the findings have impact on patients (especially vulnerable patients)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Seagar AL, et al. Investigation of two cases of *Mycobacterium chelonae* infection in haemato-oncology patients using whole-genome sequencing and a potential link to the hospital water supply. J Hosp Infect. 2021;114:111-116. doi:10.1016/j.jhin.2021.04.028	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chelonae* cluster in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	WGS results between patient strains and *Mycobacterium chelonae* isolated from environmental samples were compared to establish link of infection.	Number of positive samples, sample type, WGS results (relatedness by using single-nucleotide polymorphisms SNPs).

Assessment of evidence
Outbreak report of 2 haemato-oncology patients at the Queen Elizabeth University Hospital. WGS of patient samples were done to check for patient-patient transmission as well as water testing was performed and WGS on positive *M. chelonae* samples to check for relatedness and identify potential sources. The results showed that the patient strains were unrelated to each other, but that the isolate from one patient was closely related to environmental samples from water outlets, supporting nosocomial acquisition. 147 unfiltered water samples were tested, 68 (46%) water samples from outlets tested positive, with 34 of 68 (50%) having counts >100 colony-forming units/mL. WGS was undertaken on 31 isolates as well as the two patient isolates for comparison to identify the source/relatedness. Organism: *Mycobacterium chelonae.* Transmission mode: not confirmed. Clinical setting: haemato-oncology inpatient wards, Scotland, UK. Source: water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Brulet A, Nicolle M, Giard M et al. Fatal nosocomial *Legionella pneumophila* infection due to exposure to contaminated water	Case report	**Level 3**	This paper describes a case of fatal nosocomial legionellosis after documented washbasin water contamination in a hospital in France.	Molecular typing results (PFGE) between patient isolates and *L. pneumophila* isolated from water samples were compared.	Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
from a washbasin in a hematology unit. Infect Control Hosp Epidemiol 2008; 29:1091.					
Assessment of evidence					
Comparison of patient isolate (2 cases) and water samples by PFGE. High levels of *L. pneumophila* serogroup 5 and serogroup 1 were detected in the potable hot water of every shower sample, ranging from 350 to 165,000 colony-forming units (cfu)/L. The unit's wing inlet and outlet (i.e, the places from where the water starts and returns, respectively) were also contaminated (900 and 3,400 cfu/L, respectively). Tap water in patient room had 1,500 cfu/L. Organism: *Legionella pneumophila* serogroup 5. Setting: haemato-oncology unit, France. Transmission mode: (unclear, possibly direct ingestion and/or aspiration). Source: water system. Control measures: Flexible shower hoses removed. Hot water reheated to 58'C and hyperchlorinated twice a week, monthly Legionella screening instituted, filters on all outlets. Taps changed to simple mixer valves that did not have volumes of standing water. The hyperchlorination and water reheating alone were unsuccessful. No organisms found in water once filters were installed. Genetic relatedness: "*L. pneumophila* serogroup 5 isolates from the cold wash-basin water matched the patient's isolate and the isolate from an earlier case by genotyping with pulsed-field gel electrophoresis (PFGE)"					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Regev-Yochay G, Smollan G, Tal I, et al. Sink traps as the source of transmission of OXA-48–producing *Serratia marcescens* in an intensive care unit. Infection Control & Hospital Epidemiology. 2018 Nov; 39(11):1307-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *OXA-48–producing Serratia marcescens* in the ICU in Israel (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *S. marcescens* isolated from environmental/water samples were compared.	Number of patients with CPE infection/colonisation and their clinical characteristics, environmental samples (source, results and number of isolates), typing results (PFGE).

Assessment of evidence

Extensive control measures were put in place and carried out, but contamination of sinks seemed to be recurring. Using a combined intervention (including educational component, reducing environmental contamination load) the outbreak was contained 12 months after the start of the outbreak.

Organism: CPE, *S. marcescens* (OXA-48–producing *S. marcescens*).

Transmission mode: indirect contact of the sinks.

Clinical setting: ICU, Israel.

Source: sink drain as reservoir and likely source (pipe work and standing water within the pipes were positive).

Assessment of evidence
Control measures: Enhanced control measures were undertaken, including increased hand hygiene observations as well as educational sessions. Thorough cleaning of all surfaces and medical devices with 1,000 PPM sodium hypochlorite and quaternary ammonium, accordingly, was carried out. After identification of the sink as the source of transmission: 2 main measures were carried out: (1) sink-trap decontamination efforts and (2) an educational intervention enhancing specific infection control measures and focusing on the sink as a source of transmission. All sink traps were replaced, water supply was treated according to Legionella protocol (heating and hyper chlorination of the main water tank and terminal points for 12 hours with free residual chlorine (20–30 mg/L).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Knoester M, De Boer MG, Maarleveld JJ, et al. An integrated approach to control a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Clinical Microbiology and Infection. 2014 Apr 1;20(4):O207-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of multidrug resistant (MDR) *Pseudomonas aeruginosa* in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures. Patients that acquired the outbreak strain were also enrolled in a	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection. For the case-control study, the exposure factors were compared between cases (ICU patients that acquired the outbreak strain) and	Number of positive samples, patient characteristics and exposure factors, sample type, genotyping results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			case-control study to investigate risk factors for acquiring MDR *P. aeruginosa*.	control (ICU patient who tested at least three times negative for the outbreak strain during the follow-up period.)	

Assessment of evidence

Two cluster occurred during this outbreak. A common source was found for one the clusters. Two contaminated faucet aerators were identified. Cross-transmission by medical staff might have occurred as number of new cases decreased after improvement of IPC measures. Presence of drains were not evaluated; this has frequently been identified as a source of infection.

The case-control part of the study identified that patients who are admitted to ICU subunit I, surgery prior to or during admission and those being warmed-up with the warm-air blanker are independently associated with MDR-PA positivity.

Organism: *P. aeruginosa.*

Transmission mode: interpatient transmission by medical staff. (Indirect contact).

Clinical setting: ICU, the Netherlands.

Source: sink drain as likely reservoir, potential source.

Control measures: Chlorination of sink drains (but ineffective). Audit of care-related procedures, cleaning procedures and hygiene measures on ICU. Re-education of ICU staff on hygiene protocols. Implementation of new tracheostomy care protocol. Ban on sharing equipment between patients.

Standard contact isolation measures were implemented. Faucet aerators were replaced.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Snitkin ES, Zelazny AM, Thomas PJ, et al. Tracking a Hospital Outbreak of Carbapenem-Resistant Klebsiella pneumoniae with Whole-Genome Sequencing. Sci Transl Med. 2012 August 22; 4(148)	Outbreak report	**Level 3**	This paper describes the application of whole-genome sequencing (WGS) to track an outbreak of carbapenem-resistant *K. pneumoniae* at Clinical center in the United States.	Molecular typing results between patient strains and *K. pneumoniae* isolated from environmental/water samples were compared.	Genetic relatedness.

Assessment of evidence

18 colonised patients, 11 died. Whole genome sequencing established links between patients and environmental samples (6 drains, a ventilator and another patient room (specific location in room not stated)).

Authors focused on genetic linkage to assess patient to patient transmission, only a brief mention of genetically matched positive cultures from environmental sources but no clear acknowledgement of a transmission route from these sources/reservoirs.

Organism: *Klebsiella pneumoniae.*

Clinical setting: ICU, United States of America.

Source: unconfirmed, found in 6 sink drains and 1 ventilator.

Transmission mode: possible patient-patient and environment to patient.

Control measures: extensive cleaning and contact precautions but no details of drain cleaning.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gbaguidi-Haore H, Varin A, Cholley P, et al. A Bundle of Measures to Control an Outbreak of *Pseudomonas aeruginosa* Associated with P-Trap Contamination. Infect Control Hosp Epidemiol. 2018;39(2):164-169. doi:10.1017/ice.2017.304	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in France including finding the source and to report on the bundle of control measures.	Molecular typing of ESBL- or MBL-producing isolates (patient vs environmental isolates) using pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing (MLST).	Incident rate, infected/colonised patient characteristics, positive cultures (patient and environmental), molecular genotyping.

Assessment of evidence

Overall, 11 patients were colonised or infected with ST235 and 10 patients with ST111.

Organism: *Pseudomonas aeruginosa.*

Clinical setting: haematology unit, France.

Source: Likely reservoir of the outbreak organism were the P-traps and lower plumbing. Acquisition of the 2 outbreak strains was mainly associated with 2 specific rooms where the environment was contaminated.

Control measures: Included (1) a global clinical audit and a reminder on recommendations of hand disinfection opportunities, (2) excreta management, (3) use of gloves, (4) recall of cleaning practices, (5) discontinuation of faeces discharge in the toilets, and (6) removal of

Assessment of evidence
hand showers for rinsing the toilets. After the first results of environmental sampling, all taps and all drains of sinks and toilets were replaced. New water outlets were equipped with lockable P-traps and disposable point-of-use water filters that were changed monthly. A bleach solution (water with 2.6% active chlorine) as poured twice weekly into the blocked P-traps to allow a contact time of 15 minutes before rinsing with water. An additional measure was implemented in April 2014: P-traps were changed at patient discharge whenever a patient stay exceeded 1 week. However, the effect of these measures is not included in the study, these are just mentioned in the discussion section. Authors witnessed a recolonization of the new P-traps in rooms hosting patients who were not colonised by the epidemic strains, suggesting that *P. aeruginosa* stayed in the main pipe and recontaminated the P-traps. This explains how the pathogen contaminated new P-traps and drains of rooms hosting patients negative for *P. aeruginosa.*

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leung GHY, Gray TJ, Cheong EYL, et al. Persistence of related bla-IMP-4 metallo-beta-lactamase producing Enterobacteriaceae from clinical and environmental specimens within a burns unit in Australia - a six-year retrospective study.	Outbreak report	**Level 3**	This paper describes the investigation undertaken in a six - year persistent bla-IMP-4 metallo-beta-lactamase (MBL) producing Enterobacteriaceae within a separately confined hospital burns unit in a tertiary hospital in Australia.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Antimicrobial Resistance and Infection Control 2013, 2:35					

Assessment of evidence

23 patients, with clinical infection in 7 (2 bacteremias, 2 CVC tip infections, 3 wound infections).

Assessment of evidence: the only environment shared between patients was the shower and bathroom facilities.

Organism: *Enterobacter clocae* (most commonly detected organism), *Klebsiella pneumoniae, Enterobacter aerogenes, Klebsiella oxytoca.*

Clinical setting: burns unit, Australia.

Source: Sink and shower drains identified as reservoirs and potential source for some transmissions. Patients may have been initial source. Shower taps, handwashing sinks and taps also tested positive.

Transmission: unclear, however likely both direct and indirect.

Control measures: Monthly and then bi-monthly environmental sampling (bathroom facilities and plumbing including shower drains, ensuite room sink drains). Regular physical cleaning of drains to remove biofilm and additional cleaning with double-strength phenolic disinfectant (Phensol), later changed to chlorine-based product (Chlor-clean). Despite both regular environmental surveillance and disinfection, environmental reservoirs remained.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ambrogi V, Cavalie L, Mantion B, et al. Transmission of metallo-b-lactamase-producing *Pseudomonas aeruginosa* in a nephrology-transplant intensive care unit with potential link to the environment. Journal of Hospital Infection 92 (2016) 27-29	Outbreak report	**Level 3**	This study reports on a cluster of five cases of infection with metallo-beta-lactamase producing *P. aeruginosa* in a nephrology-transplant ICU in France.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

Genetic relatedness: All 5 clinical strains showed the same antibiotype (sensitive only to colistin), possessed bla_{vim-2} genes expressing VIM-2 carbapenemase and were genetically indistinguishable. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). No water contamination in any other areas of hospital.

Organism: *Pseudomonas aeruginosa.*

Clinical setting: nephrology transplant ICU, France.

Transmission mode: unknown (authors hypothesised that HCWs touching taps when washing hands may have cross-transferred from patients).

Assessment of evidence
Source: sinks as reservoirs and potential source. Control measures: replacement of sinks/taps with ones that have a larger space between the tap and the basin. ABHR use reinforced and flushing of outlets instigated (presumably had not been happening before). Limitations: no details on how the water samples were taken or if this extended beyond just tap water samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Weng MK, Brooks RB, Glowicz J, et al.t Outbreak investigation of *Pseudomonas aeruginosa* infections in a neonatal intensive care unit. American Journal of Infection Control 2019; 47: 1148-1150.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of *Pseudomonas aeruginosa* in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Genetic relatedness.
Assessment of evidence					
Outbreak report: Molecular typing confirmed reservoir in sink plumbing and possible hospital water as source. Potential transmission routes from contaminated breast milk, bathing, incubators. Humidifier reservoirs of incubators were filled with tap water, despite					

Assessment of evidence
manufacturer instructions recommending distilled water. Parents cleaned reusable breast pump equipment in sinks that were also used for handwashing and other medical purposes. Organism: *Pseudomonas aeruginosa.* Transmission mode: contaminated water systems. Clinical setting: NICU, United States of America. Source: not confirmed, taps/sinks as reservoirs. Control measures: Hyperchlorination of hospital water with calcium hypochlorite at 200 parts per million (ppm) for 2 hours. Supplemental hypochlorite added at municipal water intakes yielded residual chlorine levels of 2ppm at distal sites until a monochloramine system was installed. Preparation of breast milk/infant formula outwith splash zones, bathing neonates in sterile water, following manufacturer instructions for breast pump equipment drying and incubator water. Plumbing proximal to NICU sinks was replaced. No additional cases over 1 year after implementation of recommended control measures. Limitations: not all patient isolates were available for typing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wendel AF, Kolbe-Busch S, Ressina S et al. Detection and termination of an extended low-frequency hospital outbreak of GIM-1-producing	Outbreak report	**Level 3**	This paper describes an outbreak of an extensively drug-resistant GIM-1-carrying *Pseudomonas aeruginosa* Strain in a tertiary care	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa ST111 in Germany. American Journal of Infection Control 43 (2015) 635-9			hospital in Germany from 2002-2013.	establish a link of infection.	
Assessment of evidence					
A total of 199 environmental specimens were collected (pre+post flush water samples, reusable hair washbasins, sink drains, sink basins, sink counter – all taken before cleaning). The outbreak strain was detected in 6 sink drains (5 patients rooms, 1 service room) and 1 inflatable hair washbasin. Not found in tap water. Five out of 24 patients had a clinical infection, remainder were colonised. Organism: *Pseudomonas aeruginosa*. Setting: ICU, Germany. Transmission mode: likely indirect and direct, however cannot rule out patient-patient transmission. Source: sink drains as a reservoir; cannot rule out patient-patient transmission. Control measures: Use of water from patient room sinks for patient-related procedures was forbidden. Reusable hair washbasins removed. Clean materials not stored near sinks. Sink drains replaced. No further detections in the year after.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hong KB, Oh HS, Song JS et al. Investigation and Control of an	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of imipenem-resistant	Molecular typing results (multilocus sequence typing) between patient	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Outbreak of Imipenem-resistant *Acinetobacter baumannii* Infection in a Pediatric Intensive Care Unit. Pediatr Infect Dis J 2012;31: 685–690.			*Acinetobacter baumanii* in a paediatric ICU in a Children hospital in Korea.	strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Genetic relatedness.
Assessment of evidence					
Environmental samples were obtained from mechanical ventilator devices, respiratory equipment, bed rails, side tables, blood pressure cuffs, door handles, intravenous stands, keyboards, water taps and sinks. Contaminated shallow sink with high water pressure created splashing onto surrounding areas; staff were using towels to soak this up. Organism: *Acinetobacter baumannii.* Setting: paediatric ICU, Korea. Transmission route: unknown. Source: sink drain a reservoir, cannot rule out patient-patient transmission (patient as a source). Control measures: Patient and nurse cohorting, active surveillance on admission, contaminated sink was replaced. Following this the rate of colonisation decreased. Genetic relatedness: multilocus sequence typing analysis linked environmental samples from sink drain and that sink tap water to patient cases.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tofteland S, Naseer U, Lislevand JH et al. A Long-Term Low-Frequency Hospital Outbreak of KPC-Producing *Klebsiella pneumoniae* Involving Intergenus Plasmid Diffusion and a Persisting Environmental Reservoir. PLoS ONE 8(3): e59015	Outbreak report	**Level 3**	This paper reports the investigation of the molecular characteristics of a long-term, low frequency outbreak of blakpc-2 in a hospital in Norway.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness. Antimicrobial susceptibility.

Assessment of evidence

Sink drains and taps supplying water to dialysis machines were sampled. PGFE/MLST analysis of isolates were carried out. KPC-producing bacteria were detected in 4/19 environmental locations in the ICU-A (sink drains in room 5, 6, 9, and the rinsing room).

Organism*: K. pneumoniae* ST258.

Clinical setting: surgical/medical ICU, Norway.

Transmission: Patient negative on admission because positive 5 days post admission, was admitted to room vacated by positive patient; room sink drain was positive. Matching pulsotypes for all these isolates.

Source: environmental reservoir (sink drains) and patients.

Assessment of evidence
Control measures: Active surveillance on admission. The sinks and sink traps were decommissioned and the connecting pipe elbows were disinfected using a chlorine disinfectant before new sinks and sink traps were installed. Monthly environmental screening of these positive locations was then undertaken. Several sinks continued to be positive, but no further patient cases. Genetic relatedness: “PFGE and MLST typing revealed that 14 *K. pneumoniae* isolates from both patients and the environment, including the three bla$_{KPC}$-negative *K. pneumoniae* UTI-isolates, belonged to two clonally related pulsotypes (A1 and A2), that by MLST were typed to ST258”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Vergara-Lopez S, Dominguez MC, Conejo MC et al. Wastewater drainage system as an occult reservoir in a protracted clonal outbreak due to metallo-b-lactamase-producing *Klebsiella oxytoca.* Clin Microbiol Infect 2013; 19: E490–E498	Outbreak report	**Level 3**	This paper describes the investigation of a protracted nosocomial clonal outbreak of a multidrug resistant IMP-8 producing *Klebsiella oxytoca* (MDRKO) in a Spanish Hospital.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence
42 patients colonised (n=28) or infected (n=14). The average time between admission and acquisition of MDRKO was 8 days (IQR,6-37), 16 days (12-17) and 14 (9–40) days in waves 1, 2, and 3, respectively (p 0.22). A urinary catheter removed from a colonised patient and a stethoscope used with that patient yielded MDRKO. Sampling of sinks, drainpipes and traps, was carried out. Samples from room S6 were positive: MDRKO cultured from every pipe, trap and drainage grille sample taken; samples from the faucet or overflow grille were negative. Samples from the pipe connecting S6 and S7 were also positive. Organism: *Klebsiella oxytoca.* Setting: surgical/medical ICU, Spain. Transmission: unconfirmed. Source: sink drains/drainage pipes as reservoir, patients also a source. Control measures: Chemical dosing of the whole water system (a standard annual practice) did not eradicate the outbreak. Sink 6 and its drain system were permanently removed and the drain system of S7 was replaced. Then, a decision to isolate wastepipe 5, which S5 and S7 still drained into. Thus, the complete horizontal drainage system of S5 and S7 was replaced and connected up to wastepipe 4. Shut-off valves were also installed to each sink drainage system. Since then, a disinfection of the drainage system was performed twice a week using ‘Biguanid’ (quaternary ammonium compound) at 1.6% for 30 min (through closing the valves), followed by opening the valves and running hot water (70°C) for 5 min. No new cases in follow up to publication. Genetic relatedness: Selected isolates from waves 3 and 4 and all the environmental samples were studied for the presence of blaIMP-8 and molecular relatedness by PFGE profile. Every strain studied carried blaIMP-8 and they showed the same PFGE profile as previous isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gebo KA, Srinivasan A, Perl TM et al. Pseudo-outbreak of *Mycobacterium fortuitum* on a Human Immunodeficiency Virus Ward: Transient Respiratory Tract Colonization from a Contaminated Ice Machine. Clinical Infectious Diseases 2002; 35:32–8	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *M. fortuitum* recovered from the respiratory tract of hospitalized patients on an HIV ward in a tertiary hospital in the United States.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

40 patient's respiratory samples tested positive – no infection (colonisation, not a pseudo-outbreak).

Water and ice samples taken from 4 different floors in the hospital and from 6 other buildings (cold water supply on entry to ice machine, from the filter, reservoir etc), taps in sputum induction room and patient rooms, mains supply.

Water samples from ice machine tested positive. Mains water negative. Case-control added evidence to the ice machine being the likely source of colonisation for these patients.

Organism: *Mycobacterium fortuitum.*

Assessment of evidence
Clinical setting: HIV ward, United States of America. Transmission mode: direct (ingestion of ice). Source: contaminated ice machine. Outbreak report: filters added to ice machines – no further cases detected following this. Genetic relatedness: "Environmental investigation demonstrated that the *M. fortuitum* isolated from patients was identical to the ice machine isolates by pulsed-field gel electrophoresis." Limitations: Although there are no details given regarding date of positivity since admission (to rule out acquisition outwith the care setting), the epidemiological evidence supports the ice machine as the likely source.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Litvinov N, da Silva MT, van der Heijden IM, et al. An outbreak of invasive fusariosis in a children's cancer hospital. Clinical Microbiology and Infection. 2015 Mar 1;21(3):268-e1	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of invasive fusariosis in Brazil and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Fusarium* spp. isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, genotyping results.

Assessment of evidence
Outbreak was only controlled 1 year after the first case, when water filters filtering 0.2 um were installed at the exit of all faucets and showers in all patient rooms (PoU). Organism: *Fusarium.* Clinical setting: children's cancer hospital, Brazil. Source: Hospital water (contaminated water systems). Maintenance of the water reservoirs/tanks had been neglected since 2006 up until 2009. Control measures: • interruption of new admissions to the unit during 47 days • transfer of the hospitalized patients to another unit in another building of the hospital • renovation of rooms and bathrooms with closure of the communications between service floors and patient rooms; ceiling panels were replaced with plaster ceilings • disconnection of central hot water reservoir and installation of electric instant heating devices • cleaning of cold water reservoirs with chlorine and continuous chlorination of water in the reservoirs (1.5 ppm) controlled by a chlorination device • filtration of water before entry into water reservoirs (10µm filters) • 0.2-µm water filters were installed at the exit of all faucets and showers in all rooms • prospective surveillance for new cases was maintained

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jaubert J, Mougari F, Picot S P, et al. A case of postoperative breast infection by *Mycobacterium fortuitum*. American Journal of Infection Control. 2015 43: 406-408.	Case report	**Level 3**	The aim of this study was to investigate a single case of postoperative breast infection.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence

Chlorine and all other control measures for the hospital water supply were within normal ranges in the 6 months prior to the infection.

Rep-PCR match between the patient and water samples taken from taps in multiple locations including outwith the gynaecology department; so possibly widespread hospital contamination.

Organism: *Mycobacterium fortuitum*.

Transmission mode: unconfirmed, likely direct.

Clinical setting: surgical inpatient ward, France.

Source: hospital water supply.

Control measures: Staff education, use of sterile water for wound cleaning, avoidance of showers postoperatively. Unclear if point of use filters were installed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ashraf M S, Swinker M, Augustino K L, et al. Outbreak of *Mycobacterium mucogenicum* bloodstream infections among patients with sickle cell disease in an outpatient setting. Infection Control and Hospital Epidemiology. 2012 35 (11): 1132-1136.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 4 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence

All 4 patients had ports for intravenous medication. Tap water from 2 taps grew *Mycobacterium* species including *M. gordonae*, *M. szulgai*, *M, mucogenicum*, *M. kansasii*). Rep-PCR typing; isolate from tap water from tap with an aerator matched the patient ATCC strains for *M. mucogenicum* with more than 93% similarity.

Organism: *Mycobacterium mucogenicum.*

Transmission mode: Intravenous flushes performed on the sink counter from a saline bag that was hanging throughout the day over the sink, instead of using prefilled saline flushes; this is a non-sterile field. The same sink also used for handwashing.

Clinical setting: outpatient haematology clinic, United States of America.

Assessment of evidence
Source: Hospital water supply. Control measures: All aerators removed from taps, staff educated on aseptic procedures away from sinks and need for prefilled saline flushes. No mention of chlorination/other control methods of the actual water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium phocaicum* associated with an outbreak of bacteremias at a Texas hospital. Applied Environmental Microbiology. 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Apr; 74(8): 2480-2487.					
Assessment of evidence					
Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present. Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework. Organism: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* Transmission mode: unconfirmed but all patients had CVCs. Clinical setting: oncology department, United States of America. Source: hospital water supply. Control measures: not described.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Seara N, Oteo J, Carrillo R et al. Interhospital spread of NDM-7-producing Klebsiella pneumoniae	Outbreak report	**Level 3**	This paper describes an interhospital spread of carbapenem-resistant *Klebsiella pneumoniae* (CRKP) producing NDM-7 carbapenemase	Molecular typing result between patient strains and environmental strains isolated from environmental/water samples were compared to	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
belonging to ST437 in Spain. International Journal of Antimicrobial Agents 46 (2015) 169–173			across three hospitals in Spain.	establish a link of infection.	

Assessment of evidence

A total of 7 cases across 3 different hospitals (4 infected, 3 colonised) were categorised as HAI according to CDC definition (supported by admission screening). The median duration from admission to detection of CRKP in these 7 patients was 32 days (range, 21–44 days). Presence of NDM-7 producing *K. pneumoniae* in the traps of the shower and sink.

Organism: *Klebsiella pneumoniae.*

Setting: 3 different hospitals (An acute tertiary hospital, an acute rehabilitation care hospital and a secondary center that provides medical and surgery support to all other hospitals in the Madrid hospital network), Spain.

Transmission: unconfirmed.

Source: sink/shower drain as reservoir for some cases.

Control measures: Active surveillance at admission following first case. cleaning of the sink and shower with sodium hypochlorite, vaporisation of the inner trap with a steam cleaner for 1 min, and pouring 0.1% sodium hypochlorite, 0.1% sodium hydroxide and 0.1% C12–C16 alkyl dimethyl amine oxide down the drain. 2 months later NDM-producing *K. pneumoniae* was still present in the sink trap and consequently the trap was replaced.

Genetic relatedness: PFGE indicated that all CRKP isolates were closely related; MLST showed that all of the isolates belonged to ST437, a single-locus variant of ST11. 5 patients had no overlap of stay but had stayed in same room – this room had colonised sink and shower traps.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lalande V, Barbut F, Varnerot M et al. Pseudo-outbreak of *Mycobacterium gordonae* associated with water from refrigerated fountains. Journal of Hospital Infection (2001) 48: 76–79	Outbreak report	**Level 3**	This paper describes the investigation of a pseudo-outbreak of *M. gordonae* in the chest medicine department of a hospital in France.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

5 cases pseudo-outbreak (contaminated sputum samples, no infection). In total, 129 environmental samples were collected from tap water from patients' rooms (73) nurses' offices (36) and from refrigerated fountains (20). Contamination with *M. gordonae* was observed in 38.4%, 5.6%, and 25% of tap water from patients' rooms, nurses' offices and refrigerated fountains, respectively. Counts were generally low (<10 cfu/150 ml) but the refrigerated fountain counts were high (>500 cfu/150ml).

Organism: *Mycobacterium gordonae.*

Clinical setting: chest medicine, France.

Transmission mode: direct (ingestion of water).

Source: refrigerated water fountain (supported by fact that none of the cases had bronchoscopy examination before the smear-positive specimen and that sputum induction was performed without rinsing their mouth with water, using single-use disposable equipment, and all lab reagents were negative).

Control measures: rubber pipes in water fountains changed -no further cases in following 6 months.

Assessment of evidence
Genetic relatedness: “Pulsed field gel electrophoresis showed an identical pattern for strains isolated from the four patients and for strain isolated from the refrigerated water of the chest unit. Strains from other sources were unique and differed from the epidemic strain.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Durojaiye OC, Carbarns N, Murray S et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 78 (2011) 152–159.	Outbreak report	**Level 3**	This paper reports a nosocomial outbreak of MDR strains of *P. aeruginosa* among 10 patients in a renovated adult ICU in a hospital in the United Kingdom.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence
All the 10 samples collected from the taps, water outlets and water supply to the sinks in the unit grew 300 cfu/100 mL of multidrug-resistant *P. aeruginosa*.
Organism: *Pseudomonas aeruginosa.*
Clinical setting: ICU, Wales.
Transmission mode: unknown. Possible patient-patient indirect transmission as well as environmental.
Source: contaminated taps (newly installed sensor taps)

Assessment of evidence
Control measures: All sinks in the unit decommissioned and portable sinks using bottled water were arranged. All sensor taps in the unit were replaced with conventional non-sensor mixer taps – repeated sampling showed no further contamination and no more cases. Monthly water sampling continued. Limitations: no details of time from admission to positive test. Genetic relatedness: isolates from the water samples showed three different strains of *P. aeruginosa*, two of which matched the strains isolated from patients (variable number tandem repeat).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Engelhart S, Krizek L, Glasmacher A et al. *Pseudomonas aeruginosa* outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment. Journal of Hospital Infection (2002) 52: 93-98	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *P. aeruginosa* associated with contamination of surface cleaning equipment in a hematology-oncology unit in a hospital in Germany.	Molecular typing (PFGE) result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence
A total of 6 Cases identified as nosocomial infection as per CDC guidance. *P. aeruginosa* was isolated from six of 133 (4.5%) `sanitary equipment' samples (taps, 2; washbasin drains, 2; shower water, 1; tap water, 1), and from eight of 40 (20.0%) `surface cleaning equipment' samples (cleaning cloths, 4; mops, 2; cleaning solutions, 2) from both cleaning trolleys. None of 36 samples from dry environmental surfaces yielded *P. aeruginosa.* All water samples were pre-flush. The environmental isolates (11) belonged to seven different PFGE types, two of which (i.e., PFGE types A and C) were identical with the PFGE types of the clinical isolates. Organism: *Pseudomonas aeruginosa.* Clinical setting: haemato-oncology unit, Germany. Transmission mode: unconfirmed (cleaning equipment may have been a vehicle for environmental transmission in the unit). Source: sinks/taps/showers as reservoirs (and potential source) but cannot rule out patient as source for transmission. Control measures: filters fitted to showers and taps, regular disinfection of sink drains using peroxide disinfectant, re-adoption of disinfectants rather than detergents for patients immediate environment. One further case in the following 6 month period. Genetic relatedness: “Genotypic analysis by pulsed-field gel electrophoresis showed different patterns for all (N = 6) of the patient isolates, however, two of the patient isolates were identical in comparison with environmental isolates from cleaning equipment (four samples) and sanitary equipment (one sample).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lowe C, Willey B, O’Shaughnessy A et al. Outbreak of Extended-Spectrum	Outbreak investigation	**Level 3**	This paper describes a retrospective review and investigation of a *K. oxytoca* outbreak in	Molecular typing result between patient strains and environmental strain isolated from	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
β-Lactamase–producing *Klebsiella oxytoca* infections associated with contaminated handwashing sinks. Emerging infectious diseases 18.8 (2012): 1242.			an ICU of an acute tertiary care hospital in Canada.	environmental/water samples were compared to establish a link of infection.	

Assessment of evidence

Among 27 patients, 24 patients had 25 hospital-acquired infections (9 UTI, 4 of them bacteremic; 8 asymptomatic bacteriurias; 4 soft tissue infections, 1 of them bacteremic; 3 primary bacteraemia's; and 1 pneumonia with bacteraemia).

In 11 cases, clinical cultures were preceded by identified rectal colonisation; median time to first identification of a clinical isolate after recognition of colonisation was 10 days (mean 12.5 days, range 1–31 days). Isolates were considered hospital acquired if the first specimen (clinical culture or rectal swab) yielding resistant *K. oxytoca* was obtained >3 days after the admission date or if the specimen was obtained <3 days after admission in a patient who had been hospitalised at the outbreak hospital within the previous 3 months.

Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Organism: Extended-spectrum b-lactamase-producing *Klebsiella oxytoca.*

Clinical setting: ICU, Canada.

Transmission mode: unconfirmed.

Source: sink drains as reservoir.

Assessment of evidence
Control measures: Although intended only for hand hygiene, foot-operated sinks were also used for disposal of fluids, including body fluids. When sinks were identified as a potential reservoir, use of the sinks for hand hygiene only was reinforced. Attempts were made to reduce or eradicate *K. oxytoca* contamination by cleaning sinks and leaving them unused for 48 hours with disinfectant standing in traps. When this process failed, routine daily sink disinfection was initiated; sink surfaces, including taps, rims of sinks, and basins, were cleaned with a 1:16 dilution of Virox and ≈250 mL of the diluted solution was poured down the drain. Neither this daily cleaning, nor month-long trials of cleaning with bleach and with a foaming hydrogen peroxide product, resulted in reduced sink colonization rates. Sink cleaning was increased to 2×/ day in late 2007 and 3×/day in August 2008 but compliance was poor. The average rate of sink contamination during the outbreak period was 16.4% (149/910). After implementation of 3×/day cleaning/disinfection of sinks (October–December 2008), the sink colonisation rate decreased to 3.9% (3/77) during the quarter; the rate increased to 16.7% (71/424) the following quarter (January–March, 2009), when adherence to routine sink cleaning was noted to have decreased. During February–June 2010, all drains were changed, eliminating the connection with the overflow drain; the overflow holes were decommissioned; the strainers in the sink basin were replaced by strainers containing a larger number of smaller holes to reduce backsplash; and sink traps were replaced. These modifications were temporally associated with persistent declines in the rate of clinical infections. Genetic relatedness: Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Davis RJ, Jensen SO, Van Hal S et al. Whole Genome Sequencing in Real-Time Investigation and Management of a *Pseudomonas*	Outbreak report	**Level 3**	This paper describes the use of whole genome sequencing (WGS) to investigate the likely origin of an outbreak of *P. aeruginosa* in a	Molecular typing result (WGS) between patient strains and environmental strain isolated from environmental/water samples were	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa Outbreak on a Neonatal Intensive Care Unit. Infect. Control Hosp. Epidemiol. 2015;36(9):1058–1064			neonatal unit in a hospital in Australia.	compared to establish a link of infection.	

Assessment of evidence

P. aeruginosa was isolated from 8 sinks, including 4 sink drains and 5 sink splashbacks; genetic match to 6 patients. There were 6 patient colonisations and 1 infection.

The diversity in the environmental isolates indicated a large diverse bioburden with the NICU. As neonates do not bring in community acquisition, it is probable that environmental reservoirs were responsible for the colonisations (6 patients WGS was identical).

Organism: *Pseudomonas aeruginosa.*

Clinical setting: NICU, Australia.

Transmission mode: unconfirmed.

Source: sink drains as reservoir.

Control measures: Sinks replaced along with splashbacks that were in one piece and easier to clean. In the following 6 months, only 2 infants were found to be colonised with *P. aeruginosa*, and one of these had an organism that differed phenotypically from the outbreak isolate. Prior to sink replacement, aerators were changed on all taps, sinks cleaned daily with bleach and weekly screening of all babies was initiated.

Limitation: no mention of the water itself being tested at any point.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chapuis A, Amoureux L, Bador J et al. Outbreak of Extended-Spectrum Beta-Lactamase Producing *Enterobacter cloacae* with High MICs of Quaternary Ammonium Compounds in a Hematology Ward Associated with Contaminated Sinks. Front. Microbiol. 7:1070, 2016.	Outbreak report	**Level 3**	This paper describes an investigation of an outbreak of extended-spectrum beta-lactamase (ESBL) producing Enterobacter cloacae in the hematology ward of a University Hospital in France.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.
Assessment of evidence					
A total of 43 patients (10 infected (urine, wound, blood) and 33 colonised). Positive samples in patient shower drains, sink drains; 6 were identical to patient isolates. Biofilm was visible in drains and there were no positive water samples. Organism: *Enterobacter cloacae.* Clinical setting: haematology unit, France.					

Assessment of evidence
Transmission mode: unconfirmed, possible direct contact with water from drain/spray/splash as correlation between contaminated sink and subsequent acquisition in same room. Source: sink/shower drains as reservoir, however patient seeding environment not considered. Control measures: Prior to outbreak, QAC-based disinfectant poured daily into all sinks. Following environmental investigation, a bleach-based disinfection programme was implemented. Biofilm was removed on one occasion from all drains (sinks, showers) but no details given as to method (sinks had to be completely dismantled) – this did not completely eradicate the biofilm as more grew. Possible that below-concentration disinfection (as no contact time with sides of pipes) influenced the decreased susceptibility to QAC disinfectant. Genetic relatedness: "Among the 17 environmental ESBL-producing *E. cloacae* there were 9 distinct pulsotypes and 7 STs. Among the 9 pulsotypes, 6 were identical to those of patients isolates."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bousquet A, Van der Mee-Marquet N, Dubost C et al. Outbreak of CTX-M-15–producing *Enterobacter cloacae* associated with therapeutic beds and syphons in an intensive care unit.	Outbreak report	**Level 3**	This paper describes the investigation of a 4-month outbreak of extended-spectrum β-lactamase-producing *E. cloacae* between July and November 2013 in an ICU in military teaching hospital in France.	Molecular typing result (RAPD) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
American Journal of Infection Control 45 (2017) 1160-4.					
Assessment of evidence					
Total of18 ICU patients affected (8 infected, 10 colonised). Sinks and drains tested positive. Single sink in patient room used for both handwashing and disposal of body fluids, and distance between sink and patient was <1 metre. Hand hygiene with water still being preferred over alcohol gel even when not indicated. Organism: ESBL-*Enterobacter cloacae.* Clinical setting: ICU, France. Transmission mode: unconfirmed. Source: sink drains as reservoir (patients likely the original source). Control measures: replacement of all sinks in rooms, and of contaminated mattresses (patients decanted for this). Genetic relatedness: Molecular typing of the ESBL-ECL isolates using RAPD revealed that all clinical and environmental isolates except 1 had the same RAPD profile and therefore were considered likely clonally related.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al.	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a	Molecular typing result (PFGE) between patient strains and	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrobial Resistance and Infection Control (2017) 6:24			teaching hospital in Belgium.	environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Genetic relatedness.

Assessment of evidence

A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission).

Sink drain in this room was positive, as was every other isolation room on the unit.

Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc).

Organism: Enterobacteriaceae.

Clinical setting: ICU, Belgium.

Transmission mode: unconfirmed.

Source: sink drain as reservoir (and likely source for some patients).

Assessment of evidence
Control measures: daily disinfection of the sinks with a glucoprotamine product was implemented; sinks were dedicated to 'clean work' (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere. Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kossow A, Kampmeier S, Willems S et al. Control of Multidrug-Resistant *Pseudomonas aeruginosa* in Allogeneic Hematopoietic Stem Cell Transplant Recipients by a Novel Bundle Including Remodeling of Sanitary and Water Supply Systems.	Prospective outbreak investigation	**Level 3**	This paper describes the study of microbiological surveillance data on *MDRPa* for 3 years during the reconstruction of a Bone marrow transplantation center in Germany.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Clinical Infectious Diseases, 65(6); 935-942, 2017					

Assessment of evidence

The number of nosocomially-infected patients decreased from 31 in 2012-13 (9.17%) to 3 (1.68%) in 2014 ($p<0.001$).

In 2012-13, 18.94% of toilet samples were positive, 8.11% of shower samples were positive. This decreased to 6.13% of toilets and 2.96% showers in 2014 (both statistically significant reductions). During follow up, 4% of toilets and 5.59% of showers were positive. Sinks tested positive in 0.93% samples in 2012-13 and in zero samples in 2014.

Patients screened on admission and weekly thereafter. WGS indicated a close relationship between patient and environmental isolates however unable to determine exact transmission pathways.

Organism: Multi-drug resistant *Pseudomonas aeruginosa.*

Clinical setting: haematopoietic stem cell transplant unit, Germany.

Transmission mode: unconfirmed.

Source: shower drains and toilets as potential reservoirs, unable to determine exact modes of transmission however this study provides evidence that patients acquired infection likely from an environmental source.

Control measures: New shower drains installed (easy to clean/disinfect) with covers (disinfected weekly) to prevent removal by patients. Shower heads and taps fitted with point of use filters. Biorec disinfection units installed underneath all sinks (these use UV light, vibration (50-200 Hz), temperature (85'C) and have an antibacterial coating to prevent biofilm formation. Toilets replaced with rimless toilets and an automatic disinfectant flush (0.5% glucoprotamin).

Limitations: some patients not screened weekly due to their clinical situation. Culture method may not have maximised growth of admission screening samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ito K, Honda H, Yoshida M, et al. A metallo-beta-lactamase producing Enterobacteriaceae outbreak from a contaminated tea dispenser at a children's hospital in Japan. Infection Control & Hospital Epidemiology (2019), 40, 217–220	Outbreak report	**Level 3**	This study reported the investigation of an outbreak of metallo-beta-lactamase producing Enterobacteriaceae in a pediatric ward at a Children's medical center in Japan.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence

Five patient cases. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). *K. pneumoniae* strains isolated from the clinical and environmental samples all harbored the blaIMP-1 gene. A core-genome single nucleotide polymorphism (SNP)–based phylogenetic analysis revealed that 33 of the blaIMP-1-positive *K. pneumoniae* strains had a common ancestor.

No water contamination in any other areas of hospital.

Organism: MBL-producing Enterobacteriaceae (*Klebsiella pneumoniae*).

Transmission mode: potentially direct (ingestion of contaminated tea) and indirect (from environment/hands/equipment).

Clinical setting: paediatric cardiology/ophthalmology ward, Japan.

Assessment of evidence
Source: tea dispenser identified as a potential reservoir along with 2 sinks Control measures: Banning of use of public areas such as playroom and dining hall, reinforcement of appropriate standard and contact precautions, increase of routine cleaning of sinks and frequently touched areas using 0.1% hypochlorite from 1 to 3 times daily. The tea dispenser was also removed. Noted that domestic staff were not adequately educated/trained on hand hygiene. Outcome: “No MBL-producing Enterobacteriaceae were isolated from patients admitted to the ward or occupying the ward environment after banning the use of the tea dispenser.” Limitations: no details given on whether the sinks remained contaminated after the tea dispenser was removed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Botana-Rial M, Leiro-Fernández V, Núñez-Delgado M, et al. A pseudo-outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* in a bronchoscopy unit. Respiration. 2016;92(4):274-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas putida* and *Stenotrophomonas maltophilia* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Pseudomonas putida* and *Stenotrophomonas maltophilia* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence
From the information provided by the authors, it is not possible to conclude that the source of the outbreak were the bronchoscopes or the AERs. *Pseudomonas putida* and *Stenotrophomonas maltophilia* were also isolated from sinks, cleaning brushes and cleaning solutions. Thus, although the authors found AERs to be contaminated it is not certain that this was the source. This study provides evidence that inadequate disinfection of bronchoscopes can lead to infections/colonization in patients. As the reprocessors were contaminated, the bronchoscopes became contaminated when they were being reprocessed – then when these were used on the patients, the patient samples tested positive (pseudo-outbreak, as no true colonisation/infection). Organism: *Pseudomonas putida* and *Stenotrophomonas maltophilia.* Transmission mode: indirect contact (contaminated equipment). Clinical setting: bronchoscopy unit, Spain. Source: Contaminated water-based equipment (automated endoscope reprocessor).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wong V, Levi K, Baddal B, et al. Spread of *Pseudomonas fluorescens* Due to Contaminated Drinking Water in a Bone Marrow Transplant Unit.	Outbreak study	**Level 3**	This study reports the findings of the epidemiological and microbiological investigation of a *Pseudomonas fluorescens* outbreak.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Clinical Microbiology 2011, 49(6), 2093-2096.					

Assessment of evidence

Nine patient cases, 6 of this developed febrile neutropenia. All had positive pharyngeal samples. Water sample from a water dispenser in the unit tested positive and genetically matched the patient isolates. All other environmental samples were negative.

Organism: *Pseudomonas fluorescens.*

Clinical setting: bone marrow transplant unit, England, UK.

Transmission mode: direct (ingestion).

Source: chilled water dispenser as reservoir, unclear how it became contaminated (authors theorised that the nozzle may have been touched by contaminated hands).

Control measures: Removal of the contaminated chilled water dispenser (the remaining one was kept). The long-term plan for the unit is to install filtered plumbed-in main water dispensers and to implement regular qualitative and quantitative water assessments.

Genetic relatedness: All nine patient isolates and the one environmental isolate were identified as being *Pseudomonas fluorescens*. “The isolate from the water dispenser was found to be genotypically identical to the patients’ isolates: all isolates of *P. fluorescens* produced identical RAPD patterns (type b pattern), and typing by PFGE revealed that all isolates recovered were indistinguishable, with a designated profile of NOTT PF1.”

Limitations: Water was sampled via the nozzle of the chiller unit and not directly from the bottle before or after installation, so unclear where the contamination originated from.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Carbonne A, Brossier F, Arnaud I et al. Outbreak of Nontuberculous Mycobacterial Subcutaneous Infections Related to Multiple Mesotherapy Injections. Journal of Clinical Microbiology 47(6); 1961-4, 2009.	Outbreak report	**Level 3**	This paper describes an outbreak of severe subcutaneous infection due to NTM following mesotherapy in a clinic in France.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Odds ratios. Genetic relatedness.

Assessment of evidence

A total of 16 cases (12 certain, 4 probable) of NTM skin infection. Tap water samples from the room where mesotherapy had been performed showed 2,400 CFU/litre of *M. chelonae.*

Organism: *Mycobacterium chelonae.*

Setting: private mesotherapy clinic, France.

Transmission route: direct (injection).

Source: tap water (via inappropriately decontaminated injector device).

Control measures: not described.

Assessment of evidence
Genetic relatedness: “The PFGE patterns of *M. chelonae* isolates from 11 mesotherapy patients and from tap water in the medical examination room showed 100% similarity indexes by Dice analyses and were considered indistinguishable”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chroneou A, Zimmerman SK, Cook S et al. Molecular typing of *Mycobacterium chelonae* isolates from a pseudo-outbreak involving an automated bronchoscope washer. Infect Control Hosp Epidemiol 2008; 29:1088-90	Outbreak report	**Level 3**	This paper describes a pseudo-outbreak of *M. chelonae* in bronchoalveolar lavage fluid from 9 patients traced to a contaminated automated bronchoscope washer in a medical center in the United States of America.	Molecular typing result (REP-PCR) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 9 patients with positive bronchoalveolar lavage fluid specimens. None had symptoms or infection (Pseudo-outbreak). Incoming water supply and a bowl drain from the automated washer matched the 9 patient isolates (>90% similarity with REP-PCR). Organism: *Mycobacterium chelonae.*

Assessment of evidence
Clinical setting: bronchoscopy, United States of America. Transmission mode: from water supply via contaminated automated washer. Control measures: Automated washer removed from service, and new one purchased. Responsibility for changing filters assigned to biomedical staff and changed every month rather than twice per year. Authors state this eliminated the strain but not clear how this was known. Genetic relatedness: “REP-PCR findings demonstrated a greater than 90% similarity among the isolates associated with the 9 patients…, the 2 environmental isolates recovered from the drain bowl…, and the isolate recovered from the incoming water supply/”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Vijayaraghavan R, Chabdrashekhar R, Sujatha A et al. Hospital outbreak of atypical mycobacterial infection of port sites after laparoscopic surgery. Journal of Hospital Infection (2006) 64, 344-347	Outbreak report	**Level 3**	This paper describes an outbreak of atypical mycobacterial infections (AMI) in 35 patients following laparoscopy over a six-week period in a hospital in India.	N/A	Number of positive environmental and clinical isolates. Genetic relatedness.

Assessment of evidence
A total of 35 patients infected out of 156 subjected to laparoscopy over a 6-month period, all surgery by same team. Water samples taken from the scrub area, water used for the manual cleaning of instruments, and rinsing water (obtained from the hospital water supply system, boiled and cooled, and subsequently stored in autoclaved glass bottles) used for rinsing instruments taken out of the chemical disinfectant trays. Swabs taken from chemical disinfectant and prepping solutions, vapour sterilisation chambers, OR tables, theatre lights, walls/floors of OR, reusable sleeves of laparoscopy instruments, suture mesh samples, valves of CO2 cylinders/insufflator. Scrapings taken from biofilm layers from the bottom of chemical disinfectant trays, the water supply pipes and water baths for boiling rinsing water. The chemically disinfected laparoscopy instruments were rinsed with the boiled-cooled, autoclaved water prior to the operative procedure; this prepared water was contaminated with NTM (unclear how it because contaminated as NTM are likely to be killed by boiling temperatures). The mains water supply was negative. Organisms thriving within biofilm in the bottom of the disinfectant trays (which were positive) likely also re-contaminated the freshly prepared disinfectant. Organism: *Mycobacterium chelonae.* Clinical setting: OR (laparoscopy), India. Transmission mode: indirect Source: contaminated water-based equipment. Control measures: Contaminated water samples and glutaraldehyde solutions were re-autoclaved and placed in formaldehyde vapour sterilization chambers overnight; AFB were identified in all samples. Since the organism survived autoclaving, formaldehyde vapour sterilization and chemical disinfection with glutaraldehyde, ethylene gas oxide sterilization was used; following this, no viable organisms were identifiable. Limitations: While it is stated that ‘similar isolates’ [to the patient ones] were recovered from the environmental samples, typing was not conducted to confirm an exact match. However, the epi evidence is strong enough to implicate the contaminated equipment as the source.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease: The control of *Legionella* bacteria in hot and cold water systems. L8. 2013.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides the approved code of practice and guidance on regulations regarding Legionnaires' disease. The following section(s) are relevant for this research question on how routine water test results should be interpreted.

"Legionnaires' disease is normally contracted by inhaling small droplets of water (aerosols), suspended in the air, containing the bacteria. Certain conditions increase the risk from legionella if:

(a) the water temperature in all or some parts of the system may be between 20–45 °C, which is suitable for growth;

(b) it is possible for water droplets to be produced and if so, they can be dispersed;

(c) water is stored and/or re-circulated;

(d) there are deposits that can support bacterial growth, such as rust, sludge, scale, organic matter and biofilms."

Question 4: Which patient populations are considered as being at increased risk of colonisation/infection with a healthcare water system-associated organism?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and Environmental Microbiology 2019 *85*(22), e01435-19	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing.	Sample type, amount of positive samples, CFU counts, MIC, PFGE type.
Assessment of evidence					
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca.*					

Assessment of evidence
Transmission mode: contaminated water-based equipment. Clinical setting: perinatal setting/childrens hospital. Source: isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Control measures: environmental monitoring, admission screening, IPC training HCWs, renovation/contamination sinks, etc. All garments worn by newborns and children were laundered by professionally service. The washing machine was removed. The use of professional washing machines and routine checking with a temperature logger are urgent requirements.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jung J, Choi HS, Lee JY, et al. Outbreak of carbapenemase-producing Enterobacteriaceae associated with a contaminated water dispenser and sink drains in the cardiology units of a Korean hospital.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a carbapenemase-producing Enterobacteriaceae outbreak in Korea and to find the risk factors for acquiring CPE.	Epidemiologic links between patients and potential environmental sources.	Number of positive samples, sample type, typing (PFGE analysis).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection 2020; 104: 476-483.					
Assessment of evidence					
Sinks in patient rooms and water dispenser acted as reservoirs (PFGE confirmed) The water dispenser for provision of water to patients was located near a handwashing sink; of note, used dialysing solution after haemodialysis was emptied into this handwashing sink. Organism: CPE, *Citrobacter freudii, Enterobacter cloacae.* Transmission mode: contaminated water systems. Clinical setting: cardiology ICU. Source: not confirmed. Control measures: Sink drain treated with bleach (5500 ppm), water dispenser removed and water replaced with bottled water. All sink drains in the ICU were replaced.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M, et al. Pseudo-outbreak of *Mycobacterium chimaera* through aerators of hand-	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera.*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water	Number of positive samples, sample type, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
washing machines at a hematopoietic stem cell transplantation center. Infection Control and Hospital Epidemiology 2019; 40: 1433-1435.				samples were compared.	

Assessment of evidence

Outbreak investigation. A genetic relationship was found between the clinical and environmental isolates.

Organism: *M. chimaera.*

Transmission mode: contaminated water systems.

Clinical setting: stem cell transplantation center.

Source: biofilm on the aerators of the handwashing machines in each patient's room.

Control measures: Regular replacement of faucet parts can prevent biofilm formation and pseudo-outbreaks of M. chimaera through aerators. Communication with facilities maintenance personnel including officers and mechanics, and we improved the procedure for managing the units to incorporate routine work to replace aerators and their related parts every 6 months.

Definition of pseudo-outbreak not defined. From context in paper it seems to refer to cases who do no experience clinical illness.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
de Jonge E, de Boer MGJ, van Essen EHR, et al. Effects of a disinfection device on colonization of sink drains and patients during a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 2019; 102: 70-74	Outbreak investigation	**Level 3**	The aim of this study was to study the influence of installing disinfecting devices on sink drains on colonization of sinks and patients in a Dutch ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa.*	Isolated cultures of multidrug-resistant *P. aeruginosa.* before and after the 'intervention' (installation of disinfecting devices).	Number of positive samples, sample type.

Assessment of evidence

The 'intervention' setting was an active ICU unit therefore not controlled or randomised: low quality evidence.

These devices appeared to be successful at decreasing the colonisation rates of sink drains however they were not 100% effective; some sink drains occasionally tested positive for MDR-PA. This suggests that other components/distal regions of the sink plumbing remained colonised

Organism: multidrug-resistant *Pseudomonas aeruginosa.*

Transmission mode: contaminated water systems.

Assessment of evidence
Clinical setting: ICU. Source: sink drains. Control measures: IPC.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Decraene V, Phan HTT, George R, et al. A large, refractory nosocomial outbreak of *klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* demonstrates carbapenemase gene outbreaks involving sink sites require novel approaches to infection control.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	23 CRE-colonised heart patients, 2 infections (UTI, SSI).	Positive samples: 850 total samples taken from sink/drain/shower/ bath sites, 18 from toilets, hoppers or sluices, 33 from high-touch sites (keyboards, door handles, sponges). 85 samples positive, including shower drains, sink taps, sink drain tailpieces, sink drain strainers, sink trap water, toilet bowls.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Antimicrobial Agents and Chemotherapy 2018; 62 (12).					

Assessment of evidence

Outbreak report, molecular typing confirmed link between patient cases and environment. Source not identified but sink drains identified as reservoirs, likely biofilm formation.

The authors state: “Current guidelines do not address the control of large persistent outbreaks or provide advice on the sampling and management of environmental reservoirs, and there is limited evidence in support of any given measure.”

Organism: *Klebsiella pneumoniae* Carbapenemase-Producing *Escherichia coli* (Carbapenem-resistant Enterobacteriaceae (CRE))

Transmission mode: contaminated water systems.

Clinical setting: Heart Centre. Manchester.

Source: not confirmed; sink drain identified as reservoirs, likely biofilm formation.

Control measures: Sink trap replacement for colonised sinks, horizontal pipework cleaning with a brush to remove biofilm. Replacement of the plumbing infrastructure back to the central drainage stacks. Replaceable sink plughole devices designed to prevent water aerosolisation in the sink U-bend and to limit biofilm formation (HygieneSiphon; Aquafree) were installed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW and Holden E. Waterborne *Pseudomonas*	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the UK (including	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated	Number of positive samples, sample type, typing results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa transmission in a hematology unit? American Journal of Infection Control 2018; 46: 383-386.			finding the source) and to determine the impact of infection prevention and control measures.	from environmental/water samples were compared.	
Assessment of evidence					
Outbreak report – molecular typing conducted (PFGE). Transmission of *Pseudomonas aeruginosa*; transmission route via prep trays from contaminated water outlet. Hickman lines entry route. Organism: *Pseudomonas aeruginosa.* Transmission mode: contaminated water systems. Clinical setting: hematology unit, UK. Source: transmission route via prep trays from contaminated water outlet. Hickman lines entry route. Control measures: POU filters were installed on all outlets in the hematology ward. Filters were already on all outlets apart from those in the intravenous prep room. Trays were cleaned with quaternary ammonium compound wipes (Clinell Universal wipes, GAMA Healthcare UK) and dried thoroughly.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW, Tracey J, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas*	Molecular typing results between patient strains and	Clinical surveillance of *P. aeruginosa* infection took place.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Continued transmission of *Pseudomonas aeruginosa* from a wash hand basin tap in a critical care unit. Journal of Hospital Infection 2016; 94: 8-12.			*aeruginosa* cluster in the burns room of a critical care unit in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	*Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Water samples from all tap outlets in the unit were collected as per HTM 04-01. All isolates were typed.

Assessment of evidence

Genotyping conducted. Tap was found to be contaminated. Unable to determine the exact transmission route.

The authors state that remedial actions to decontaminate the tap as recommended by the National 04-01 addendum were insufficient.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: not determined exact transmission route.

Clinical setting: critical care unit (burn unit) UK.

Source: Contaminated water system. Tap was found to be contaminated.

Control measures: Control measures at UHB include disposal of waste water in the sluice where possible, and, if not, the use of absorbent gel sheets to solidify patient waste water being disposed of in a macerator.

The new cleaning method, developed by the housekeeping staff and infection control, involves a three-cloth cleaning technique to reduce contamination.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Regev-Yochay G, Smollan G, Tal I, et al. Sink traps as the source of transmission of OXA-48–producing *Serratia marcescens* in an intensive care unit. Infection Control & Hospital Epidemiology. 2018 Nov;39(11):1307-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *OXA-48–producing Serratia marcescens* in the ICU in Israel (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *S. marcescens* isolated from environmental/water samples were compared.	Number of patients with CPE infection/colonisation and their clinical characteristics, environmental samples (source, results and number of isolates), typing results (PFGE).

Assessment of evidence

Extensive control measures were put in place and carried out, but contamination of sinks seemed to be recurring. Using a combined intervention (including educational component, reducing environmental contamination load) the outbreak was contained 12 months after the start of the outbreak.

Organism: CPE, *S. marcescens* (OXA-48–producing *S. marcescens*).

Transmission mode: indirect contact of the sinks.

Clinical setting: ICU.

Source: sink.

Assessment of evidence
Control measures: enhanced control measures were undertaken, including increased hand hygiene observations as well as educational sessions. Thorough cleaning of all surfaces and medical devices with 1,000 PPM sodium hypochlorite and quaternary ammonium, accordingly, was carried out. After identification of the sink as the source of transmission: 2 main measures were carried out: (1) sink-trap decontamination efforts and (2) an educational intervention enhancing specific infection control measures and focusing on the sink as a source of transmission. All sink traps were replaced, water supply was treated according to Legionella protocol (heating and hyper chlorination of the main water tank and terminal points for 12 hours with free residual chlorine (20–30 mg/L).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Watkins LK, Toews KA, Harris AM, et al. Lessons from an outbreak of Legionnaires' disease on a hematology-oncology unit. Infection control & hospital epidemiology. 2017 Mar;38(3):306-13.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of Legionnaires' disease on a hematology-oncology unit (including finding the source) and to determine the impact of infection prevention and control measures.	Clinical and environmental isolates were compared by monoclonal antibody and sequence-based typing.	Number of positive samples, sample type, typing results (monoclonal antibody and sequence-based typing)
Assessment of evidence					
Investigation suggests that the potable water system was the likely source of infection. Lp1 strains isolated from water on the unit were indistinguishable from all 3 clinical specimens by SBT.					

Assessment of evidence

The median time between symptom onset and *Legionella* testing was 8.5 days (range, 0–65 days)

The authors suggest that a single case of LD that is definitely healthcare associated should prompt a full investigation. No further cases were identified after implementation of 0.2um point-of-use filters.

Lessons learned from this outbreak:

- hospital had legionella water management program, however providers were not routinely notified of positive environmental testing results. Clinicians may therefore have been less likely to include diagnostic testing for LD in their initial management of patients
- regular clinician education should be integral part of a hospitals *Legionella* water management program
- some cases were incorrectly misclassified as community acquired rather than HAI

Organism: *Legionella.*

Transmission mode: indirect contact.

Clinical setting: hematology-oncology unit.

Source: contamination of the unit's potable water system (contaminated water systems).

Control measures: water restrictions (limiting contact with the affected building potable water to washing visibly soiled hands) were implements for all patients, visitors and staff. Bottled water was provided for drinking and hygiene activities, and alcohol-based hand sanitizer was provided for routine hand cleansing. Water restrictions were lifted once 0.2 um PoU filters were obtained for all sinks, shower heads, and ice machines.

Remediation of the potable water system was initiated once environmental samples were obtained and consisted of superheating each of the 3 water-riser systems to 160°F, flushing, and hyperchlorination (a chlorine injection system was installed for emergency remediation). Ongoing monitoring of chlorine at points of use and follow-up sampling with subsequent remediation as needed were advised.

Assessment of evidence
Limitations: only confirmed cases were included in the study; potentially underestimating the actual extent of the outbreak. No control group was included. Unable to determine which of the measures was responsible for ending the outbreak as all measures were implemented simultaneously.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence
The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (including. presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff.

Assessment of evidence
Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room Organism: *Pantoea agglomerans.* Transmission mode: indirect/aerosolisation. Clinical setting: oncology clinic. Source: pharmacy sink, however primary source associated with this, not identified. Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping. Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding. Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods. Chemotherapy preparations were moved off-site and improved the building water system. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak	Molecular typing results between patient strains and *P. aeruginosa* isolated	Positive patient samples, positive environmental (water

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit. Journal of hospital infection. 2016 Sep 1;94(1):2-7.			(including finding the source) and to determine the impact of infection prevention and control measures.	from environmental/water samples were compared to establish a link of infection.	and tap) samples, genotyping (DLST).
Assessment of evidence					
Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit. *Pseudomonas aeruginosa* has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients. Organism: *Pseudomonas aeruginosa.* Transmission mode: Contaminated environment, however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission. Clinical setting: ICU – burn unit.					

Assessment of evidence
Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa. Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily. Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aspelund AS, Sjöström K, Liljequist BO, et al. Acetic acid as a decontamination method for sink drains in a nosocomial outbreak of metallo-β-lactamase-producing *Pseudomonas aeruginosa*.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2016 Sep 1;94(1):13-20.					
Assessment of evidence					
Typing was performed. PA was found in 4/9 drainpipes that were cultured after replacement of the sinks, indicating a reservoir further down the pipes. Typing of clinical and sink drain isolates revealed identical or closely related strains. Organism: *Pseudomonas aeruginosa.* Transmission mode: indirect contact; (likely splashing of the water in the sink or similar). Clinical setting: three different wards in University hospital in Sweden. Source: sink drains (and further down in the pipes). Control measures: Replacement of contaminated sinks, awaiting replacement acetic acid was poured once weekly into colonized sink drains. Following this, all sinks and plumbing's were changed. Acetic acid treatment was then terminated. Hot water flushing of drainpipes, change of sink drain, siphon, and pipes to the wall were changed at the same time.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Litvinov N, da Silva MT, van der Heijden IM, et al. An outbreak of invasive fusariosis in	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of invasive fusariosis in Brazil and to determine the impact of infection	Molecular typing results between patient strains and *Fusarium* spp. isolated from environmental/water samples were	Positive patient samples, positive environmental samples, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
a children's cancer hospital. Clinical Microbiology and Infection. 2015 Mar 1;21(3):268-e1			prevention and control measures.	compared to establish a link of infection.	

Assessment of evidence

Outbreak was only controlled 1 year after the first case, when water filters filtering 0.2 um were installed at the exit of all faucets and showers in all patient rooms (PoU).

Organism: *Fusarium.*

Clinical setting: children's cancer hospital.

Source: hospital water (contaminated water systems).

Control measures:

- interruption of new admissions to the unit during 47 days
- transfer of the hospitalized patients to another unit in another building of the hospital
- renovation of rooms and bathrooms with closure of the communications between service floors and patient rooms; ceiling panels were replaced with plaster ceilings
- disconnection of central hot water reservoir and installation of electric instant heating devices
- cleaning of cold water reservoirs with chlorine and continuous chlorination of water in the reservoirs (1.5 ppm) controlled by a chlorination device
- Filtration of water before entry into water reservoirs (10- µm filters)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leitner E, Zarfel G, Luxner J, et al. Contaminated handwashing sinks as the source of a clonal outbreak of KPC-2-producing *Klebsiella oxytoca* on a hematology ward. Antimicrobial agents and chemotherapy. 2015 Jan 1;59(1):714-6	Outbreak investigation	**Level 3**	The aim of this study was to investigate a KPC-2-producing *Klebsiella oxytoca* clonal outbreak on a hematology ward in Austria and to determine the source.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results (MLST).

Assessment of evidence

Authors conclude that the starting point of this outbreak started with a colonized patient from the ICU who was later transferred to the hematology ward.

It is hypothesized that KPC-2-producing *K. oxytoca* got into the sink most likely during personal hygiene activities or by disposal of contaminated body fluids, where it persisted. Authors also hypothesise that patients were contaminated by aerosols when using the sink although this is not proven from the study.

Organism: *Klebsiella oxytoca.*

Transmission mode: indirect/aerosolisation.

Clinical setting: hematology ward.

Assessment of evidence
Source: handwashing sink.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wolf I, Bergervoet PW, Sebens FW, et al. The sink as a correctable source of extended-spectrum β-lactamase contamination for patients in the intensive care unit. Journal of Hospital Infection. 2014 Jun 1;87(2):126-30.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonization of extended-spectrum b-lactamase-positive bacteria (ESBLs) in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures (for example self-disinfecting siphons).	Molecular typing results between clinical strains and ESBLs isolated from environmental/water samples were compared to establish a link of colonization.	Number of positive samples, sample type and species, genotyping results (AFLP).

Assessment of evidence
Patients were not infected but colonized. ESBLs originating from sinks in patient's rooms were linked to patients who stayed in ICU. Organism: extended-spectrum b-lactamase-positive bacteria (ESBLs). Transmission mode: assuming indirect contact; however this is not confirmed from the study. Clinical setting: ICU.

Assessment of evidence
Source: sink (contaminated water systems). Control measures: All 13 siphons from sinks in the ICU patient rooms and five siphons from sinks at other locations where medical workers wash their hands frequently (two toilets, the medication room, the scullery room and the staff room) were replaced. To monitor the effect of this intervention, all 18 sinks were sampled for the presence of ESBL 1,2,3,4,6,8 months after the intervention. During month 8, samples were cultured non-selectively to determine the whole microbial flora present in the sinks. Limitation: Positive clinical strains were only compared to isolates taken from sinks. Therefore it can be argued that the sink was the actual source, or whether it might have been the reservoir.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lucero CA, Cohen AL, Trevino I, et al. Outbreak of *Burkholderia cepacia* complex among ventilated pediatric patients linked to hospital sinks. American journal of infection control. 2011 Nov 1;39(9):775-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* complex outbreak and to determine the source.	Molecular typing results between clinical strains and *B cenocepacia* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type and species, bionumeric analysis, genotyping results (PFGE).

Assessment of evidence
B. cenocepacia was not cultured directly from hospital water, but its recovery from drains suggest that the organism was present either in the water or in contaminated products placed in sinks. Organism: *B cenocepacia.* Transmission mode: indirect contact. Clinical setting: ICU - ventilated paediatric patients. Source: sink drains and ventilation components. Control measures: not reported.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient. Organism: *Mycobacterium mucogenicum.* Transmission mode: indirect/aerosolization. Clinical setting: University-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients. Source: water contamination of central venous catheters (CVCs) during bathing Control measures: • replace showerheads and hoses on the BMT inpatient units. Optimal frequency of showerhead and hose replacement is undetermined • allow shower hoses to hang straight with no dependent loops when not in use to decrease the risk of bacteria multiplying to higher levels in stagnant water • educate all direct care providers, patients, and family members on the risks of water contamination of CVCs during bathing and on prevention methods to use during bathing to minimize water contact • disconnect IV catheters prior to bathing when possible If catheters cannot be disconnected, then cover connections with waterproof materials.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pena C, Dominguez MA, Pujol M, et al. An outbreak of carbapenem-resistant	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Pseudomonas*	Molecular typing results between clinical strains and Carbapenem-resistant	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa in a urology ward. Clinical microbiology and infection. 2003 Sep;9(9):938-43.			*aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	*Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	
Assessment of evidence					
Typing indicated that the CRPA outbreak resulted from the contamination of the cystoscopy room via an unsealed drain. The outbreak ended when the drain was sealed. Organism: Carbapenem-resistant *Pseudomonas aeruginosa.* Transmission mode: indirect contact. Clinical setting: cystoscopy room. Source: unsealed drain. Control measures: Strict adherence to disinfection protocol. Examination of cystoscopy room and repairs were undertaken. Surgical drape should only be used once, and the open drainage of the floor should be provisionally closed.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al.	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between	Molecular typing results between clinical strains and *P.*	Number of positive samples, sample type, relationship

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Analysis of transmission pathways of *Pseudomonas aeruginosa* between patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.			*Pseudomonas aeruginosa* infection and faucet contamination in a surgical ICU.	*aeruginosa* visolated from environmental/water samples were compared to establish transmission pathways.	between genotypes (RAPD).

Assessment of evidence

The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed.

Organism: *Pseudomonas aeruginosa.*

Transmission mode: Indirect (potentially hands of HCWs, transfer of colonized patients between wards, splashing of water around the washbasin).

Clinical setting: SICU and other surgical wards.

Source: individual faucets.

Control measures: an intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention.

Infections caused by PA: Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonized with *P. aeruginosa* were wounds and the pharynx.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a haemato-oncology unit. Journal of Hospital Infection, 79; 339-343. 2011.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in Edinburgh and to determine the impact of infection prevention and control measures.	N/A	Number of positive samples, sample type and species.

Assessment of evidence

Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.)

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: haemato-oncology unit.

Source: water system.

Control measures: The cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet

Assessment of evidence
rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced. Limitations: no matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence
Organism: *Mycobacterium mucogenicum.* Source: contaminated automatic water tap. Clinical setting: paediatric haemato-oncology. Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet. Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.

Assessment of evidence
Organism: *Mycobacterium abscessus.* Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients. Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gbaguidi-Haore H, Varin A, Cholley P, et al. A Bundle of Measures to Control an Outbreak of *Pseudomonas aeruginosa* Associated with P-Trap Contamination. Infect Control Hosp Epidemiol. 2018;39(2):164-169. doi:10.1017/ice.2017.304	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in France including finding the source and to report on the bundle of control measures.	Molecular typing of ESBL- or MBL-producing isolates (patient vs environmental isolates) using pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing (MLST).	Incident rate, infected/colonised patient characteristics, positive cultures (patient and environmental), molecular genotyping.

Assessment of evidence

Organism: *Pseudomonas aeruginosa.*

Clinical setting: patients in haematology units are at increased risk of *P. aeruginosa* infection/colonisation.

Source: likely reservoir of the outbreak organism were the P-traps.

Control measures: The authors mention that a number of control measures (a bundle) successfully stopped the outbreak. However, the effect of these measures is not included in the study, these are just mentioned in the discussion section.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Wafer T, et al. Investigation and control of an outbreak due to a contaminated hospital water system, identified following a rare case of *Cupriavidus pauculus* bacteraemia. J Hosp Infect. 2021;111:53-64. doi:10.1016/j.jhin.2021.02.001	Outbreak investigation	**Level 3**	The aim of this study was to investigate rare case of *Cupriavidus pauculus* bloodstream infection (incl finding the source) which led to the investigation and control of a contaminated water system in a new build hospital due to another 22 patients infected with waterborne pathogens in the following few months.	N/A	Water/Environmental contamination - The unit undertook frequent water testing and had prior agreed cut-off levels of <10 cfu/mL at 37°C and, <100 cfu/mL at 22°C.

Assessment of evidence

This study initially investigated a *Cupriavidus pauculus* bloodstream infection in an immunosuppressed patient which turned into the investigation and control of a contaminated water system in a new build hospital due to another 22 patients infected with waterborne pathogens in the following few months.

Clinical setting/Patient population at risk: haemato-oncology ward. All patients were paediatric haemato-oncology patients with either underlying haematological or solid tumor malignancy. All patients had Hickman lines in situ and required treatment with intravenous

Assessment of evidence
antibiotics and in most cases line removal. Only sporadic cases of infection were found in the adult population and this might be due to behavioural factors of children such as splashing while washing (hands) and small toys pushed down drains. Due to their smaller appearance, the central line sites are closer to outlets, drains and toilets. Limitations: • described as one incident categorised in 3 phases which were all separate outbreaks (different organisms) – this makes it slightly unclear • not all water samples were sent for typing. Neither were multiple colonies selected from each agar plate for typing. Therefore, it is not clear what the exact source was of the patient infections • combination of control measures makes it difficult to determine which part was responsible for the impact

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jolivet S., Couturier J., Vuillemin X., et al. Outbreak of OXA-48-producing Enterobacterales in a haematological ward associated with an uncommon environmental reservoir, France, 2016 to 2019.	Outbreak investigation (including case-control element)	**Level 3**	The aim of this study was to investigate a OXA-48-producing Enterobacterales outbreak in France (including finding the source) and to determine the impact of infection prevention and control measures.	Phylogenetic properties of isolates and epidemiologic links between patients and environmental sources.	Number of clinical cases with OXA-48-producing Enterobacterales infection or colonisation in the haematological ward. Contamination/ growth of CPE in environmental samples. Antimicrobial

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Euro Surveill. 2021;26(21):pii=2000118					resistance and typing.

Assessment of evidence

This outbreak highlights the possible role of toilets as a source of transmission of OXA-48 CPE. It was successfully controlled only after replacing all the toilets in the ward.

Organism: A total of 78 OXA-48 CPE were detected including 22 *C. freundii*, 19 *E. coli*, 15 *K. pneumoniae*, seven *Klebsiella oxytoca*, six *Enterobacter cloacae*, two *Citrobacter koseri*, two *Enterobacter aerogenes*, one *Hafnia alvei*, one *Kluyvera cryocrescens*, one *Citrobacter amalonaticus*, one *Morganella morganii*, and one *Raoultella ornithinolytica*

Transmission mode: indirect contact (toilet splashback).

Clinical setting: haematological ward of a French hospital.

Source: toilets rims.

Control measures: Following the identification of the toilets as a potential source of the outbreak, intensive toilet cleaning with descaling and bleaching (initially daily, then weekly) was implemented. Afterwards, 23 environmental samples were taken (including 21 toilet rims and two drains), and only one toilet remained positive for OXA-48-producing *C. freundii*. This toilet was successfully re-decontaminated by performing a single additional cleaning and bleaching. In August 2018, all toilets bowls and tanks in two units with environmental CPE-positive samples were replaced by rimless toilets.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler M. A., Osman F., Marx J. J., et al.	Outbreak investigation	**Level 3**	An epidemiological and laboratory investigation of a	Molecular genotyping results (WGS) between	Case-control study: ICU admission, 30-day mortality and 90-

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hospital-acquired *Legionella pneumonia* outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020	(including case-control element)		hospital-acquired *Legionella pneumonia* outbreak at of The University of Wisconsin Hospital. Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia*	patient strains and *L. pneumonia* isolated from environmental/water samples were compared to establish link of colonisation/infection	day mortality, Demographic data and patient factors, pertinent exposures Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of *Legionella* in environmental samples taken from patient rooms and clinical units, molecular type of isolates found.
Assessment of evidence					
This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the implementation of changes to the water treatment strategy and it is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters.					

Assessment of evidence
Organism: *Legionella pneumonia.* Transmission mode: direct (from water system). Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients. The case-control study showed that being a current smoker, having showered during admission and being on prescribed steroids prior to admission were the strongest predictors for acquiring Legionella disease during the outbreak. Source: hospital water circuit. Control measures: Showering activities were promptly restricted, water distribution system was hyperchlorinated with 50-200 ppm free chlorine overnight, POU filters were installed on showerheads and faucets. Other interventions included removal of the old water heaters and associated dead end water pipes. Limitations: case-control element only had 13 cases which is very low to make proper statements on risk factors.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tracy M, Ryan L, Samarasekara H, et al. Removal of sinks and bathing changes to control multidrug-resistant Gram-negative bacteria in a neonatal intensive care unit: a	Outbreak investigation	**Level 3**	The aim of this study was to retrospectively investigate a multidrug-resistant Gram-negative bacteria outbreak in Australia. The intervention was the removal of 6 of 8	This study did not provide rates of infection pre and post intervention however detailed the overall numbers of infected/colonised neonates pre and post and provided a description of the	Number of positive patient cases per phase, time to colonisation, intervention measures (and their differences between phases).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
retrospective investigation. Journal of Hospital Infection, 104; 508-510, 2020.			handwash sinks and strict avoidance of tap water for patient care activities.	incidents in a 10 year follow up.	
Assessment of evidence					
In-house PCR screening of MRGNB isolates detected the presence of a blaIMP4 allele. Retrospective testing revealed this resistant strain had been present since the 7th month of the outbreak. Every sink in the neonatal unit contained blaIMP4-positive coliforms on initial screening, and half the bays recolonized despite the intensive cleaning regime. Some of the environmental isolates were matched phenotypically to clinical colonisation specimens but not by WGS. Average time to colonisation was 10 days (range 0-66). Organism: all cases were enterobacteraeciae (including Carbapenem-resistant organisms like Serratia), correspondence from the author. Clinical setting: neonatal ICU. In phase 1 of the outbreak, 52 neonates were positive for a multi-drug resistant Gram-negative bacteria (MRGNB). The average number of new cases ranged from 2-12 per week. Average time to colonisation was 10 days (range 0-66).					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cadot L, Bruguière H, Jumas-Bilak E, et al. Extended spectrum beta-lactamase-	Outbreak investigation	**Level 3**	The aim of this study was to investigate an extended spectrum beta-lactamase-producing *Klebsiella*	Molecular genotyping results between patient strains and *Klebsiella pneumoniae* isolated	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
producing *Klebsiella pneumoniae* outbreak reveals incubators as pathogen reservoir in neonatal care center. Eur J Pediatr. 2019;178(4):505-513. doi:10.1007/s00431-019-03323-w			*pneumoniae* outbreak in France (including finding the source) and to determine the impact of infection prevention and control measures.	from environmental samples were compared to establish link of infection.	

Assessment of evidence

90 neonates colonised over a 3 month period. 2 of these developed infection. The strain of ESBL KP isolated from incubator displayed the same PFGE profiles as clinical strains demonstrating the persistence of the epidemic strain in one incubator despite the cleaning protocol.

For every patient, the onset of digestive colonization was from 10 to 80 days.

Provides evidence that mattresses and incubators can remain contaminated and may pose a reservoir for infection even after decontamination. Steam cleaning may not be suitable for mattresses as residual moisture can support grown of organisms.

Setting: neonatal ICU.

Organism: *Klebsiella pneumonia.*

Transmission route: not confirmed, however multiple environmental contamination identified and incubators and incubator mattresses found to be contaminated.

Assessment of evidence
Control measures: Incubators initially cleaned with disinfectant and then steam cleaned. Steam cleaning stopped after residual moisture noted and contamination remained after cleaning. Switched to disinfection only. No further cases but low level contamination persisted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Seagar AL, et al. Investigation of two cases of *Mycobacterium chelonae* infection in haemato-oncology patients using whole-genome sequencing and a potential link to the hospital water supply. J Hosp Infect. 2021;114:111-116. doi:10.1016/j.jhin.2021.04.028	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chelonae* cluster in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	WGS results between patient strains and *Mycobacterium chelonae* isolated from environmental samples were compared to establish link of infection.	Number of positive samples, sample type, WGS results (relatedness by using single-nucleotide polymorphisms SNPs).
Assessment of evidence					
Outbreak report of 2 haemato-oncology patients at the Queen Elizabeth University Hospital. WGS of patient samples were done to check for patient-patient transmission as well as water testing was performed and WGS on positive *M. chelonae* samples to check for					

Assessment of evidence
relatedness and identify potential sources. The results showed that the patient strains were unrelated to each other, but that the isolate from one patient was closely related to environmental samples from water outlets, supporting nosocomial acquisition. 147 unfiltered water samples were tested, 68 (46%) water samples from outlets tested positive, with 34 of 68 (50%) having counts >100 colony-forming units/mL. WGS was undertaken on 31 isolates as well as the two patient isolates for comparison to identify the source/relatedness. Organism: *Mycobacterium chelonae.* Transmission mode: not confirmed. Clinical setting: haemato-oncology inpatient wards Source: outlets.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leung GHY, Gray TJ, Cheong EYL, et al. Persistence of related bla-IMP-4 metallo-beta-lactamase producing Enterobacteriaceae from clinical and environmental specimens within a burns unit in	Outbreak report	**Level 3**	This paper describes the investigation undertaken in a six - year persistent bla-IMP-4 metallo-beta-lactamase (MBL) producing Enterobacteriaceae within a separately confined hospital burns unit in a	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Australia - a six-year retrospective study. Antimicrobial Resistance and Infection Control 2013, 2:35			tertiary hospital in Australia.		
Assessment of evidence					
23 patients, with clinical infection in 7 (2 bacteremias, 2 CVC tip infections, 3 wound infections). Assessment of evidence: The only environment shared between patients was the shower and bathroom facilities. Organism: *Enterobacter clocae* (most commonly detected organism), *Klebsiella pneumoniae, Enterobacter aerogenes, Klebsiella oxytoca.* Clinical setting: Burns unit, Australia. Source: Sink and shower drains identified as reservoirs and potential source for some transmissions. Patients may have been initial source. Transmission: Unclear, however likely both direct and indirect. Control measures: Monthly and then bi-monthly environmental sampling (bathroom facilities and plumbing including shower drains, ensuite room sink drains). Regular physical cleaning of drains to remove biofilm and additional cleaning with double-strength phenolic disinfectant (Phensol), later changed to chlorine-based product (Chlor-clean). Despite both regular environmental surveillance and disinfection, environmental reservoirs remained.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ambrogi V, Cavalie L, Mantion B, et al. Transmission of metallo-b-lactamase-producing *Pseudomonas aeruginosa* in a nephrology-transplant intensive care unit with potential link to the environment. Journal of Hospital Infection 92 (2016) 27-29	Outbreak report	**Level 3**	This study reports on a cluster of five cases of infection with metallo-beta-lactamase producing *P. aeruginosa* in a nephrology-transplant ICU in France.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

Genetic relatedness: All 5 clinical strains showed the same antibiotype (sensitive only to colistin), possessed bla_{vim-2} genes expressing VIM-2 carbapenemase and were genetically indistinguishable. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). No water contamination in any other areas of hospital.

Organism: *Pseudomonas aeruginosa*

Clinical setting: Nephrology transplant ICU, France.

Transmission mode: Unknown (authors hypothesised that HCWs touching taps when washing hands may have cross-transferred from patients).

Assessment of evidence
Source: Sinks as reservoirs and potential source Control measures: Replacement of sinks/taps with ones that have a larger space between the tap and the basin. ABHR use reinforced and flushing of outlets instigated (presumably had not been happening before). Limitations: no details on how the water samples were taken or if this extended beyond just tap water samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ashraf M S, Swinker M, Augustino K L, et al. Outbreak of *Mycobacterium mucogenicum* bloodstream infections among patients with sickle cell disease in an outpatient setting. Infection Control and Hospital Epidemiology. 2012 35 (11): 1132-1136.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 4 cases of M. mucogenicum bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence
All 4 patients had ports for intravenous medication. Tap water from 2 taps grew *Mycobacterium* species including *M. gordonae*, *M. szulgai*, *M, mucogenicum*, *M. kansasii*). Rep-PCR typing; isolate from tap water from tap with an aerator matched the patient ATCC strains for *M. mucogenicum* with more than 93% similarity. Organism: *Mycobacterium mucogenicum.* Transmission mode: Intravenous flushes performed on the sink counter from a saline bag that was hanging throughout the day over the sink, instead of using prefilled saline flushes; this is a non-sterile field. The same sink also used for handwashing. Clinical setting: Outpatient haematology clinic, United States of America. Source: Hospital water supply. Control measures: All aerators removed from taps, staff educated on aseptic procedures away from sinks and need for prefilled saline flushes. No mention of chlorination/other control methods of the actual water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium*	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
phocaicum associated with an outbreak of bacteremias at a Texas hospital. Applied Environmental Microbiology. 2008. Apr; 74(8): 2480-2487.					
Assessment of evidence					
Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present. Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework. Organism: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* Transmission mode: unconfirmed but all patients had CVCs. Clinical setting: Oncology department, United States of America Source: Hospital water supply Control measures: not described.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Davis RJ, Jensen SO, Van Hal S et al. Whole Genome Sequencing in Real-Time Investigation and Management of a *Pseudomonas aeruginosa* Outbreak on a Neonatal Intensive Care Unit. Infect. Control Hosp. Epidemiol. 2015;36(9):1058–1064	Outbreak report	**Level 3**	This paper describes the use of whole genome sequencing (WGS) to investigate the likely origin of an outbreak of *P. aeruginosa* in a neonatal unit in a hospital in Australia.	Molecular typing result (WGS) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

P. aeruginosa was isolated from 8 sinks, including 4 sink drains and 5 sink splashbacks; genetic match to 6 patients. There were 6 patient colonisations and 1 infection.

The diversity in the environmental isolates indicated a large diverse bioburden with the NICU. As neonates do not bring in community acquisition, it is probable that environmental reservoirs were responsible for the colonisations (6 patients WGS was identical).

Organism: *Pseudomonas aeruginosa*

Clinical setting: NICU, Australia

Transmission mode: Unconfirmed.

Assessment of evidence
Source: Sink drains as reservoir. Control measures: Sinks replaced along with splashbacks that were in one piece and easier to clean. In the following 6 months, only 2 infants were found to be colonised with *P. aeruginosa*, and one of these had an organism that differed phenotypically from the outbreak isolate. Prior to sink replacement, aerators were changed on all taps, sinks cleaned daily with bleach and weekly screening of all babies was initiated. Limitation: No mention of the water itself being tested at any point.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrobial Resistance and Infection Control (2017) 6:24	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a teaching hospital in Belgium.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission). Sink drain in this room was positive, as was every other isolation room on the unit. Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc). Organism: Enterobacteriaceae Clinical setting: ICU, Belgium. Transmission mode: Unconfirmed. Source: Sink drain as reservoir (and likely source for some patients). Control measures: daily disinfection of the sinks with a glucoprotamine product was implemented; sinks were dedicated to 'clean work' (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere. Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kossow A, Kampmeier S, Willems S et al. Control of Multidrug-Resistant *Pseudomonas*	Prospective outbreak investigation	**Level 3**	This paper describes the study of microbiological surveillance data on *MDRPa* for 3 years during the	Molecular typing result between patient strains and environmental strain isolated from environmental/water	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa in Allogeneic Hematopoietic Stem Cell Transplant Recipients by a Novel Bundle Including Remodeling of Sanitary and Water Supply Systems. Clinical Infectious Diseases, 65(6); 935-942, 2017			reconstruction of a Bone marrow transplantation center in Germany.	samples were compared to establish a link of infection.	

Assessment of evidence

The number of nosocomially-infected patients decreased from 31 in 2012-13 (9.17%) to 3 (1.68%) in 2014 ($p<0.001$).

In 2012-13, 18.94% of toilet samples were positive, 8.11% of shower samples were positive. This decreased to 6.13% of toilets and 2.96% showers in 2014 (both statistically significant reductions). During follow up, 4% of toilets and 5.59% of showers were positive. Sinks tested positive in 0.93% samples in 2012-13 and in zero samples in 2014.

Patients screened on admission and weekly thereafter. WGS indicated a close relationship between patient and environmental isolates however unable to determine exact transmission pathways.

Organism: Multi-drug resistant *Pseudomonas aeruginosa*

Clinical setting: Haematopoietic stem cell transplant unit, Germany

Transmission mode: Unconfirmed.

Assessment of evidence
Source: Shower drains and toilets as potential reservoirs, unable to determine exact modes of transmission however this study provides evidence that patients acquired infection likely from an environmental source. Control measures: New shower drains installed (easy to clean/disinfect) with covers (disinfected weekly) to prevent removal by patients. Shower heads and taps fitted with point of use filters. Biorec disinfection units installed underneath all sinks (these use UV light, vibration (50-200 Hz), temperature (85'C) and have an antibacterial coating to prevent biofilm formation. Toilets replaced with rimless toilets and an automatic disinfectant flush (0.5% glucoprotamin). Limitations: some patients not screened weekly due to their clinical situation. Culture method may not have maximised growth of admission screening samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al. Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. Infection control and hospital	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon *(*including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, DNA fingerprinting results (PCR-RFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
epidemiology. 2004 Mar 1;25(3):231-9.					
Assessment of evidence					
Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections. Tap water and swab from inside tab were positive. Organism: *Burkholderia cepacia* Transmission mode: contaminated tap water that contaminated alcohol-based products. Clinical setting: hospital Source: contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with *B. cepacia*). Control measures: once organisms were cultures from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards. Type of infection: bloodstream infections Limitation: only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central	Molecular typing results between patient strains and	Number of positive samples, sample

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
A cluster of central line–associated bloodstream infections due to rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature. Infection control & hospital epidemiology. 2015 Jan;36(1):76-80.			line–associated nontuberculous mycobacteria bloodstream infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	nontuberculous mycobacteria isolated from environmental/water samples were compared to establish a link of infection.	type, genotyping results.
Assessment of evidence					
The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was shower water (mains potable water samples were negative). Submersion of CVC during bathing, showering or toileting seemed to be the port of entry.					

Assessment of evidence
Organism: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.) Transmission mode: Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Clinical setting: hematology-oncology ward Source: contaminated shower water Control measures: Catheter/port removal and antimicrobial therapy.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wong V, Levi K, Baddal B, et al. Spread of *Pseudomonas fluorescens* Due to Contaminated Drinking Water in a Bone Marrow Transplant Unit. Journal of Clinical Microbiology 2011, 49(6), 2093-2096.	Outbreak study	**Level 3**	This study reports the findings of the epidemiological and microbiological investigation of a *Pseudomonas fluorescens* outbreak.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness
Assessment of evidence					
Nine patient cases, 6 of this developed febrile neutropenia. All had positive pharyngeal samples. Water sample from a water dispenser in the unit tested positive and genetically matched the patient isolates. All other environmental samples were negative.					

Assessment of evidence
Organism: *Pseudomonas fluorescens* Clinical setting: Bone marrow transplant unit, England UK. Transmission mode: Direct (ingestion). Source: Chilled water dispenser as reservoir, unclear how it became contaminated (authors theorised that the nozzle may have been touched by contaminated hands). Control measures: Removal of the contaminated chilled water dispenser (the remaining one was kept). The long-term plan for the unit is to install filtered plumbed-in main water dispensers and to implement regular qualitative and quantitative water assessments. Genetic relatedness: All nine patient isolates and the one environmental isolate were identified as being *Pseudomonas fluorescens*. "The isolate from the water dispenser was found to be genotypically identical to the patients' isolates: all isolates of *P. fluorescens* produced identical RAPD patterns (type b pattern), and typing by PFGE revealed that all isolates recovered were indistinguishable, with a designated profile of NOTT PF1." Limitations: Water was sampled via the nozzle of the chiller unit and not directly from the bottle before or after installation, so unclear where the contamination originated from.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease: The control of *Legionella* bacteria in hot and cold water systems. L8.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2013.					

Assessment of evidence

This British document provides the approved code of practice and guidance on regulations regarding Legionnaires' disease. The following section(s) are relevant for this research question on patient populations at increased risk of colonisation/infection with a healthcare water system-associated organisms (in this case *Legionella* spp.):

'Legionellosis is a collective term for diseases caused by legionella bacteria including the most serious legionnaires' disease, as well as the similar but less serious conditions of Pontiac fever and Lochgoilhead fever. Legionnaires' disease is a potentially fatal form of pneumonia and everyone is susceptible to infection. The risk increases with age, but some people are at higher risk, eg people over 45, smokers and heavy drinkers, people suffering from chronic respiratory or kidney disease, diabetes, lung and heart disease or anyone with an impaired immune system. '

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients. American Journal of Kidney Diseases.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (e.g. age and comorbid conditions). The second investigation	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection. Risk factors for becoming a case are investigated using	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2019 Nov 1;74(5):610-9.			looked at factors specific to a patient during a particular treatment.	case-control study designs (2x).	

Assessment of evidence

In this study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of bloodstream infections.

Organism: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae.* Bloodstream infections.

Transmission mode: indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes).

Clinical setting: outpatient haemodialysis facilities

Source: dialysis station wall boxes (contaminated water-based equipment)

Control measures: implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.

Question 5: What types of infection can healthcare water system-associated organisms cause?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Campos-Gutierrez S, Ramos-Real MJ, Abreu R, et al. Pseudo-outbreak of *Mycobacterium fortuitum* in a hospital bronchoscopy unit. American Journal of Infection Control 2020; 48: 765-769.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a pseudo-outbreak of *Mycobacterium fortuitum* in Spain (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *M. fortuitum* isolated from a water sample (tap) were compared	Number of positive samples, sample type, typing results (by restriction fragment length polymorphism and by enterobacterial repetitive intergenic consensus sequences)

Assessment of evidence

The hospital water supply showed to be contaminated with *M. fortuitum*, which is why its use in the rinsing of high-level disinfection led to a recontamination of the bronchoscopy.

Organism: *Mycobacterium fortuitum*

Transmission mode: contaminated water-based equipment

Clinical setting: pneumology bronchoscopy unit

Source: the hospital water used by the bronchoscope automatic washing machine (without antibacterial filter)

Control measures: not using the washing machine without manually cleaning and disinfecting it with prefiltered water using the Pall AquaSafe Water Filter until purchasing a new washing machine. As a surveillance measure, an environmental microbiologic study of the

Assessment of evidence
hospital water was established every 15 days, in which, since this outbreak, an RGM study was included. Installation of filters in those taps where water is taken from to rinse invasive instruments after disinfection. The authors describe a pseudo-outbreak as real clustering of false infections or artefactual clustering of real infections, which is often identified when there is increased recovery of unusual microorganisms. They however call it a pseudo-outbreak because there was no clinical impact on patients.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Constantinides B, Chau KK, Phuong Quan T, et al. Genomic surveillance of *Escherichia coli* and *Klebsiella* spp. in hospital sink drains and patients. Microbial Genomics 2020; 6: 4-16.	Surveillance study	**Level 3**	The aim of this study was to investigate the prevalence of contamination of healthcare sinks by strains of *E. coli* and *Klebsiella* spp.	Phylogenies of sink drain aspirates sampled over 12 weeks across three wards and patient samples.	Number of positive samples, sample type, whole-genome sequence analysis (including metagenomic sequencing)

Assessment of evidence
In this study isolates were identified from sinks from different hospital wards and were linked retrospectively to isolate results from patients staying in the same units during the same time period. Genomic overlap with sink isolates was only identified in 1/46 of all sequenced isolates causing clinical urine-infection over the same timeframe, associated with acquisition from a sink source. Organism/ infection: Enterobacterales species (*E. coli* and *Klebsiella* spp). Bloodstream infections.

Assessment of evidence
Transmission mode: not confirmed. Clinical setting: general medicine ward in hospital UK Source: possibly a sink Control measures: not documented Even though isolates from the sinks were compared to isolates from patients' samples there was no epidemiological data used to investigate whether this correlation is actual true. Both microbiological and epi data is needed to link strains to infection. This study provides evidence that sinks can be colonised with a wide abundance of microorganisms that are associated with healthcare-associated infections, indicating a possible reservoir and risk of infection. This study provides evidence for the source of infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW, Tracey J, et al. Continued transmission of *Pseudomonas aeruginosa* from a wash hand basin tap in a critical care unit. Journal of Hospital Infection 2016; 94: 8-12.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* cluster in the burns room of a critical care unit in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared	Clinical surveillance of *P. aeruginosa* infection took place. Water samples from all tap outlets in the unit were collected as per HTM 04-01. All isolates were typed.

Assessment of evidence
Genotyping conducted. Tap was found to be contaminated. Unable to determine the exact transmission route. The authors state that remedial actions to decontaminate the tap as recommended by the National 04-01 addendum were insufficient. Organism/ infection: *Pseudomonas aeruginosa.* Burns wound infection. Transmission mode: not determined exact transmission route. Clinical setting: critical care unit (burn unit) UK Source: contaminated water system. Tap was found to be contaminated. Control measures: Control measures at UHB include disposal of waste water in the sluice where possible, and, if not, the use of absorbent gel sheets to solidify patient waste water being disposed of in a macerator. The new cleaning method, developed by the housekeeping staff and infection control, involves a three-cloth cleaning technique to reduce contamination.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an Oncology Clinic—Illinois, 2012-2013. Infection control and hospital	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (including finding the source) and to determine the impact of infection	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
epidemiology. 2017 Mar;38(3):314.			prevention and control measures.		

Assessment of evidence

The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (including. presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff.

Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room

Organism/ infection: *Pantoea agglomerans.* Bloodstream infections.

Transmission mode: indirect/aerosolisation.

Clinical setting: oncology clinic.

Source: pharmacy sink, however primary source associated with this, not identified.

Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping.

Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding.

Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods.

Chemotherapy preparations were moved off-site and improved the building water system.

Assessment of evidence
Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al. A cluster of central line–associated bloodstream infections due to rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central line–associated nontuberculous mycobacteria bloodstream infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and nontuberculous mycobacteria isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection control & hospital epidemiology. 2015 Jan;36(1):76-80.					
Assessment of evidence					
The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was the tap water supply. Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Organism/ infection: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.). Central-line associated bloodstream infections. Transmission mode: Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Clinical setting: hematology-oncology ward Source: contaminated water systems Control measures: Catheter/port removal and antimicrobial therapy.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al. Analysis of transmission pathways of *Pseudomonas*	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between *Pseudomonas aeruginosa* infection and faucet	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water	Number of positive samples, sample type, relationship between genotypes (RAPD)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa between patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.			contamination in a surgical ICU.	samples were compared to establish transmission pathways.	

Assessment of evidence

The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed.

Organism/ infection: *Pseudomonas aeruginosa.* Infections included pneumonia, tracheobronchitis, wound infections, septicaemia, urinary tract infection. Colonisations included wounds and the pharynx.

Transmission mode: Indirect (potentially hands of HCWs, transfer of colonized patients between wards, splashing of water around the washbasin).

Clinical setting: SICU and other surgical wards

Source: individual faucets

Control measures: an intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention.

Infections caused by PA: Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonized with *P. aeruginosa* were wounds and the pharynx

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients. American Journal of Kidney Diseases. 2019 Nov 1;74(5):610-9.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (for example age and comorbid conditions). The second investigation looked at factors specific to a patient during a particular treatment.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection. Risk factors for becoming a case are investigated using case-control study designs (2x).	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence

In this study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of bloodstream infections.

Organism/ infection: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae.* Bloodstream infections.

Transmission mode: indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes).

Clinical setting: outpatient haemodialysis facilities

Assessment of evidence
Source: dialysis station wall boxes (contaminated water-based equipment) Control measures: implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al. Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. Infection control and hospital epidemiology. 2004 Mar 1;25(3):231-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon *(*including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, DNA fingerprinting results (PCR-RFLP).

Assessment of evidence
Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections. Organism/infection: *Burkholderia cepacian.* Catheter-associated bloodstream infections. Transmission mode: contaminated tap water that contaminated alcohol-based products. Clinical setting: hospital Source: contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with B. cepacia). Control measures: once organisms was cultures from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards. Type of infection: bloodstream infections Limitation: only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western	N/A	Number of positive samples, sample type and species.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
haemato-oncology unit. Journal of Hospital Infection, 79; 339-343. 2011.			General Hospital in Edinburgh and to determine the impact of infection prevention and control measures.		

Assessment of evidence

Organism/infection: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.). CVC-associated bloodstream infection.

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: Haemato-oncology unit.

Source: water system.

Control measures: the cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced.

Assessment of evidence
Limitations: Similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence
Organism/ infection: *Mycobacterium mucogenicum.* Bloodstream infection.
Source: Contaminated automatic water tap.
Clinical setting: Paediatric haemato-oncology

Assessment of evidence
Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet. Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.
Assessment of evidence					
Organism: *M. abscessus.* Respiratory infection, bloodstream infection, wound infection (unclear how many/which were colonisations versus infections). Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients.					

Assessment of evidence
Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease. Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM, Chinn RYW, Arduino MJ, et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/American Hospital Association; 2004.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally-mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible.					

Assessment of evidence
It states that “pseudo-outbreaks of *Mycobacterium chelonae*, *M. gordonae*, and *M. xenopi* have been associated with both bronchoscopy and gastrointestinal endoscopy when tap water is used to provide irrigation to the site or to rinse off the viewing tip in situ, or when the instruments are inappropriately reprocessed with tap water in the final steps.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). Legionella and the prevention of legionellosis. ISBN 92 4 156297 8 (NLM classification: WC 200) © World Health Organization 2007	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This guidance document details Legionella infection caused by *Legionella* spp, (*Legionella pnemophila* causing 90% of infections). The type of infection is mainly in the respiratory system, but it is mentioned in this guidance that it can spread (which is classed as disseminated disease) from there to the rest of the body. Examples of sites where Legionellae have been detected are: the spleen, liver, kidney, myocardium, bone and bone marrow, joints, inguinal and intrathoracic lymph nodes and digestive tract.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M, et al. Pseudo-outbreak of *Mycobacterium chimaera* through aerators of hand-washing machines at a hematopoietic stem cell transplantation center. Infection Control and Hospital Epidemiology 2019; 40: 1433-1435.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared	Number of positive samples, sample type, typing results.

Assessment of evidence

Outbreak investigation. A genetic relationship was found between the clinical and environmental isolates.

Organism: *M. chimaera.*

Transmission mode: contaminated water systems

Clinical setting: stem cell transplantation center

Source: biofilm on the aerators of the handwashing machines in each patient's room

Assessment of evidence
Control measures: Regular replacement of faucet parts can prevent biofilm formation and pseudo-outbreaks of M. chimaera through aerators. Communication with facilities maintenance personnel including officers and mechanics, and we improved the procedure for managing the units to incorporate routine work to replace aerators and their related parts every 6 months. Definition of pseudo-outbreak not defined.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-outbreak attributed to contaminated rinse water. American Journal of Infection Control. 2020 Jan 1;48(1):26-32.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE)

Assessment of evidence
The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope. Organism: *P. aeruginosa*

Assessment of evidence
Transmission mode: indirect contact. Clinical setting: bronchoscopy unit Source: sink connecting tube was implicated as the source of *P aeruginosa* contamination to bronchoscopes. Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
El Sahly HM, Septimus E, Soini H, et al. *Mycobacterium simiae* pseudo-outbreak resulting from a contaminated hospital water supply in Houston, Texas. Clinical infectious diseases. 2002 Oct 1;35(7):802-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium simiae* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Mycobacterium simiae* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Results of genotyping showed that this nosocomial *M. simiae* pseudo-outbreak was caused by contaminated hospital water supply. Organism: *Mycobacterium simiae* Transmission mode: not discussed. Clinical setting: hospital setting Source: contaminated water supply Control measures: not discussed

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Botana-Rial M, Leiro-Fernández V, Núñez-Delgado M, et al. A pseudo-outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* in a bronchoscopy unit. Respiration. 2016;92(4):274-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas putida* and *Stenotrophomonas maltophilia* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Pseudomonas putida* and *Stenotrophomonas maltophilia* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence
From the information provided by the authors, it is not possible to conclude that the source of the outbreak were the bronchoscopes or the AERs. *Pseudomonas putida* and *Stenotrophomonas maltophilia* were also isolated from sinks, cleaning brushes and cleaning solutions. Thus, although the authors found AERs to be contaminated it is not certain that this was the source. However, this study provides evidence that inadequate disinfection of bronchoscopes can lead to infections/colonization in patients. Organism: *Pseudomonas putida* and *Stenotrophomonas maltophilia* Transmission mode: indirect contact (contaminated equipment) Clinical setting: bronchoscopy unit. Source: Contaminated water-based equipment (bronchoscopes). Although source uncertain. Control measures: -

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium*	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
phocaicum associated with an outbreak of bacteremias at a Texas hospital. Applied Environmental Microbiology. 2008. Apr; 74(8): 2480-2487.					
Assessment of evidence					
Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present. Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework. Organism/ infection: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* CVC-associated bloodstream infection. Transmission mode: unconfirmed but all patients had CVCs. Clinical setting: Oncology department, United States of America Source: Hospital water supply Control measures: not described.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ashraf M S, Swinker M, Augustino K L, et al. Outbreak of *Mycobacterium mucogenicum* bloodstream infections among patients with sickle cell disease in an outpatient setting. Infection Control and Hospital Epidemiology. 2012 35 (11): 1132-1136.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 4 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence

All 4 patients had ports for intravenous medication. Tap water from 2 taps grew *Mycobacterium* species including *M. gordonae*, *M. szulgai*, *M, mucogenicum*, *M. kansasii*). Rep-PCR typing; isolate from tap water from tap with an aerator matched the patient ATCC strains for *M. mucogenicum* with more than 93% similarity.

Organism/ infection: *Mycobacterium mucogenicum.* Bloodstream infections.

Transmission mode: Intravenous flushes performed on the sink counter from a saline bag that was hanging throughout the day over the sink, instead of using prefilled saline flushes; this is a non-sterile field. The same sink also used for handwashing.

Clinical setting: Outpatient haematology clinic, United States of America.

Assessment of evidence
Source: Hospital water supply. Control measures: All aerators removed from taps, staff educated on aseptic procedures away from sinks and need for prefilled saline flushes. No mention of chlorination/other control methods of the actual water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chroneou A, Zimmerman SK, Cook S et al. Molecular typing of *Mycobacterium chelonae* isolates from a pseudo-outbreak involving an automated bronchoscope washer. Infect Control Hosp Epidemiol 2008; 29:1088-90	Outbreak report	**Level 3**	This paper describes a pseudo-outbreak of *M. chelonae* in bronchoalveolar lavage fluid from 9 patients traced to a contaminated automated bronchoscope washer in a medical center in the United States of America.	Molecular typing result (REP-PCR) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness
Assessment of evidence					
A total of 9 patients with positive bronchoalveolar lavage fluid specimens. None had symptoms or infection (Pseudo-outbreak). Incoming water supply and a bowl drain from the automated washer matched the 9 patient isolates (>90% similarity with REP-PCR). Organism: *Mycobacterium chelonae*					

Assessment of evidence
Clinical setting: Bronchoscopy, United States of America Transmission mode: from water supply via contaminated automated washer Control measures: automated washer removed from service, and new one purchased. Responsibility for changing filters assigned to biomedical staff and changed every month rather than twice per year. Authors state this eliminated the strain but not clear how this was known. Genetic relatedness: “REP-PCR findings demonstrated a greater than 90% similarity among the isolates associated with the 9 patients…, the 2 environmental isolates recovered from the drain bowl…, and the isolate recovered from the incoming water supply/”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary bypass since reports from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and presentation, outcome. Growth/contamination of air/environmental samples, whole-genome sequencing

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			heater-cooler units (HCUs) used during bypass.		data (phylogenetic relatedness)

Assessment of evidence

This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year.

Organism: *Mycobacterium chimaera*

Transmission mode: Indirect contact/ Aerosolisation

Clinical setting: Cardiothoracic surgery, England UK

Source: Cardiopulmonary bypass heater-cooler units

Control measures: N/A

Limitations: A 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including	Molecular typing results between clinical strains and *M. mucogenicum*	Number of positive samples, sample

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.			finding the source) and to determine the impact of infection prevention and control measures.	isolated from environmental/water samples were compared to establish a link of infection.	type, genotyping results.

Assessment of evidence

Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient. *M. mucogenicum* also found in the hot water source in the main hospital, and the city water source for the hospital.

Organism: *Mycobacterium mucogenicum*

Transmission mode: indirect/ aerosolisation

Clinical setting: University-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients.

Source: water contamination of central venous catheters (CVCs) during bathing

Control measures: The following control measures were recommended and implemented.

- Showerheads and hoses on the Bone marrow transplant (BMT) units were replaced.
- Shower hoses were allowed to hang straight with no dependent loops when not in use to reduce the risk of bacteria multiplying to higher levels in stagnant water.

Assessment of evidence
• Direct care providers, patients and family members were educated on the risks of water contamination of central venous catheters (CVC) during bathing and on prevention methods to minimize water contact during bathing. • IV catheters were disconnected before bathing when possible. • Catheter connections were covered with waterproof material if they could not be disconnected

Question 6: What are the incubation periods of healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary bypass since reports from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of heater-cooler units (HCUs) used during bypass.	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and presentation, outcome. Growth/contamination of air/environmental samples, whole-genome sequencing data (phylogenetic relatedness)
Assessment of evidence					
This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It					

Assessment of evidence
also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year. Organism: *Mycobacterium chimaera* Transmission mode: indirect contact/ Aerosolisation Clinical setting: cardiothoracic surgery Source: cardiopulmonary bypass heater-cooler units Control measures: N/A Limitations: A 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible Mention of maximum documented latency period of 4 years described in Sax H, Bloemberg G, Hasse B, et al. Prolonged outbreak of *Mycobacterium chimaera* infection after open-chest heart surgery. Clin Infect Dis 2015; 61:67–75.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sax H., Bloemberg G., Hasse B., et al. Prolonged Outbreak of *Mycobacterium chimaera* Infection After Open-Chest Heart Surgery.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chimaera* outbreak in Switzerland (including finding the source) and to determine the impact of infection	Molecular genotyping results between patient strains and *Mycobacterium chimaera* isolated from environmental/water samples were	Clinical and patients' characteristics of probable cases including surgery type, type of implant, latency, positive cultures. Growth/ contamination of air/environmental/

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Clinical Infectious Diseases 2015;61(1):67–75			prevention and control measures.	compared to establish link of infection.	water samples, genotype, outbreak management.

Assessment of evidence

This outbreak investigation started after 2 patients were found to have *Mycobacterium chimaera* infection and an in-depth outbreak investigation was done to detect the source, including retrospective case detection, prospective surveillance, on-site observations, and targeted microbiological sampling of patients and the hospital environment. In total, 6 patients met the case definition; All patients had undergone open-chest heart surgery involving implants and the use of heater-cooler units at the University Hospital of Zurich between 2008 and 2012. *Mycobacterium chimaera* was cultured from 5 heater-cooler units and an air sample. Latency between surgery and manifest infection ranged between 1.5 and 3.6 years.

Organism: *Mycobacterium chimaera* (NTM)

Transmission mode: indirect contact/Aerosolisation

Clinical setting: open-chest heart surgery patients

Source: heater-cooler unit reservoirs

Control measures: Not under control when published (Only used factory-new heater-cooler units with daily water changes and POU filters, however there was another positive sample in Sept 2014 from 1 heater-cooler unit. At the time of writing (Dec 2014), the construction of custom-built containers with high-efficiency particulate air filters to house heater-cooler units that cannot be placed outside the operating room is under way.)

Incubation time: Latency between surgery and manifest infection ranged between 1.5 and 3.6 years

Limitations:

- No genotypic link between patients and environmental samples
- All drinking water fountains in the hospital ICUs tested positive, so cannot rule out that this was another potential source

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). Legionella and the prevention of legionellosis. ISBN 92 4 156297 8 (NLM classification: WC 200) © World Health Organization 2007	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This piece of evidence provides a comprehensive overview of the sources, ecology and lab identification of Legionella and provides guidance on assessment and management of risks.

WHO defines the incubation period as the time interval between initial exposure to infection and the appearance of the first symptom or sign of disease.

Incubation period for Legionnaires disease is 2-10 days, rarely up to 20 days. The evidence referenced for this is an epidemiological study of an outbreak associated with a flower show in the Netherlands, that found average incubation period of 7 days

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
European Centre for Disease Prevention and Control (ECDC). Legionnaires' disease outbreak investigation toolbox - Incubation period. (Accessed 2022)	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
States the incubation period is between 2-10 days although it is recognised it can extend to longer than 10 days. References 3 peer-reviewed reports from community outbreaks (1 in Netherlands linked to flower show, 1 in Melbourne linked to an aquarium, 1 in Japan). This supports an average median incubation period of 6 days with the majority having a 2-10 day incubation period. ECDC therefore advises that when investigating potential travel-related cases, a 14 day exposure period should be considered. Limitations: this data does not include nosocomial outbreaks, it is unclear whether the incubation period may differ in the hospital population for example if prolonged incubation periods are common due to immunosuppression. This incubation period however will also include potential healthy persons e.g. healthcare workers who may also be at risk.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ref XX. Public Health Scotland. Legionnaires' disease in Scotland.	Incidence report	**Level 3**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Surveillance report 2017 to 2022					
Assessment of evidence					
This report provides a summary of sporadic cases and those reported to PHS from 2017 to 2022. There were no hospital-associated cases during the period 2017 to 2022.					

Question 7: What is the period of communicability for healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Panagea S, Winstanley C, Walshaw MJ, et al. Environmental contamination with an epidemic strain of *Pseudomonas aeruginosa* in a Liverpool cystic fibrosis centre, and	Environmental study	**Level 3**	The aim of this study was determine the extent of environmental contamination with the *P. aeruginosa* Liverpool epidemic strain (LES) to identify possible	Survival of LES on dry surfaces compared with that of other CF *P. aeruginosa* strains to explore factors that might contribute to its high transmissibility.	Growth/contamination of LES *P. aeruginosa* of environmental samples and test surfaces (Cfu/sample).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
study of its survival on dry surfaces. Journal of Hospital Infection (2005) 59, 102–107			reservoirs and routes of cross-infection.		

Assessment of evidence

Organism: *Pseudomonas aeruginosa*

Transmission mode: airborne dissemination plays a significant role in patient-to-patient spread of this organism. 80% of the air samples inside the patient's room were positive for LES and was still detected in absence of patients for 1-3hr prior to testing. The positive rooms tested negative 3hr after discharge and room cleaning.

Clinical setting: CF inpatient and outpatient ward

Source: non-epidemic *P. aeruginosa* was found on wash basin, bath tub, shower drains, bathroom/toilet handles/surfaces. LES was found on patients' hands, clothes, bed linen and in sink of colonized patients' room as well as on respiratory equipment, sink and in the air of the patients' room, the ward corridor and outpatient clinic rooms (consultation room, corridor, waiting room and spirometry room).

Control measures: N/A

Environmental survival: Lab based study showed viable counts of *P. aeruginosa* after 48 hours on dry surfaces. Environmental air sampling found *P. aeruginosa* to survive in the air surrounding colonised CF patients (patients' room, corridor, consultation room, waiting room, spirometry room) up to 3 hours following their discharge.

Limitations: Testing focused on the Liverpool epidemic strain (LES); however, there was also non-LES *P. aeruginosa* detected which is also a risk for this patient group. Environmental survival on dry surfaces done in laboratory/simulation, therefore not to include in review.

Question 8: What are the known transmission routes of healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Heireman L, Hamerlinck H, Vandendriessche S, et al. Toilet drain water as a potential source of hospital room-to-room transmission of carbapenemase-producing *Klebsiella pneumoniae*. Journal of Hospital Infection 2020; 106: 232-239.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a OXA-48-producing *Klebsiella pneumonia* outbreak in Belgium (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Klebsiella pneumonia* isolated from environmental/water samples were compared	Number of positive samples, sample type, whole-genome sequencing results and phylogenetic analysis
Assessment of evidence					
Toilets and drain water appeared to be the source of this outbreak. The common strain found in all outbreak isolates suggests that the strain may have spread between rooms by drain water. Organism: OXA-48-producing *Klebsiella pneumonia* Transmission mode: contaminated toilet water – possibly plume from flushed toilets (aerosols/droplet dispersion).					

Assessment of evidence
Clinical setting: Burn unit of University hospital Source: toilet drain water. Control measures: bleach added to daily toilet cleaning regime, sampling of toilet water (even though did not completely prevent the presence of carbapenemase-producing *K. pneumonia*).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and environmental microbiology 2019; 85.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing	Sample type, amount of positive samples, CFU counts, MIC, PFGE type

Assessment of evidence
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca* Transmission mode: contaminated water-based equipment (washing machine) Clinical setting: Perinatal setting/childrens hospital Source: Isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Control measures: environmental monitoring, admission screening, IPC training HCWs, renovation/contamination sinks, etc. All garments worn by newborns and children were laundered by professionally service. The washing machine was removed. The use of professional washing machines and routine checking with a temperature logger are urgent requirements.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Campos-Gutierrez S, Ramos-Real MJ, Abreu R, et al. Pseudo-outbreak of *Mycobacterium fortuitum* in a hospital bronchoscopy unit. American Journal of Infection Control 2020; 48: 765-769.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a pseudo-outbreak of *Mycobacterium fortuitum* in Spain (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *M. fortuitum* isolated from a water sample (tap) were compared	Number of positive samples, sample type, typing results (by restriction fragment length polymorphism and by enterobacterial repetitive intergenic consensus sequences)

Assessment of evidence
The hospital water supply showed to be contaminated with *M. fortuitum*, which is why its use in the rinsing of high-level disinfection led to a recontamination of the bronchoscopy. Organism: *Mycobacterium fortuitum* Transmission mode: contaminated water-based equipment Clinical setting: pneumology bronchoscopy unit Source: the hospital water used by the bronchoscope automatic washing machine (without antibacterial filter) Control measures: not using the washing machine without manually cleaning and disinfecting it with prefiltered water using the Pall AquaSafe Water Filter until purchasing a new washing machine. As a surveillance measure, an environmental microbiologic study of the hospital water was established every 15 days, in which, since this outbreak, an RGM study was included. Installation of filters in those taps where water is taken from to rinse invasive instruments after disinfection. The authors describe a pseudo-outbreak as real clustering of false infections or artefactual clustering of real infections, which is often identified when there is increased recovery of unusual microorganisms. They however call it a pseudo-outbreak because there was no clinical impact on patients.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jung J, Choi HS, Lee JY, et al. Outbreak of carbapenemase-producing Enterobacteriaceae associated with a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a carbapenemase-producing Enterobacteriaceae outbreak in Korea and to find the risk	Epidemiologic links between patients and potential environmental sources	Number of positive samples, sample type, typing (PFGE analysis)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
contaminated water dispenser and sink drains in the cardiology units of a Korean hospital. Journal of Hospital Infection 2020; 104: 476-483.			factors for acquiring CPE.		
Assessment of evidence					
Sinks in patient rooms and water dispenser acted as reservoirs (PFGE confirmed) The water dispenser for provision of water to patients was located near a handwashing sink; of note, used dialysing solution after haemodialysis was emptied into this handwashing sink. Organism: CPE, *Citrobacter freudii, Enterobacter cloacae* Transmission mode: possible spraying/splashing of contaminated water from handwashing sink to water dispenser. Clinical setting: Cardiology ICU Source: not confirmed Control measures: Sink drain treated with bleach (5500 ppm), water dispenser removed and water replaced with bottled water. All sink drains in the ICU were replaced.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW and Holden E. Waterborne *Pseudomonas aeruginosa* transmission in a hematology unit? American Journal of Infection Control 2018; 46: 383-386.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the UK (including finding the source) and to determine the impact of infection prevention and control measures	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence

Outbreak report – molecular typing conducted (PFGE).

Transmission of *Pseudomonas aeruginosa*; transmission route via prep trays from contaminated water outlet. Hickman lines entry route.

Organism: *Pseudomonas aeruginosa*

Transmission mode: contaminated water systems

Clinical setting: Hematology unit, UK.

Source: transmission route via prep trays from contaminated water outlet. Hickman lines entry route.

Control measures: POU filters were installed on all outlets in the hematology ward. Filters were already on all outlets apart from those in the intravenous prep room. Trays were cleaned with quaternary ammonium compound wipes (Clinell Universal wipes, GAMA Healthcare UK) and dried thoroughly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Botana-Rial M, Leiro-Fernández V, Núñez-Delgado M, et al. A pseudo-outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* in a bronchoscopy unit. Respiration. 2016;92(4):274-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas putida* and *Stenotrophomonas maltophilia* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Pseudomonas putida* and *Stenotrophomonas maltophilia* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence

From the information provided by the authors, it is not possible to conclude that the source of the outbreak were the bronchoscopes or the AERs. *Pseudomonas putida* and *Stenotrophomonas maltophilia* were also isolated from sinks, cleaning brushes and cleaning solutions. Thus, although the authors found AERs to be contaminated it is not certain that this was the source.

However, this study provides evidence that inadequate disinfection of bronchoscopes can lead to infections/colonization in patients.

Organism: *Pseudomonas putida* and *Stenotrophomonas maltophilia*

Transmission mode: indirect contact (contaminated equipment)

Clinical setting: bronchoscopy unit.

Source: Contaminated water-based equipment (bronchoscopes). Although source uncertain.

Assessment of evidence
Control measures: -

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Regev-Yochay G, Smollan G, Tal I, et al. Sink traps as the source of transmission of OXA-48–producing *Serratia marcescens* in an intensive care unit. Infection Control & Hospital Epidemiology. 2018 Nov;39(11):1307-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *OXA-48–producing Serratia marcescens* in the ICU in Israel (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *S. marcescens* isolated from environmental/water samples were compared.	Number of patients with CPE infection/colonisation and their clinical characteristics, environmental samples (source, results and number of isolates), typing results (PFGE).

Assessment of evidence
Extensive control measures were put in place and carried out, but contamination of sinks seemed to be recurring. Using a combined intervention (including educational component, reducing environmental contamination load) the outbreak was contained 12 months after the start of the outbreak. Organism: CPE, *S. marcescens* (OXA-48–producing *S. marcescens*) Transmission mode: indirect contact of the sinks

Assessment of evidence
Clinical setting: ICU Source: sink Control measures: enhanced control measures were undertaken, including increased hand hygiene observations as well as educational sessions. Thorough cleaning of all surfaces and medical devices with 1,000 PPM sodium hypochlorite and quaternary ammonium, accordingly, was carried out. After identification of the sink as the source of transmission: 2 main measures were carried out: (1) sink-trap decontamination efforts and (2) an educational intervention enhancing specific infection control measures and focusing on the sink as a source of transmission. All sink traps were replaced, water supply was treated according to Legionella protocol (heating and hyper chlorination of the main water tank and terminal points for 12 hours with free residual chlorine (20–30 mg/L).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (incl finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence
The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (including presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff. Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room. Organism: *Pantoea agglomerans* Transmission mode: indirect/aerosolisation. Healthcare workers hand were sampled, tested negative (poor hand hygiene was observed). Splash/spray from sink to infusate equipment. Clinical setting: oncology clinic. Source: pharmacy sink, however primary source associated with this, not identified. Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping. Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding. Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods. Chemotherapy preparations were moved off-site and improved the building water system. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit. Journal of hospital infection. 2016 Sep 1;94(1):2-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Assessment of evidence

Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit.

Pseudomonas aeruginosa has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients.

Organism: *Pseudomonas aeruginosa*

Transmission mode: indirect contact from contaminated hydrotherapy equipment (shower mattress); however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the

Assessment of evidence
same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission. Clinical setting: ICU – burn unit. Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa. Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily. Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhou Z, Hu B, Gao X, et al. Sources of sporadic *Pseudomonas aeruginosa* colonizations/ infections in surgical ICUs: Association	Outbreak investigation	**Level 3**	The aim of this study was to investigate *Pseudomonas aeruginosa* colonizations/ infections in surgical ICUs and to determine the source(s).	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
with contaminated sink trap. Journal of Infection and Chemotherapy. 2016 Jul 1;22(7):450-5.				establish a link of infection.	
Assessment of evidence					
Genotyping was performed. 64.7% (11/17) of exogenous sourced cases were associated with contaminated sink traps. Whereas, no strains (genotypes) recovered from tap water were identical to that from patients. Organism: *Pseudomonas aeruginosa* Transmission mode: water fittings (drains) found to be contaminated but exact transmission mode to patient unconfirmed. Clinical setting: ICU Source: contaminated sink traps. (contaminated water systems) Control measures: -					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al. A cluster of central line–associated	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central line–associated	Molecular typing results between patient strains and nontuberculous	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
bloodstream infections due to rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature. Infection control & hospital epidemiology. 2015 Jan;36(1):76-80.			nontuberculous mycobacteria bloodstream infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	mycobacteria isolated from environmental/water samples were compared to establish a link of infection.	

Assessment of evidence

The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was the tap water supply. Submersion of CVC during bathing, showering or toileting seemed to be the port of entry.

Organism: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.)

Transmission mode: Submersion of CVC during bathing, showering or toileting seemed to be the port of entry.

Assessment of evidence
Clinical setting: hematology-oncology ward Source: contaminated water systems Control measures: Catheter/port removal and antimicrobial therapy.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Knoester M, De Boer MG, Maarleveld JJ, et al. An integrated approach to control a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Clinical Microbiology and Infection. 2014 Apr 1;20(4):O207-15.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of multidrug resistant (MDR) *Pseudomonas aeruginosa* in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures. Patients that acquired the outbreak strain were also enrolled in a case-control study to investigate risk	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection. For the case-control study, the exposure factors were compared between cases (ICU patients that acquired the outbreak strain) and control (ICU patient who tested at least	Number of positive samples, patient characteristics and exposure factors, sample type, genotyping results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			factors for acquiring MDR *P. aeruginosa*.	three times negative for the outbreak strain during the follow-up period.)	

Assessment of evidence

Two clusters occurred during this outbreak. A common source was found for one of the clusters. Two contaminated faucet aerators were identified. Cross-transmission by medical staff might have occurred as the number of new cases decreased after improvement of IPC measures. Presence of drains were not evaluated; this has frequently been identified as a source of infection.

The case-control part of the study identified that patients who are admitted to ICU subunit I, surgery prior to or during admission and those being warmed-up with the warm-air blanket are independently associated with MDR-PA positivity.

Organism: *P. aeruginosa*

Transmission mode: indirect contact probable

Clinical setting: ICU

Source: no common source was found.

Control measures: chlorination of sink drains (but ineffective). Audit of care-related procedures, cleaning procedures and hygiene measures on ICU. Re-education of ICU staff on hygiene protocols. Implementation of new tracheostomy care protocol. Ban on sharing equipment between patients.

Standard contact isolation measures were implemented. Faucet aerators were replaced.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guyot A, Turton JF, Garner D. Outbreak of *Stenotrophomonas maltophilia* on an intensive care unit. Journal of Hospital Infection. 2013 Dec 1;85(4):303-7	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Stenotrophomonas maltophilia* outbreak (including finding the source) and to highlight the risk from contaminated devices for supply of drinking water.	Typing results of the *Stenotrophomonas maltophilia* patient strains vs *S. maltophilia* isolated from environmental/water samples.	Incidence of outbreak strains, PFGE profiles from patient's vs water strains.

Assessment of evidence

Typing was performed. A tap (in ICU kitchen) that had a water-cooler for drinking water was the source of *S. maltophilia* on ICU in a UK hospital, because a carbon filter had not only removed the disinfectant chlorine dioxide before the water-cooler, but had also accumulated organics, which serve as nutrients for bacteria facilitating the growth of biofilms on downstream tubing.

On review of nursing practices, the nurses reported that they had discarded the water from tooth-brushing or patients' drinking water into handwash basins. They revealed also that they had used cooled water from the ICU kitchen from the special tap for cooled water for serving patients drinking water and mouth care.

Organism: *Stenotrophomonas maltophilia*

Transmission mode: Direct contact

Clinical setting: ICU

Source: water-cooler for drinking water

Assessment of evidence
Control measures: Chilling unit and tubing was removed from the tap. Since that time no more FR04 and FR06 genotypes have been found in ICU and the *Stenotrophomonas* prevalence has fallen to <2% of admissions. This chilling unit was installed in 2009 and the carbon filter had been changed quarterly, but not the tubing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schneider H, Geginat G, Hogardt M, et al. *Pseudomonas aeruginosa* outbreak in a pediatric oncology care unit caused by an errant water jet into contaminated siphons. The Pediatric infectious disease journal. 2012 Jun 1;31(6):648-50.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results (RAPD-PCR and single-nucleotide polymorphism–type *P. aeruginosa* microarray).

Assessment of evidence
Contaminated aerosols may have emerged from the siphon at every water use. Patients could have acquired infection with the outbreak clone due to inhalation of contaminated aerosols (patients B and C), via smear infection with water drops directly from the water tap (patients B and C) or through horizontal transmission from contaminated persons such as staff or family members (patient A). Organism: *Pseudomonas aeruginosa* Transmission mode: Aerosolisation, indirect contact Clinical setting: pediatric oncology care unit (POCU) Source: contaminated siphons. Control measures: new water taps were installed throughout entire POCU to avoid direct water flow into the sink. Siphons in the anterooms in isolation rooms 2 and 3 were additionally replaced. Patients and staff were obliged to rinse the water taps with running hot water preceding every water use.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Rogues AM, Boulestreau H, Lashéras A, et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonisation of *Pseudomonas aeruginosa* in a French ICU (including finding the source) and to determine the impact of infection	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of colonisation.	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection. 2007 Sep 1;67(1):72-8.			prevention and control measures.		

Assessment of evidence

Pseudomonas aeruginosa was found in tap water samples in patients' rooms more than in other tap water in the unit. Chronological epidemiological analysis and PFGE results suggested transmission from tap water to patient in 7 cases of the 15 strains (roughly half) identified 72 h after patient's admission. Six patients had a strain undetected in water but found in at least one other patient during the same stay suggesting cross-transmission. Six out of the 153 patients were identified as carriers on admission. Among seven *P. aeruginosa* strains isolated from HCW hands, the genotype obtained was the same as that from the last patient they had touched in six cases, and in the seventh with the last tap water sample used.

Both water-related and non-water related strains appeared to have spread in half of the instances.

Organism: *Pseudomonas aeruginosa*

Transmission mode: indirect transmission; carriage by patients and water source.

Clinical setting: ICU

Source: contaminated water systems, and colonised patients

Control measures: twice monthly disinfection. An aqueous solution (4.5%) of sodium hypochlorite (diluted household bleach) was injected into taps with a 60 mL syringe for 15 min. Aerators were removed every two weeks, immersed and brushed in a detergent-disinfectant solution. The disinfection programme was instituted. Hand disinfection with an alcohol-based solution was required between patient contacts. Only bottled water was used for enteral nutrition and to administer drugs through gastric tubes. Bottled water is not sterile but analyses performed every year on bottles used for immunocompromised patients in another unit were always satisfactory. Sterile water was used for mouth care.

A defective flexible bronchoscope was contaminated and then later removed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pena C, Dominguez MA, Pujol M, et al. An outbreak of carbapenem-resistant *Pseudomonas aeruginosa* in a urology ward. Clinical microbiology and infection. 2003 Sep;9(9):938-43.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and Carbapenem-resistant *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence

Typing indicated that the CRPA outbreak resulted from the contamination of the cystoscopy room via an unsealed drain. The outbreak ended when the drain was sealed.

Organism: Carbapenem-resistant *Pseudomonas aeruginosa*

Transmission mode: Indirect contact. The urology surgical drape was routinely re-used on several patients despite it being single-use; the drape may have been contaminated from the open drain in the room which was seen to have back flow (patient fluids ran into this drain). Samples from the open drain, drape, and surgical table tested positive.

Clinical setting: cystoscopy room

Source: Unsealed drain

Assessment of evidence
Control measures: Strict adherence to disinfection protocol. Examination of cystoscopy room and repairs were undertaken. Surgical drape should only be used once, and the open drainage of the floor should be provisionally closed.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al. Analysis of transmission pathways of *Pseudomonas aeruginosa* between patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between *Pseudomonas aeruginosa* infection and faucet contamination in a surgical ICU.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish transmission pathways.	Number of positive samples, sample type, relationship between genotypes (RAPD)

Assessment of evidence
The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed. Organism: *Pseudomonas aeruginosa* Transmission mode: Indirect (potentially hands of HCWs, transfer of colonized patients between wards, splashing of water around the washbasin).

Assessment of evidence
Clinical setting: SICU and other surgical wards Source: individual faucets Control measures: an intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention. Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonized with *P. aeruginosa* were wounds and the pharynx.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bukholm G, Tannæs T, Kjelsberg AB, et al. An outbreak of multidrug-resistant *Pseudomonas aeruginosa* associated with increased risk of patient death in an intensive care unit. Infection Control & Hospital Epidemiology. 2002 Aug;23(8):441-6.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in Norway (including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results (AFLP) between clinical strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, DNA fingerprinting results (AFLP).

Assessment of evidence
Outbreak eventually stopped after implementation of the pasteurization procedure for water taps and use of sterile water for drugs and food. Organism: *Pseudomonas aeruginosa* Transmission mode: indirect transmission Clinical setting: ICU Source: Wash basin, tap (inside and out) were contaminated. Decontaminated connection tubes for ventilator suction were found to be contaminated. Control measures: Contact isolation regimens were implemented in rooms with contaminated patients, change of AB policy. Pasteurization of the water taps was implemented.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hota S, Hirji Z, Stockton K, et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* colonization and infection secondary to imperfect intensive care unit room design.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection Control & Hospital Epidemiology. 2009 Jan;30(1):25-33.					

Assessment of evidence

Typing was performed using PFGE. This study shows the importance of proper designs of sinks as well as room designs.

Transmission of outbreak organism to patients by means of fluorescent marker testing was visually demonstrated.

Organism: *Pseudomonas aeruginosa*

Transmission mode: probably through contamination of the area where sterile procedures and medication preparation were performed through the splash of drain contents.

Clinical setting: intensive care unit or transplant units of a tertiary care hospital

Source: hand hygiene sink drains

Control measures: the use of contact precautions (wearing of gowns and gloves by healthcare workers and single room isolation of the patient) for all colonized or infected cases; staff education; enhanced environmental cleaning; disinfection of hand hygiene sink drains; closure of hand hygiene sinks; and renovation of hand hygiene sinks to prevent splashing of drain contents.

Limitation: control measures part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tosh PK, Disbot M, Duffy JM, et al. Outbreak of *Pseudomonas aeruginosa* surgical site infections after arthroscopic procedures: Texas, 2009. Infection Control & Hospital Epidemiology. 2011 Dec;32(12):1179-86.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* isolated from environmental/surgical equipment samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
Evidence from the investigation suggests that this outbreak was most likely the result of inadequate instrument reprocessing that led to retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel. Organism: *Pseudomonas aeruginosa* Transmission mode: direct insertion of contaminated instruments or by infusion of fluid through the contaminated lumen. Clinical setting: ORs Source: retained tissue in the arthroscope inflow/outflow cannulae and in the shaver handpiece suction channel. (contaminated instruments) Control measures: closing the OR pod where the majority of arthroscopic procedures were performed, replacing the arthroscopic instruments, returning to use of more rigid suction tubing for arthroscopy, and changing the instrument reprocessing protocols. Instrument					

Assessment of evidence
reprocessing protocols were adjusted. The gross decontamination room was redesigned to improve workflow, instrument reprocessing staff received annual training and certification, and tracking of the individual instruments used in each surgery was initiated. Limitation: even though statistics are explained in methods, p-values etc are not provided. IPC measures are part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM, Chinn RYW, Arduino MJ, et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/American Hospital Association; 2004.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally-mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on transmission routes: “Moist environments and aqueous solutions in health-care settings have the potential to serve as reservoirs for waterborne microorganisms. Under favorable environmental circumstances (e.g., warm temperature and the presence of a source of nutrition), many bacterial and some protozoal microorganisms can either proliferate in active growth or remain for long periods in highly stable, environmentally resistant (yet infectious) forms. Modes of transmission for waterborne infections include direct contact [e.g., that required for hydrotherapy]; ingestion of water [e.g., through consuming contaminated ice]; indirect-contact transmission [e.g., from an improperly reprocessed medical device]; inhalation of aerosols dispersed from water sources; and aspiration of contaminated water. The first three modes of transmission are commonly associated with infections caused by gram-negative bacteria and nontuberculous mycobacteria (NTM). Aerosols generated from water sources contaminated with Legionella spp. often serve as the vehicle for introducing legionellae to the respiratory tract.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a haemato-oncology unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in Edinburgh and to	N/A	Number of positive samples, sample type and species.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection, 79; 339-343. 2011.			determine the impact of infection prevention and control measures.		

Assessment of evidence

Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.)

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: Haemato-oncology unit.

Source: water system.

Control measures: the cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced.

Limitations: Similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence

Organism: *Mycobacterium mucogenicum*

Source: Contaminated automatic water tap. review of practices for handling CVCs revealed that instructions for bathing patients were inadequate, as the exit sites were not properly covered; catheters could have been exposed to shower water.

Clinical setting: Paediatric haemato-oncology

Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet.

Assessment of evidence
Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.
Assessment of evidence					
Organism: *M. abscessus* Transmission mode: tap water to patient. Aerosolisation - possibly cardiac heater cooler units in cardiac patients (the tap used to fill the units was positive). Multiple other water sources were positive including patient taps, ice machine. Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase				

Assessment of evidence
2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease. Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leitner E, Zarfel G, Luxner J, et al. Contaminated handwashing sinks as the source of a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a KPC-2-producing *Klebsiella oxytoca* clonal outbreak on a	Molecular typing results between patient strains and *P. aeruginosa* isolated from	Number of positive samples, sample type, genotyping results (MLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
clonal outbreak of KPC-2-producing *Klebsiella oxytoca* on a hematology ward. Antimicrobial agents and chemotherapy. 2015 Jan 1;59(1):714-6			hematology ward in Austria and to determine the source.	environmental/water samples were compared to establish a link of infection.	
Assessment of evidence					
The starting point of this outbreak started with a colonized patient from the ICU who was later transferred to the hematology ward. It is hypothesized that KPC-2-producing *K. oxytoca* got into the sink most likely during personal hygiene activities or by disposal of contaminated body fluids, where it persisted. Authors also hypothesise that patients were contaminated by aerosols when using the sink although this is not proven from the study. Organism: *Klebsiella oxytoca* Transmission mode: indirect/aerosolisation Clinical setting: Hematology Ward Source: handwashing sink. Control measures: -					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Halstead F. D., Niebel M., Garvey M., et al *Pseudomonas aeruginosa* infection in augmented care: the molecular ecology and transmission dynamics in four large UK hospitals. Journal of Hospital Infection 111 (2021) 162e168	Surveillance study	**Level 3**	This study aimed to investigate the transmission of *P. aeruginosa* from water to adults in a non-outbreak augmented care setting.	Phylogenetic relatedness between clinical and environmental samples.	Number of outlets sampled, number of positive outlets per sampling period (beginning, middle, end), phylogenetic relatedness between clinical and environmental samples.

Assessment of evidence

In this study of four anonymized UK hospitals, 881 water outlet samples were taken from 774 taps and 107 showers and the genetic relatedness was compared to 120 clinical *P. aeruginosa* samples to investigate the transmission of *P. aeruginosa* from the water outlet to the adult patients in the 23 augmented care units.

Organism: *P. aeruginosa*

Transmission mode: Direct/indirect from taps and showers. Exact mode not proven.

Clinical setting: Augmented care units

Source: Water from outlets (taps and showers) was positive.

Assessment of evidence
Control measures: N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary bypass since reports from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of heater-cooler units (HCUs) used during bypass.	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and presentation, outcome. Growth/ contamination of air/environmental samples, whole-genome sequencing data (phylogenetic relatedness)

Assessment of evidence
This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an

Assessment of evidence
increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year. Organism: *Mycobacterium chimaera* Transmission mode: Aerosolisation. Clinical setting: cardiothoracic surgery Source: cardiopulmonary bypass heater-cooler units Control measures: N/A Limitations: A 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Infections Associated with Heater Cooler Units Used in Cardiopulmonary Bypass and ECMO - Information for healthcare providers in the UK	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Version 2. 2017.					

Assessment of evidence

The following sections of this UK guidance document are relevant for this research question on transmission routes:

"During 2014-15, PHE were made aware of cases of *Mycobacterium chimaera* endocarditis or deep infection following cardiac surgery in Switzerland, Germany and The Netherlands. *M. chimaera* is a recently described species within the *Mycobacterium avium* complex, a group of environmental organisms usually associated with lung infections, or systemic infections in the immunocompromised host. A Swiss investigation implicated the Sorin (now LivaNova) 3T heater cooler unit (HCU) of the cardiopulmonary bypass equipment, with the transmission of bacteria to the surgical site by aerosolisation of contaminated water from within the unit. The LivaNova device is widely used in the UK and internationally. Maquet, another manufacturer of devices used in the UK, has also indicated that *M. chimaera* has been identified in its HCU water tanks and issued advice to manage any associated risk."

Transmission mode: aerosolisation of *M. chimaera* from the contaminated water heater cooler unit.

Clinical settings: cardiac surgery

Source: contaminated water heater cooler units

Control measures: replacement of units

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sax H., Bloemberg G., Hasse B., et al. Prolonged Outbreak of *Mycobacterium chimaera* Infection	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chimaera* outbreak in Switzerland	Molecular genotyping results between patient strains and *Mycobacterium*	Clinical and patients' characteristics of probable cases including surgery type, type of implant,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
After Open-Chest Heart Surgery. Clinical Infectious Diseases 2015;61(1):67–75			(including finding the source) and to determine the impact of infection prevention and control measures.	*chimaera* isolated from environmental/water samples were compared to establish link of infection.	latency, positive cultures. Growth/ contamination of air/environmental/water samples, genotype, outbreak management.

Assessment of evidence

This outbreak investigation started after 2 patients were found to have *Mycobacterium chimaera* infection and an in-depth outbreak investigation was done to detect the source, including retrospective case detection, prospective surveillance, on-site observations, and targeted microbiological sampling of patients and the hospital environment. In total, 6 patients met the case definition; All patients had undergone open-chest heart surgery involving implants and the use of heater-cooler units at the University Hospital of Zurich between 2008 and 2012. *Mycobacterium chimaera* was cultured from 5 heater-cooler units and an air sample. Latency between surgery and manifest infection ranged between 1.5 and 3.6 years.

Organism: *Mycobacterium chimaera* (NTM)

Transmission mode: Aerosolisation

Clinical setting: open-chest heart surgery patients

Source: heater-cooler unit reservoirs

Control measures: Not under control when published (Only used factory-new heater-cooler units with daily water changes and POU filters, however there was another positive sample in Sept 2014 from 1 heater-cooler unit. At the time of writing (Dec 2014), the construction of custom-built containers with high-efficiency particulate air filters to house heater-cooler units that cannot be placed outside the operating room is under way.)

Incubation time: Latency between surgery and manifest infection ranged between 1.5 and 3.6 years

Assessment of evidence
Limitations: • No genotypic link between patients and environmental samples • All drinking water fountains in the hospital ICUs tested positive, so cannot rule out that this was another potential source

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for Decontamination and testing of Cardiac Heater Cooler Units (HCUs). 2019	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results. The following sections of this guidance document are relevant for this research question on transmission routes: “HCUs are used during cardiac surgery procedures for cooling or warming the patient connected to an extracorporeal perfusion circuit, keeping the patient’s body temperature constant during procedures. There is no contact (except in very rare cases) between the patient and the water circulating through the HCU or the perfusion circuit. However, nontuberculous mycobacteria (NTM) can be aerosolised by					

Assessment of evidence
the HCU to the vicinity. Ultraclean air ventilation systems have proven to be inefficient against *M. chimaera* infections, thus the HCU decontamination."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for the interpretation and clinical management of endoscopy final rinse water. 2019.	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document aims to enhance patient safety and reduce risks of decontamination related Healthcare Associated Infection (HAI) by standardising the interpretation of and clinical management of endoscopy final rinse water results nationally, based on available scientific evidence, current practices and an estimation of infection risk within NHSScotland following endoscopic procedures. The following sections of this guidance document are relevant for this research question on transmission routes: "To develop guidance for the clinical management of endoscopy final rinse water a data linkage exercise was performed with the aim of quantifying possible HAI risk related to endoscopy procedures. This was carried out in 2016/17 and attempted to estimate the risk of infection and identify potential infection clusters following endoscopic procedures. Data linkage was performed on endoscopic procedures carried out in Scotland with positive isolates post procedure reported via Electronic Communication of Surveillance in Scotland (ECOSS).

Assessment of evidence
The data linkage study planned for publication in 2018 found the risk of infection following an endoscopic procedure in Scotland was 1.5 – 3.3% over the 5 year study period; lower than reported rates found in the literature."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard MM, et al. Investigation of an *Enterobacter hormaechei* OXA-436 carbapenemase outbreak: when everything goes down the drain. Infect Prev Pract. 2022;4(3):100228. Published 2022 Jun 30. doi:10.1016/j.infpip.2022.100228	Outbreak investigation	**Level 3**	The aim of the study was to investigate a *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Timeline of outbreak and overlap of patients, amount of positive environmental samples, whole genome sequencing results (MLST types).
Assessment of evidence					
This study investigated an outbreak of *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene in the Cardiology department of a hospital in Denmark. Various environmental swab samples were taken (from shower drains, floor drains below sinks, sinks, bedpan boilers/instrument washers) and WGS results (MSLT types) revealed a link between patient strains and two environmental strains taken					

Assessment of evidence
from the shower drains in the only two patient bathrooms in the unit. Staff reported that these drains had a tendency to become partly blocked resulting in regular overflow of water from the drains while patients were showering. Outbreak measures described below resolved the outbreak and no new cases nor new positive environmental samples were found after 3 years. Organism: *Enterobacter hormaechei* OXA-436 carbapenemase Transmission mode: possibly splashing and spraying from shower drain water Clinical setting: Cardiology department. Source: Shower drains (overflow of water from clogged drains while showering) Control measures: Physical floor grate and traps were changed and fixed to the drain. The bathrooms were emptied and cleaned. The part of the floor drains, that wasn't possible to change were manually cleaned and afterward rinsed with vinegar. Finally the bathrooms were disinfected with vaporized hydrogen peroxide (RHEA Compact) following cleaning. The shower heads were relocated so that the water did not hit the drain directly (reducing splash risk). The waste pipes were cleaned and the function of the drains and sewer system re-established to prevent overflow. In addition to the regular cleaning of the two bathrooms, an extra daily cleaning with chlorine disinfection of all contact points was established. Limitations: • Patient characteristics are not provided, only that the patients were admitted to the same department (different times 6/7)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
de Jonge E, de Boer MGJ, van Essen EHR, et al. Effects of a disinfection device	Outbreak investigation	**Level 3**	The aim of this study was to study the influence of installing disinfecting devices on sink drains on	Isolated cultures of multidrug-resistant *P. aeruginosa.* before and after the 'intervention'	Number of positive samples, sample type

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
on colonization of sink drains and patients during a prolonged outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 2019; 102: 70-74			colonization of sinks and patients in a Dutch ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa.*	(installation of disinfecting devices)	

Assessment of evidence

The 'intervention' setting was an active ICU unit therefore not controlled or randomised; low quality evidence.

These devices appeared to be successful at decreasing the colonisation rates of sink drains however they were not 100% effective; some sink drains occasionally tested positive for MDR-PA. This suggests that other components/distal regions of the sink plumbing remained colonized.

Organism: multidrug-resistant *Pseudomonas aeruginosa*

Transmission mode: contaminated water systems to patient (likely indirect as ICU so patients bedbound, HCWs accessing sinks).

Clinical setting: ICU

Source: sink drains

Control measures: IPC

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wong V, Levi K, Baddal B, et al. Spread of *Pseudomonas fluorescens* Due to Contaminated Drinking Water in a Bone Marrow Transplant Unit. Journal of Clinical Microbiology 2011, 49(6), 2093-2096.	Outbreak study	**Level 3**	This study reports the findings of the epidemiological and microbiological investigation of a *Pseudomonas fluorescens* outbreak.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

Nine patient cases, 6 of this developed febrile neutropenia. All had positive pharyngeal samples. Water sample from a water dispenser in the unit tested positive and genetically matched the patient isolates. All other environmental samples were negative.

Organism: *Pseudomonas fluorescens*

Clinical setting: Bone marrow transplant unit, England UK.

Transmission mode: Direct (ingestion).

Source: Chilled water dispenser as reservoir, unclear how it became contaminated (authors theorised that the nozzle may have been touched by contaminated hands).

Control measures: Removal of the contaminated chilled water dispenser (the remaining one was kept). The long-term plan for the unit is to install filtered plumbed-in main water dispensers and to implement regular qualitative and quantitative water assessments.

Assessment of evidence
Genetic relatedness: All nine patient isolates and the one environmental isolate were identified as being *Pseudomonas fluorescens*. "The isolate from the water dispenser was found to be genotypically identical to the patients' isolates: all isolates of *P. fluorescens* produced identical RAPD patterns (type b pattern), and typing by PFGE revealed that all isolates recovered were indistinguishable, with a designated profile of NOTT PF1." Limitations: Water was sampled via the nozzle of the chiller unit and not directly from the bottle before or after installation, so unclear where the contamination originated from.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient. *M. mucogenicum* also found in the hot water source in the main hospital, and the city water source for the hospital. Organism: *Mycobacterium mucogenicum* Transmission mode: indirect/ aerosolisation Clinical setting: University-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients. Source: water contamination of central venous catheters (CVCs) during bathing Control measures: The following control measures were recommended and implemented. • Showerheads and hoses on the Bone marrow transplant (BMT) units were replaced. • Shower hoses were allowed to hang straight with no dependent loops when not in use to reduce the risk of bacteria multiplying to higher levels in stagnant water. • Direct care providers, patients and family members were educated on the risks of water contamination of central venous catheters (CVC) during bathing and on prevention methods to minimize water contact during bathing. • IV catheters were disconnected before bathing when possible. • Catheter connections were covered with waterproof material if they could not be disconnected

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from	Number of positive samples, sample type, antimicrobial susceptibility, DNA

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. Infection control and hospital epidemiology. 2004 Mar 1;25(3):231-9.			*(*including finding the source) and to determine the impact of infection prevention and control measures.	environmental/water samples were compared to establish link of infection.	fingerprinting results (PCR-RFLP).
Assessment of evidence					
Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections. Tap water and swab from inside tab were positive. Organism: *Burkholderia cepacia* Transmission mode: contaminated tap water that contaminated alcohol-based products. Clinical setting: hospital Source: contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with *B. cepacia*). Control measures: once organisms were cultures from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards.					

Assessment of evidence
Type of infection: bloodstream infections Limitation: only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium phocaicum* associated with an outbreak of bacteremias at a Texas hospital. Applied Environmental Microbiology. 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Apr; 74(8): 2480-2487.					

Assessment of evidence

Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present.

Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework.

Organism/ infection: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* CVC-associated bloodstream infection.

Transmission mode: unconfirmed but all patients had CVCs.

Clinical setting: Oncology department, United States of America

Source: Hospital water supply

Control measures: not described.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leung GHY, Gray TJ, Cheong EYL, et al. Persistence of related bla-IMP-4 metallo-beta-lactamase producing	Outbreak report	**Level 3**	This paper describes the investigation undertaken in a six - year persistent bla-IMP-4 metallo-beta-lactamase (MBL) producing Enterobacteriaceae	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Enterobacteriaceae from clinical and environmental specimens within a burns unit in Australia - a six-year retrospective study. Antimicrobial Resistance and Infection Control 2013, 2:35			within a separately confined hospital burns unit in a tertiary hospital in Australia.		

Assessment of evidence

23 patients, with clinical infection in 7 (2 bacteremias, 2 CVC tip infections, 3 wound infections).

Assessment of evidence: The only environment shared between patients was the shower and bathroom facilities.

Organism: *Enterobacter clocae* (most commonly detected organism), *Klebsiella pneumoniae, Enterobacter aerogenes, Klebsiella oxytoca.*

Clinical setting: Burns unit, Australia.

Source: Sink and shower drains identified as reservoirs and potential source for some transmissions. Patients may have been initial source. Shower taps, handwashing sinks and taps also tested positive.

Transmission: Unclear, however likely both direct and indirect.

Control measures: Monthly and then bi-monthly environmental sampling (bathroom facilities and plumbing including shower drains, ensuite room sink drains). Regular physical cleaning of drains to remove biofilm and additional cleaning with double-strength phenolic disinfectant (Phensol), later changed to chlorine-based product (Chlor-clean). Despite both regular environmental surveillance and disinfection, environmental reservoirs remained.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-outbreak attributed to contaminated rinse water. American Journal of Infection Control. 2020 Jan 1;48(1):26-32.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE).

Assessment of evidence

The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope.

Organism: *P. aeruginosa*

Transmission mode: indirect contact.

Clinical setting: bronchoscopy unit

Source: sink connecting tube was implicated as the source of *P aeruginosa* contamination to bronchoscopes.

Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these

Assessment of evidence
measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lanini S, D'Arezzo S, Puro V, et al. Molecular epidemiology of a Pseudomonas aeruginosa hospital outbreak driven by a contaminated disinfectant-soap dispenser. PLoS ONE. 2011 Feb 16; 6(2):e17064.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of *P. aeruginosa* at a haematology unit in Italy.	Environmental isolates compared to patient isolates.	Number of positive samples, sample type, typing results (RAPD and MLST).

Assessment of evidence
Four environmental samples were positive (2 from soap dispensers, 2 from water outlets in patients rooms). Soap strains were genotypically identical to clinical strains. The water isolates did not match. Organism: *P. aeruginosa* Transmission mode: Indirect – via contaminated HCW hands from the contaminated soap dispenser (Triclosan soap).

Assessment of evidence
Clinical setting: Haematology unit. Source: Contaminated soap dispenser. Control measures: Removal of soap dispenser.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Eckmanns T, Oppert M, Martin M, et al. An outbreak of hospital-acquired Pseudomonas aeruginosa infection caused by contaminated bottled water in intensive care units. Clinical Microbiology and Infection. 2008; 14(5): 454-458.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of P. aeruginosa at 6 ICUs in Germany.	Environmental isolates compared to patient isolates.	Number of positive samples, sample type, typing results (r-PCR, AFP typing, PFGE).

Assessment of evidence
The samples from bottled water were a genetic match to isolates from 19 infected or colonised ICU patients. Tap water samples did not match. Organism: *P. aeruginosa*

Assessment of evidence
Transmission mode: Aspiration – from contaminated bottled water. Lung infections probably caused by transmission through aspiration from the oropharynx to the lungs (from orally administered medications), and from aspiration from nasogastric tubes when bottled water used to prepare food. Clinical setting: ICU. Source: Contaminated bottled water. Control measures: removal of bottled water.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Weng MK, Brooks RB, Glowicz J, et al.t Outbreak investigation of *Pseudomonas aeruginosa* infections in a neonatal intensive care unit. American Journal of Infection Control 2019; 47: 1148-1150.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of *Pseudomonas aeruginosa* in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Genetic relatedness
Assessment of evidence					
Outbreak report: Molecular typing confirmed reservoir in sink plumbing and possible hospital water as source. Potential transmission routes from contaminated breast milk, bathing, incubators. Humidifier reservoirs of incubators were filled with tap water, despite					

Assessment of evidence
manufacturer instructions recommending distilled water. Parents cleaned reusable breast pump equipment in sinks that were also used for handwashing and other medical purposes. Organism: *Pseudomonas aeruginosa* Transmission mode: Contaminated water systems Clinical setting: NICU, United States of America Source: Not confirmed, taps/sinks as reservoirs; possible routes include contaminated breast pump equipment and humidifier reservoirs of incubators. Control measures: Hyperchlorination of hospital water with calcium hypochlorite at 200 parts per million (ppm) for 2 hours. Supplemental hypochlorite added at municipal water intakes yielded residual chlorine levels of 2ppm at distal sites until a monochloramine system was installed. Although hyperchlorination reduced post-filter water samples HPCs to <3 CFU/mL, P. aeruginosa was still cultured from first-catch faucet water samples from 3 of 5 NICU faucets sampled. Preparation of breast milk/infant formula outwith splash zones, bathing neonates in sterile water, following manufacturer instructions for breast pump equipment drying and incubator water. Plumbing proximal to NICU sinks was replaced. POU filters installed on all sinks taps. No additional cases (active surveillance on admission) over 1 year after implementation of recommended control measures. Limitations: Not all patient isolates were available for typing.

Question 9: Which healthcare procedures present an increased risk of transmission of healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-outbreak attributed to contaminated rinse water. American Journal of Infection Control. 2020 Jan 1;48(1):26-32.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE).

Assessment of evidence

The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope.

Organism: *P. aeruginosa*

Transmission mode: indirect contact.

Clinical setting: bronchoscopy unit

Assessment of evidence
Source: sink connecting tube was implicated as the source of *P aeruginosa* contamination to bronchoscopes. Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Bradley CW and Holden E. Waterborne *Pseudomonas aeruginosa* transmission in a hematology unit? American Journal of Infection Control 2018; 46: 383-386.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the UK (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Number of positive samples, sample type, typing results (PFGE).
Assessment of evidence					
Outbreak report – molecular typing conducted (PFGE). Transmission of *Pseudomonas aeruginosa*; transmission route via prep trays from contaminated water outlet. Hickman lines entry route.					

Assessment of evidence
Organism: *Pseudomonas aeruginosa* Transmission mode: contaminated water systems Clinical setting: Hematology unit, UK. Source: transmission route via prep trays from contaminated water outlet. Hickman lines entry route. Control measures: POU filters were installed on all outlets in the hematology ward. Filters were already on all outlets apart from those in the intravenous prep room. Trays were cleaned with quaternary ammonium compound wipes (Clinell Universal wipes, GAMA Healthcare UK) and dried thoroughly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Botana-Rial M, Leiro-Fernández V, Núñez-Delgado M, et al. A pseudo-outbreak of *Pseudomonas putida* and *Stenotrophomonas maltophilia* in a bronchoscopy unit. Respiration. 2016;92(4):274-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas putida* and *Stenotrophomonas maltophilia* pseudo-outbreak and to determine the source.	Molecular typing results between clinical strains and *Pseudomonas putida* and *Stenotrophomonas maltophilia* isolated from environmental/water samples were compared to determine the source of the pseudo-outbreak.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence
From the information provided by the authors, it is not possible to conclude that the source of the outbreak were the bronchoscopes or the AERs. *Pseudomonas putida* and *Stenotrophomonas maltophilia* were also isolated from sinks, cleaning brushes and cleaning solutions. Thus, although the authors found AERs to be contaminated it is not certain that this was the source. However, this study provides evidence that inadequate disinfection of bronchoscopes can lead to infections/colonization in patients. Organism: *Pseudomonas putida* and *Stenotrophomonas maltophilia* Transmission mode: indirect contact (contaminated equipment) Clinical setting: bronchoscopy unit. Source: Contaminated water-based equipment (bronchoscopes). Although source uncertain. Control measures: -

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of hospital infection. 2016 Sep 1;94(1):2-7.					

Assessment of evidence

Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit.

Pseudomonas aeruginosa has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients.

Organism: *Pseudomonas aeruginosa*

Transmission mode: contaminated environment; however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11, suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission.

Clinical setting: ICU – burn unit.

Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa.

Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily.

Assessment of evidence
Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tagashira Y, Kozai Y, Yamasa H, et al. A cluster of central line–associated bloodstream infections due to rapidly growing nontuberculous mycobacteria in patients with hematologic disorders at a Japanese tertiary care center: an outbreak investigation and review of the literature. Infection control & hospital	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of central line–associated nontuberculous mycobacteria bloodstream infections in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and nontuberculous mycobacteria isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
epidemiology. 2015 Jan;36(1):76-80.					
Assessment of evidence					
The outbreak appeared to be caused by 2 different clones of *M. mucogenicum* as well as *M. canariasense*. Type matching of isolates from blood cultures and environmental/water cultures indicated that the origin of these organisms was the tap water supply. Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Organism: Rapidly Growing Nontuberculous Mycobacteria (*M. mucogenicum* and *M. canariasense*.) Transmission mode: Submersion of CVC during bathing, showering or toileting seemed to be the port of entry. Clinical setting: hematology-oncology ward Source: contaminated water systems Control measures: Catheter/port removal and antimicrobial therapy.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Reuter S, Sigge A, Wiedeck H, et al. Analysis of transmission pathways of *Pseudomonas aeruginosa* between	Prospective single cohort study	**Level 3**	This study aimed to investigate the association between *Pseudomonas aeruginosa* infection and faucet contamination in a surgical ICU.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish	Number of positive samples, sample type, relationship between genotypes (RAPD)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
patients and tap water outlets. Critical care medicine. 2002 Oct 1;30(10):2222-8.				transmission pathways.	

Assessment of evidence

The principal route of transmission appears to be personnel, because during most of their stay in the SICU, patients are immobilized and are washed in bed.

Organism: *Pseudomonas aeruginosa*

Transmission mode: Indirect (potentially hands of HCWs, transfer of colonized patients between wards, splashing of water around the washbasin).

Clinical setting: SICU and other surgical wards

Source: individual faucets

Control measures: an intensive program of cleaning and autoclaving of the aerators was performed, however, tap water cultures were positive for the same strain before and after the implementation of this intervention.

Infections caused by PA: Infections caused by *P. aeruginosa* were infections of the airways (i.e., pneumonia, tracheobronchitis), wound infections, septicaemia, and urinary tract infections, and organs colonized with *P. aeruginosa* were wounds and the pharynx

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients. American Journal of Kidney Diseases. 2019 Nov 1;74(5):610-9.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (for example age and comorbid conditions). The second investigation looked at factors specific to a patient during a particular treatment.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection. Risk factors for becoming a case are investigated using case-control study designs (2x).	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence

In this study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of BSIs.

Organism: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae*

Transmission mode: indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes).

Clinical setting: outpatient haemodialysis facilities

Assessment of evidence
Source: dialysis station wall boxes (contaminated water-based equipment) Control measures: implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM, Chinn RYW, Arduino MJ, et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). Chicago IL; American Society for Healthcare Engineering/America	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
n Hospital Association; 2004.					
Assessment of evidence					
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally-mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on healthcare procedures with a risk of transmission of waterborne organisms: “Inappropriate reprocessing of instruments with tap water The use of tap water in medical care (e.g., in direct patient care, as a diluent for solutions, as a water source for medical instruments and equipment, and during the final stages of instrument disinfection) therefore presents a potential risk for exposure. Colonized patients also can serve as a source of contamination, particularly for moist environments of medical equipment (e.g., ventilators).”					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a haemato-oncology unit.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in Edinburgh and to	N/A	Number of positive samples, sample type and species.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection, 79; 339-343. 2011.			determine the impact of infection prevention and control measures.		

Assessment of evidence

Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.)

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: Haemato-oncology unit.

Source: water system.

Control measures: the cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced.

Limitations: Similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence

Organism: *Mycobacterium mucogenicum*

Source: Contaminated automatic water tap. Review of practices for handling CVCs revealed that instructions for bathing patients were inadequate, as the exit sites were not properly covered; catheters could have been exposed to shower water.

Clinical setting: Paediatric haemato-oncology

Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet.

Assessment of evidence
Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on our seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation. Clinical Infectious Diseases, 64 (7), 902-911, 2017.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.
Assessment of evidence					
Organism: *M. abscessus* Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients. Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease					

Assessment of evidence
Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth. Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM. Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chand M., Lamagni T., Kranzer K., et al. Insidious Risk of Severe *Mycobacterium chimaera* Infection in	Surveillance study	**Level 3**	To quantify the risk of *Mycobacterium chimaera* infection to cardiac surgery patients that had undergone cardiopulmonary	Phylogenetic relatedness between clinical and environmental samples.	Clinical characteristics of probable cases including site of infection, median time between surgery and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cardiac Surgery Patients. Clinical Infectious Diseases. 2017;64(3):335–42			bypass since reports from NL, Germany and US showed patients to be infected by contaminated aerosols from the water tanks of heater-cooler units (HCUs) used during bypass.		presentation, outcome. Growth/ contamination of air/environmental samples, whole-genome sequencing data (phylogenetic relatedness)

Assessment of evidence

This UK surveillance study was prompted after international alerts on *Mycobacterium chimaera* infection and its association with cardiopulmonary bypass heater-cooler units and thus increasing risk for cardiac surgery patients. This national surveillance showed an increased risk for cardiothoracic patients undergoing bypass. Aerosol release was detected through breaches in the heater-cooler tanks. It also showed an incubation time between surgery and presentation ranging from 3 months to 5.1 years with 7 cases presenting within 1 year.

Organism: *Mycobacterium chimaera*

Transmission mode: indirect contact/Aerosolisation

Clinical setting: cardiothoracic surgery

Source: cardiopulmonary bypass heater-cooler units

Control measures: N/A

Assessment of evidence
Limitations: A 5-year period of risk after surgery based on the observed maximum incubation (4 year) was used, but longer latency is possible

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Infections Associated with Heater Cooler Units Used in Cardiopulmonary Bypass and ECMO - Information for healthcare providers in the UK Version 2. 2017.	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
The following sections of this UK guidance document are relevant for this research question on healthcare procedures with a risk of transmission of waterborne organisms: ““During 2014-15, PHE were made aware of cases of *Mycobacterium chimaera* endocarditis or deep infection following cardiac surgery in Switzerland, Germany and The Netherlands. *M. chimaera* is a recently described species within the *Mycobacterium avium* complex, a group of environmental organisms usually associated with lung infections, or systemic infections in the immunocompromised host. A Swiss investigation implicated the Sorin (now LivaNova) 3T heater cooler unit (HCU) of the cardiopulmonary bypass equipment, with the transmission of bacteria to the surgical site by aerosolisation of contaminated water from within the unit. The LivaNova device is widely

Assessment of evidence
used in the UK and internationally. Maquet, another manufacturer of devices used in the UK, has also indicated that M. chimaera has been identified in its HCU water tanks and issued advice to manage any associated risk." Transmission mode: aerosolisation of *M. chimaera* from the contaminated water heater cooler unit. Clinical settings: cardiac surgery Source: contaminated water heater cooler units Control measures: replacement of units

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sax H., Bloemberg G., Hasse B., et al. Prolonged Outbreak of *Mycobacterium chimaera* Infection After Open-Chest Heart Surgery. Clinical Infectious Diseases 2015;61(1):67–75	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium chimaera* outbreak in Switzerland (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of probable cases including surgery type, type of implant, latency, positive cultures. Growth/ contamination of air/environmental/water samples, genotype, outbreak management.
Assessment of evidence					
This outbreak investigation started after 2 patients were found to have *Mycobacterium chimaera* infection and an in-depth outbreak investigation was done to detect the source, including retrospective case detection, prospective surveillance, on-site observations, and					

Assessment of evidence
targeted microbiological sampling of patients and the hospital environment. In total, 6 patients met the case definition; All patients had undergone open-chest heart surgery involving implants and the use of heater-cooler units at the University Hospital of Zurich between 2008 and 2012. *Mycobacterium chimaera* was cultured from 5 heater-cooler units and an air sample. Latency between surgery and manifest infection ranged between 1.5 and 3.6 years. Organism: *Mycobacterium chimaera* (NTM) Transmission mode: indirect contact/ Aerosolisation Clinical setting: open-chest heart surgery patients Source: heater-cooler unit reservoirs Control measures: Not under control when published (Only used factory-new heater-cooler units with daily water changes and POU filters, however there was another positive sample in Sept 2014 from 1 heater-cooler unit. At the time of writing (Dec 2014), the construction of custom-built containers with high-efficiency particulate air filters to house heater-cooler units that cannot be placed outside the operating room is under way.) Incubation time: Latency between surgery and manifest infection ranged between 1.5 and 3.6 years Limitations: • No genotypic link between patients and environmental samples • All drinking water fountains in the hospital ICUs tested positive, so cannot rule out that this was another potential source

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for Decontamination and testing of Cardiac Heater Cooler Units (HCUs). 2019	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results. The following sections of this guidance document are relevant for this research question on healthcare procedures with a risk of transmission of waterborne organisms:

“HCUs are used during cardiac surgery procedures for cooling or warming the patient connected to an extracorporeal perfusion circuit, keeping the patient’s body temperature constant during procedures. There is no contact (except in very rare cases) between the patient and the water circulating through the HCU or the perfusion circuit. However, nontuberculous mycobacteria (NTM) can be aerosolised by the HCU to the vicinity. Ultraclean air ventilation systems have proven to be inefficient against M. chimaera infections, thus the HCU decontamination processes is crucial.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for the interpretation and clinical management of endoscopy final rinse water. 2019.	Guidance (non-systematic)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document aims to enhance patient safety and reduce risks of decontamination related Healthcare Associated Infection (HAI) by standardising the interpretation of and clinical management of endoscopy final rinse water results nationally, based on available scientific evidence, current practices and an estimation of infection risk within NHSScotland following endoscopic procedures. The following sections of this guidance document are relevant for this research question on healthcare procedures with a risk of transmission of waterborne organisms:

“To develop guidance for the clinical management of endoscopy final rinse water a data linkage exercise was performed with the aim of quantifying possible HAI risk related to endoscopy procedures. This was carried out in 2016/17 and attempted to estimate the risk of infection and identify potential infection clusters following endoscopic procedures. Data linkage was performed on endoscopic procedures carried out in Scotland with positive isolates post procedure reported via Electronic Communication of Surveillance in Scotland (ECOSS). The data linkage study planned for publication in 2018 found the risk of infection following an endoscopic procedure in Scotland was 1.5 – 3.3% over the 5 year study period; lower than reported rates found in the literature.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard MM, et al. Investigation of an *Enterobacter hormaechei* OXA-436 carbapenemase outbreak: when everything goes down the drain. Infect Prev Pract. 2022;4(3):100228. Published 2022 Jun 30. doi:10.1016/j.infpip.2022.100228	Outbreak investigation	**Level 3**	The aim of the study was to investigate a *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Timeline of outbreak and overlap of patients, amount of positive environmental samples, whole genome sequencing results (MLST types).

Assessment of evidence

This study investigated an outbreak of *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene in the Cardiology department of a hospital in Denmark. Various environmental swab samples were taken (from shower drains, floor drains below sinks, sinks, bedpan boilers/instrument washers) and WGS results (MSLT types) revealed a link between patient strains and two environmental strains taken from the shower drains in the only two patient bathrooms in the unit. Staff reported that these drains had a tendency to become partly blocked resulting in regular overflow of water from the drains while patients were showering. Outbreak measures described below resolved the outbreak and no new cases nor new positive environmental samples were found after 3 years.

Organism: *Enterobacter hormaechei* OXA-436 carbapenemase

Assessment of evidence
Transmission mode: Clinical setting: Cardiology department. Source: Shower drains (overflow of water from clogged drains while showering) Control measures: Physical floor grate and traps were changed and fixed to the drain. The bathrooms were emptied and cleaned. The part of the floor drains, that wasn't possible to change were manually cleaned and afterward rinsed with vinegar. Finally the bathrooms were disinfected with vaporized hydrogen peroxide (RHEA Compact) following cleaning. The shower heads were relocated so that the water did not hit the drain directly (reducing splash risk). The waste pipes were cleaned and the function of the drains and sewer system re-established to prevent overflow. In addition to the regular cleaning of the two bathrooms, an extra daily cleaning with chlorine disinfection of all contact points was established. Limitations: • Patient characteristics are not provided, only that the patients were admitted to the same department (different times 6/7)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.					

Assessment of evidence

Typing revealed that a blood isolate of *M. mucogenicum* matched an isolate from a shower in the same room used by the case-patient. *M. mucogenicum* also found in the hot water source in the main hospital, and the city water source for the hospital.

Organism: *Mycobacterium mucogenicum*

Transmission mode: indirect/ aerosolisation

Clinical setting: University-affiliated, tertiary-care medical center. bone marrow transplant (BMT) and oncology patients.

Source: water contamination of central venous catheters (CVCs) during bathing

Control measures: The following control measures were recommended and implemented.

- Showerheads and hoses on the Bone marrow transplant (BMT) units were replaced.
- Shower hoses were allowed to hang straight with no dependent loops when not in use to reduce the risk of bacteria multiplying to higher levels in stagnant water.
- Direct care providers, patients and family members were educated on the risks of water contamination of central venous catheters (CVC) during bathing and on prevention methods to minimize water contact during bathing.
- IV catheters were disconnected before bathing when possible.
- Catheter connections were covered with waterproof material if they could not be disconnected

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nasser RM, Rahi AC, Haddad MF, et al. Outbreak of *Burkholderia cepacia* bacteremia traced to contaminated hospital water used for dilution of an alcohol skin antiseptic. Infection control and hospital epidemiology. 2004 Mar 1;25(3):231-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Burkholderia cepacia* bacteremia outbreak in Lebanon *(*including finding the source) and to determine the impact of infection prevention and control measures.	DNA fingerprinting results between patient strains and *Burkholderia cepacia* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antimicrobial susceptibility, DNA fingerprinting results (PCR-RFLP).

Assessment of evidence

Report of a nosocomial outbreak of intravenous cathether-related *Burkholderia cepacia* bloodstream infections. Tap water and swab from inside tab were positive.

Organism: *Burkholderia cepacia*

Transmission mode: contaminated tap water that contaminated alcohol-based products.

Clinical setting: hospital

Source: contaminated water tap that seeded the alcohol storage and transfer vessels. Contaminated water-based products (alcohol antiseptic solutions contaminated by tap water that was contaminated with *B. cepacia*).

Assessment of evidence
Control measures: once organisms were cultures from pharmacy water, staff used sterile water for alcohol dilution. Use of commercially prepared, individually packaged, single-use alcohol and povidone-iodine swabs for antisepsis of the sites of intravenous catheters was implement hospital-wide afterwards. Type of infection: bloodstream infections Limitation: only very few isolates were retrieved and analysed. Circumstances in which this outbreak occurred is not similar to UK (war-zone Lebanon).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cooksey R C, Jhung M A, Yakrus M A, et al. Multiphasic approach reveals genetic diversity of environmental and patient isolates of *Mycobacterium mucogenicum* and *Mycobacterium phocaicum* associated with an outbreak of bacteremias at a Texas hospital.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 5 cases of *M. mucogenicum* bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Applied Environmental Microbiology. 2008. Apr; 74(8): 2480-2487.					

Assessment of evidence

Genotyping identified clusters within both the patient and environmental isolates; one patient isolate matched a water sample. Very genetically diverse contamination present.

Due to construction, the water in the floors above the oncology department had been stagnant for several months; then a generator failure caused a drop in water pressure allowing water from the floors above to flow into the oncology department pipework.

Organism/ infection: *Mycobacterium mucogenicum, Mycobacterium phocaicum.* CVC-associated bloodstream infection.

Transmission mode: unconfirmed but all patients had CVCs.

Clinical setting: Oncology department, United States of America

Source: Hospital water supply

Control measures: not described.

Question 10: What are the microbiological water testing requirements at commissioning?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum (SHTM) 04-01. Water safety for healthcare premises Part A: Design, installation and testing. 2014.	Guidance (Expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Engineering Scottish Health Technical Memorandum is created by HFS with participation of the National Water Services Advisory Group and follows on from the HTM 04-01 Part A produced by the Department of Health. The aim of this document (and the rest of the SHTM series) is to advice on water safety and therefore minimise the risk of HAIs and it provides guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

The following paragraphs are relevant for this research question on the microbiological water testing requirements at commissioning:

“Water quality is governed by the Water Supply (Water Fittings) Regulations 1999, building regulations, approved codes of practice and technical standards intended to safeguard quality.”

Assessment of evidence
“After disinfection, microbiological tests for bacteria colony counts at 37°C and coliform bacteria, including Escherichia coli, should be carried out under the supervision of the infection prevention control team to establish that the work has been satisfactorily completed. Water samples should be taken from selected areas within the distribution system. The system should not be brought into service until the infection control team certifies that the water is of potable quality.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part A: Design, installation and commissioning. 2016.	Guidance (Expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British guidance document created by Department of Health and aims to “promote good practice for those responsible for the design, installation, commissioning, operation and maintenance of water services in healthcare premises The following paragraphs are relevant for this research question on the microbiological water testing requirements at commissioning: “Sampling 15.32 The WSG should discuss and agree a sampling regime and appropriate parameters (physical, chemical and microbiological) depending on the intended use of the system and vulnerability of the patients. This should be agreed prior to tender. “

Assessment of evidence
“15.33 Sampling should be carried out prior to any construction/refurbishment works and immediately prior to handover, but no sooner than 48 hours after disinfection. It is recommended that sampling is undertaken by an accredited organisation independent of the contractor”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum (SHTM) 04-01. The control of *Legionella*, hygiene, ‘safe’ hot water, cold water and drinking water systems. Part E: Alternative materials and filtration. 2014.	Guidance (Expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Engineering Scottish Health Technical Memorandum is created by HFS with participation of the National Water Services Advisory Group. The aim of this document is to advice on water safety and therefore minimise the risk of HAIs and it provides guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.					

Assessment of evidence
The following paragraphs are relevant for this research question on the microbiological water testing requirements at commissioning: “When all disinfection work has been completed the whole system should be drained down, thoroughly flushed out and fully recharged with fresh water in preparation for commissioning and 'balancing' the hot water system.” “Water samples should be obtained from appropriate points in the system after each recharging. Potability analysis of these samples of water should be carried out by the Public Analyst, or an approved independent body, and the contractor should supply a full set of the analysis to the site supervisor for approval before the system is put into use.” Figure 2.2 Sequence of events: When taking sample for Potability Analysis, “for refurbishment work, take samples before and after refurbishment.” Note under Figure 2.2: “The potability sampling analysis referred to in Figure 2.2 must not be taken within the ‘active’ period following sterilisation. A period of at least three days – and preferably five – should be allowed for the system to settle prior to sampling activities commencing.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Summary of Incident and Findings of the NHS Greater Glasgow and Clyde: Queen Elizabeth University Hospital/Royal Hospital for Children water contamination	Incident report	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
incident and recommendations for NHSScotland. Final V2. 2018.					

Assessment of evidence

Between the period of 29th January and 26th September 2018, 23 cases of blood stream infections (11 different organisms) with organisms potentially linked to water contamination were identified. As a result, further testing of the water supply was undertaken across both hospital sites early in the investigation. This testing identified widespread contamination of the water system.

Organism(s): *Cupriavidus pauculus* (1), *Pseudomonas fluorescens* (1), *Pseudomonas aeruginosa* (3), *Stenotrophomonas maltophilia* (12), *Acinetobacter ursingii* (2), *Enterobacter cloacae* (7), *Klebsiella oxytoca* (1), *Serratia marcescens* (1), *Pseudomonas putida* (1), *Pantoea* sp (1), *Klebsiella pneumonia* (1), *Chryseomonas indologenes*(1)

Transmission mode: Contaminated water system.

Clinical setting: Paediatric haemato-oncology unit

Source: wash hand basin, drain - contaminated water system

Control measures: Control measures implemented included sanitisation of the water supply to ward 2A, installation of the use of point of use filters in wash hand basins and showers in ward 2A/B and other areas where patients were considered high risk. Drain decontamination was undertaken and on 26th September 2018 wards 2A/B were closed and patients decanted to ward 6A QEUH and 4B QEUH.

The following sections of this report are relevant for this research question on the microbiological water testing requirements at commissioning:

“As part of the normal water system commissioning water samples were obtained. Initial preliminary findings have identified that prior to handover from the contractor there were a number of water samples taken that produced results with high level of total viable counts

Assessment of evidence
(TVCs). TVCs are indicators that there are hygiene issues within the water system and are quantified as a generic indicator for microbial contamination. Specific microorganisms which can be tested for include: Coliforms, *Escherichia coli* (including O157), *Pseudomonas aeruginosa*, *Salmonella* spp, *Campylobacter* spp and Environmental Mycobacteria. Testing for these is not conducted as standard within current guidance and typically occurs in response to a suspected or confirmed outbreak, or due to identification of a series of sequential cases. In response to the high levels of TVCs found as part of the pre handover commissioning sanitisation of the water supply was undertaken by the contractor, with some impact and a reduction in TVCs in most areas, however there are a number of reports which indicate that there may still have been a number of areas with higher than normally acceptable levels of TVCs”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Published Document provides guidance on cleaning, flushing and disinfection of services supplying water for domestic purposes within buildings and their curtilages, including those for the production of foods, but excluding closed systems or other industrial processes. This publication is not to be regarded as a British Standard. The following paragraphs are relevant for this research question on the microbiological water testing requirements at commissioning: “8.3.4 To confirm effective disinfection, any required microbiological samples should be taken between two and seven days after the system is treated. Samples taken immediately after a disinfection process might give false negative results.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The British Standards Institution. 7592:2022. Sampling for Legionella bacteria in water systems – Code of practice. 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus Legionella. It is applicable to sampling artificial water systems and also gives methods for sampling of biofilms and sediments that might be present in water systems. Some of the same sampling principles can be applied to natural water systems. The standard is applicable to both sampling for routine monitoring and in outbreak investigations. For the latter, recommendations and guidance on the selection of sampling points are given. The rationale for the selection of sampling points for					

Assessment of evidence
particular situations is also discussed. This British Standard is intended for use by all those involved in water sampling for legionellae including the persons taking samples on site and their employers. The following paragraphs are relevant for this research question on the microbiological water testing requirements at commissioning: “Commissioning and recommissioning COMMENTARY ON CLAUSE 15 Commissioning and recommissioning plans for water systems in new builds or refurbishments may include legionella sampling to verify that water systems have been managed effectively to minimize the risk of ingress during construction and installation; particularly in buildings most likely to pose a risk of outbreaks of infection, for example, hospitals, nursing homes and care facilities for the elderly, hotels, and multi-occupancy buildings. In practice, this is likely to be for all buildings except domestic premises.” “A risk assessment should be carried out before progression to the commissioning stage and a sampling plan, which includes the number of samples, locations to be sampled, the timing of sampling and the parameters, including Legionella, to be analysed, should be agreed by the project WSG before the system is filled with water, especially in a building where the population is considered at increased risk of Legionnaires’ disease.” “NOTE Clients can require that sampling is witnessed by a client representative or carried out independently of the contractors and analysed by laboratories of their choice and accredited for all the parameters required.” “Samples should be collected from hot- and cold-water systems and any associated systems and equipment indicated on the sampling plan after they have been filled, disinfected and flushed, and the system returned to normal disinfectant levels. “ “Specialist systems, including medical devices, should be sampled according to manufacturers’ or best relevant practice guidance. “ “Samples should not be collected immediately after disinfection and flushing but after the system has been allowed to settle for at least 48 h, to allow sub-lethally damaged legionellae to recover and avoid false negative results. Where a staged occupation is planned, the sampling plan should reflect the need to sample after each section is filled. Repeat sampling should be carried out to a sampling plan agreed by WSG when there is a delay between commissioning and occupation and normal usage not more than a month before occupation, to allow for culture results to be returned and any remedial action taken.”

Question 11: What are the responsibilities of the IPC team in regards to water safety at commissioning?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Engineering Scottish Health Technical Memorandum is created by HFS with participation of the National Water Services Advisory Group and follows on from the HTM 04-01 Part B produced by the Department of Health. The aim of this document (and the rest of the SHTM series) is to advice on water safety and therefore minimise the risk of HAIs and it provides guidance on the design, installation and operation of specialised building and engineering technology used in the delivery of healthcare.

The following paragraphs are relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning:

Assessment of evidence
"The Infection Control Manager, the Infection Prevention and Control Doctor (also known as the Infection Control Doctor) and the Consultant Microbiologist are nominated by management to advise on infection control policy and to have responsibility for the maintenance of water quality from the point it leaves the tap. " "The policy should be acceptable to the Infection Prevention & Control Team and they should agree any amendment to that policy." "Water Safety Groups (WSG) within NHS Boards will be led and chaired, as a minimum, by the Responsible Person (Water) who will ensure that responsibility is taken for microbiological hazards and are identified by appropriate Group members They will assess risks, identify and monitor control measures and develop incident protocols. WSG should be a sub-group of and report to the Chair of the hospital Infection Control Committee and ensure a coordinated approach exists between Infection Prevention and Control Teams, clinical staff and Estates & Facilities on all water issues. There should be a clear line of responsibility to the Chief Executive through the Infection Control or other Committee." "Water Safety Plan and Risk Assessment of Water Distribution Systems" "5.28 A risk assessment of the water distribution system in a healthcare facility is a legislative requirement. A water safety plan (WSP) approach, incorporating a risk assessment, is outlined in the World Health Organisation (WHO) document Water Safety in Buildings, 2011." The latest HPS/HFS Guidance on Pseudomonas aeruginosa – advice for augmented care units, also recommends that a Water Safety Group (WSG) commissions and develops a WSP which includes a risk assessment. The key steps of a WSP, including a risk assessment, are outlined in this document."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Summary of Incident and Findings of the	Incident report	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
NHS Greater Glasgow and Clyde: Queen Elizabeth University Hospital/Royal Hospital for Children water contamination incident and recommendations for NHSScotland. Final V2. 2018.					

Assessment of evidence

Between the period of 29th January and 26th September 2018, 23 cases of blood stream infections (11 different organisms) with organisms potentially linked to water contamination were identified. As a result, further testing of the water supply was undertaken across both hospital sites early in the investigation. This testing identified widespread contamination of the water system.

Organism(s): *Cupriavidus pauculus* (1), *Pseudomonas fluorescens* (1), *Pseudomonas aeruginosa* (3), *Stenotrophomonas maltophilia* (12), *Acinetobacter ursingii* (2), *Enterobacter cloacae* (7), *Klebsiella oxytoca* (1), *Serratia marcescens* (1), *Pseudomonas putida* (1), *Pantoea* sp (1), *Klebsiella pneumonia* (1), *Chryseomonas indologenes*(1)

Transmission mode: Contaminated water system.

Clinical setting: Paediatric haemato-oncology unit

Source: wash hand basin, drain - contaminated water system

Control measures: Control measures implemented included sanitisation of the water supply to ward 2A, installation of the use of point of use filters in wash hand basins and showers in ward 2A/B and other areas where patients were considered high risk. Drain

Assessment of evidence
decontamination was undertaken and on 26th September 2018 wards 2A/B were closed and patients decanted to ward 6A QEUH and 4B QEUH. The following sections of this report are relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning: “HAI-SCRIBE (2007) was in place during the construction and handover of both buildings. Implementation of HAI-SCRIBE should be the responsibility of a multidisciplinary team of specialists with appropriate skills.” “Evidence has been reviewed in relation to the infection control sign-off of results and the system at commissioning/handover. Whilst there is evidence of involvement with initial results and sanitisation there is no evidence of ongoing input or sign off from the Infection Prevention and Control Team (IPCT). It is noted that there is lack of clarity in current national guidance relating to roles and responsibilities of the IPCT in the commissioning, design and handover of new or refurbished builds. Water was first placed on the Infection prevention and control (IPCT) risk register in 2018. The IPC risk register is reviewed on an annual basis with risks considered and prioritised using a risk scoring system. Water safety was added to the risk register in 2018 in response to the emerging evidence of potential issues associated with this incident. Prior to 2018 water safety did not feature in the IPC risk priorities when scored.” “NHSGGC employed a robust approach to the design stage of the hospital project by means of a dedicated Infection Prevention and Control Nurse (IPCN) seconded as part of the project team to support the IPCT aspect of the design stage, commissioning and handover stage.” “Whilst there was dedicated resource allocated to the project team, there is no documented evidence of NHSGGC Infection Prevention and Control Team involvement in the commissioning or handover process of the project. However NHSGGC has provided a statement from the Lead Infection Control doctor at the time to confirm that they were involved in reviewing some aspects of the initial water testing methodology and the results for QEUH and RHC during commissioning and handover. The Lead ICD has confirmed being involved in: • Quality assurance of the water testing methodology used by the commissioning engineers. • Liaising with Facilities Colleagues in reviewing the water testing results supplied by the commissioning engineers. • Recommending further actions (dosing), for a small number of outlets with TVCs above the acceptable limits.”

Assessment of evidence
"In addition to a nurse consultant being seconded as a dedicated resource to the project team with involvement in design, commissioning and handover, the project team were supported by the IPCT. This support included regular review of the new builds hospital project at the infection control committee and senior IPC meetings. NHSGGC reported that both the infection control manager and associate director of nursing (infection control) liaised regularly with the project associate nurse director and ensured the numerous commissioning groups established were supported by a member of the IPCT. In addition all wards were reviewed by a member of the IPCT prior to occupation by patients."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland (HFS). SHFN 30 Part A: Manual Information for Design Teams, Construction Teams, Estates and Facilities and Infection Prevention and Control Teams. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
The Scottish Health Facilities Note 30 (SHFN30) is the first point of reference on prevention and control of infection for healthcare estates and facilities managers, architects, builders, engineers, surveyors, health planners and Infection Control Teams working on healthcare estate, new build and refurbishment projects.

Assessment of evidence
It mentions that a multi-disciplinary team, including infection control professionals, is necessary for the success of a new build or refurbishment healthcare project and thus the responsibilities are shared. The following paragraphs are relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning: “The Infection Prevention and Control Team should be consulted throughout a building or renovation project and their advice and recommendations taken into account and documented.” “Upon completion of construction, the facility must be brought into use; the complexity of the task involved generally means that a Commissioning Manager and Commissioning Team will be needed. Senior managers, infection prevention and control teams, specialist teams and users should be fully involved in the process.“ “To assist with understanding and mitigating risks associated with bacterial contamination of water distribution and supply systems, it is recommended that the NHS Board should have in place a Water Safety Plan (WSP) as outlined in SHTM 04-01 providing a risk management approach to the microbiological safety of water and establishing good practice in local water distribution and supply. Those organisations with robust water management policies for Legionella will already have in place much of the integral requirements for delivering a WSP.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The British Standards Institution. BS 8580-2:2022. Water quality. Part 2: Risk assessments for *Pseudomonas aeruginosa* and other	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
waterborne pathogens - Code of practice. 2022.					
Assessment of evidence					
This British Standard gives guidance (including recommendations) on how to carry out risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens (autochthonous) that can colonize and grow within water systems and the associated environment Legionella is not included as that is covered in BS 8580-1:2019. The following paragraph is relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning: “Input from microbiologists and the IPCT should be sought prior to the risk assessment to identify the types and location of infections which could be linked to exposure to water and for assessment of surveillance practices.”					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The British Standards Institution. BS 8680:2020. Water quality — Water safety plans — Code of practice. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard guidance (including recommendations) for the development of a water safety plan (WSP) for premises (incl healthcare) with water systems which can pose a risk to those exposed, either from the water itself, aerosols derived from it or the surrounding environment. The British Standard is applicable to WSP development for new buildings, modifications and renovations to existing water systems and can also be applied retrospectively to control risks to health from all types of water use. The following paragraphs are relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning: “Those responsible for water safety within a business or organization should develop and implement a documented WSP to safely manage all water-related risks. The scope and complexity of the WSP and supporting documentation in the form of policies, procedures/method statements, risk assessments, schemes of control, record keeping, monitoring, training and other relevant documentation should be proportional to the type of water-related activities carried out and the scale and complexity of the business/organization. The WSP should not be a large, unwieldy document which includes all method statements, procedures, risk assessments, etc., but a high-level strategic document which refers to and takes these into account. In large buildings or where there are complex systems, specialist uses of water and/or a more susceptible population, there should be a multidisciplinary team, referred to here as the water safety group (WSG) (see 3.32). To ensure effective ownership and provide assurance on the effective management of water safety and associated risk management, the organizational structure, lines of accountability and communication up to top level management by the WSG should be clear and facilitate the regular reporting and review of the status of water risk management and the supporting infrastructure. An effective WSP should identify and assess all water which could pose a risk of harm to staff, visitors, members of the public or patients (where applicable) on site and, where appropriate, steps should be in place to manage these risks. The responsible person (RP) or WSG or, in healthcare, the accountable officer responsible for water safety (see HTM 00-01 [19]), should ensure there is an initial high-level assessment of what is already in place to identify any gaps in the robustness of the current water safety governance and management measures, and any need for amendment or development.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
SHFN 30. Part B: Manual Information for Design Teams, Construction Teams, Estates & Facilities and Infection Prevention & Control Teams. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

The Scottish Health Facilities Note 30 (SHFN30) is the first point of reference on prevention and control of infection for healthcare estates and facilities managers, architects, builders, engineers, surveyors, health planners and Infection Control Teams working on healthcare estate, new build and refurbishment projects.

It mentions that a multi-disciplinary team, including infection control professionals, is necessary for the success of a new build or refurbishment healthcare project and thus the responsibilities are shared.

The following paragraph is relevant for this research question on the responsibilities of the IPC team in regards to water safety at commissioning:

“HAI-SCRIBE is an acronym for Healthcare Associated Infection System (for) Controlling Risk In the Built Environment. The procedure has been developed as a framework for these groups to work together to identify, manage and mitigate issues in the built environment impacting on infection prevention and control risks. Throughout this document, the term ‘Project Team’ is referred to. The term describes the team of NHS Staff assembled to fulfil the role of ‘The Client’ and to manage the delivery of the project. Through the various stages of the project it may include NHS Project Managers, Clinicians, Estates Staff and Infection Prevention and Control specialists.”

Question 12: Is routine water testing to detect healthcare water system-associated organisms recommended?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on whether routine water testing is recommended. Table 3a provides an overview of testing requirements for hydrotherapy pool water samples which is weekly while in use (Legionella quarterly).					

Assessment of evidence
Table 5 provides an overview of testing requirements for renal dialysis fluid: It recommends to sample dialysis fluids monthly as well as product water used to prepare dialysate using standard microbiologic assay methods for healthcare water system-associated microorganisms. Table 6 provides an overview of testing requirements for endoscopy final rinse water: testing for the presence of environmental mycobacteria and *P. aeruginosa* should be done quarterly.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Guidance for Decontamination and testing of Cardiac Heater Cooler Units (HCUs). 2019.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance “sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results.” The following section(s) are relevant for this research question on whether routine water testing is recommended. On water testing, the document provides the following guidance: • “Water samples should be taken fortnightly and tested for total viable bacterial counts (TVCs) as long as test results remain within parameters. Samples should be taken monthly for Mycobacterium chimera and *Legionella* species.					

Assessment of evidence
• Microbiology staff or estates staff will provide the containers for collection of the water samples. • Mycobacterium cultures take eight weeks to process however subsequent samples should continue to be taken and submitted whilst results are awaited. This allows clear identification of time if a look back exercise is requires if positive results are reported. • *Legionella*, Pseudomonas species and coliforms results are generally available within a few days. This is subject to local testing arrangements. • Staff should follow manufacturer's instructions for the taking of water samples from the HCU and SICP's within the NIPCM and PPE requirements of COSHH regulations."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for the interpretation and clinical management of endoscopy final rinse water. 2019.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance "aims to enhance patient safety and reduce risks of decontamination related Healthcare Associated Infection (HAI) by standardising the interpretation of and clinical management of endoscopy final rinse water results nationally, based on available scientific evidence, current practices and an estimation of infection risk within NHSScotland following endoscopic procedures." The following section(s) are relevant for this research question on whether routine water testing is recommended.					

Assessment of evidence
The document makes the following recommendations: • Testing laboratories should use the methodology in BS EN ISO 15883 (2006) to assess the final rinse water TVC/*Pseudomonas aeruginosa* PA in the endoscope washer-disinfector. • Testing laboratories should be accredited for testing of endoscopy rinse water. • Staff responsible for undertaking testing of final rinse water should be trained in the aseptic process for collection and transportation of samples as described in SHTM 2030 and BS EN ISO 15883. • Weekly microbiological testing should be undertaken as described in SHTM 2030. • Where positive TVC counts of >10 cfu/100ml are identified on subsequent tests the testing laboratory should provide detail on the number and type of indicators of bacterial contamination found on the second result. • Where positive TVC counts of >100 cfu/100ml are identified the testing laboratory should provide detail on the number and type of indicators of bacterial contamination found. • Health boards should monitor results and analyse trends.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Walker JT, Bak A, Marsden G et al Final rinse water quality for flexible endoscopy to minimize the risk of post-endoscopic infection. Report	Guidelines	**AGREE: Recommend**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
from Healthcare Infection Society Working Party. Journal of Hospital Infection 124 (2022) 79e96					
Assessment of evidence					
The Healthcare Infection Society (HIS) Working Party have produced detailed guidelines on final rinse water. “The recommendations describe measures that are practicable for minimizing the risk of post-endoscopic infection or pseudo-infection related to final rinse water for flexible endoscopy when used by healthcare workers carrying out or advising on the decontamination of flexible endoscopes.” The following section(s) are relevant for this research question on whether routine water testing is recommended. • “ER1.1 Monitor the final rinse water for total viable counts (TVC) weekly and test for the presence of environmental mycobacteria and *Pseudomonas aeruginosa* quarterly. • ER1.2 Consider testing for other micro-organisms of significance, as based on local circumstances (e.g. *Legionella pneumophila* and other). • ER1.3 There is no need to monitor endotoxin levels routinely but consider doing so if the major water supply problem has been identified”					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Wafer T, et al. Investigation and control of an outbreak due to a contaminated hospital water system, identified following a rare case of *Cupriavidus pauculus* bacteraemia. Journal of hospital infection 2021; 111, 53–64.	Outbreak investigation	**Level 3**	The study aimed to describe the investigation of a waterborne infection outbreak in a new build hospital and the measures taken to control it.	N/A	Number of positive-patient, water and outlet samples; TVC (CFU/ml). Pulsotypes and genotypes of patient and tap water isolates.

Assessment of evidence

This study initially investigated a *Cupriavidus pauculus* bloodstream infection in an immunosuppressed patient which turned into the investigation and control of a contaminated water system in a new build hospital with 22 other patients infected with various other waterborne pathogens in the following few months.

Organisms: *C. pauculus* was the indicator organism. However, further testing detected “over 60 species of Gram-negative bacteria (including *Aspergillus* spp.) and atypical mycobacteria from water and system components”.

Transmission mode: Direct contact with water through showering or splashing likely as all the patients had Hickman lines. Patient to patient transmission ruled out as typing of patient isolates showed that all isolates were unique.

Assessment of evidence
Clinical setting: Paediatric haemato-oncology Unit Source: Water system components *C. pauculus* which was the indicator organism for the outbreak was detected during routine testing at the sterile aseptic Pharmacy unit. Limitations: i. Described as one incident categorised in 3 phases which were all separate outbreaks (different organisms) – this makes it slightly unclear. The methods were also not very clearly written especially with respect to typing of the isolates. ii. Not all water samples were sent for typing. Neither were multiple colonies selected from each agar plate for typing. Therefore, it is not clear what the exact source was of the patient infections. However, the authors clearly stated isolate from the first Patient matched the water isolate on Pulsed-field gel electrophoresis (PFGE). iii. Combination of control measures makes it difficult to determine which part was responsible for the impact.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM,Chinn RYW, Arduino MJ et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Control Practices Advisory Committee (HICPAC). American Society for Healthcare Engineering/American Hospital Association; 2004.					

Assessment of evidence

These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on whether routine testing in healthcare settings is recommended:

“Health-care facilities use at least two general strategies to prevent health-care associated legionellosis when no cases or only sporadic cases have been detected. The first is an environmental surveillance approach involving periodic culturing of water samples from the hospital’s potable water system to monitor for *Legionella spp*”. P69

“Scheduled microbiologic monitoring for *legionellae* remains controversial because the presence of legionellae is not necessarily evidence of a potential for causing disease. CDC recommends aggressive disinfection measures for cleaning and maintaining devices known to transmit legionellae but does not recommend regularly scheduled microbiologic assays for the bacteria. However, scheduled monitoring of potable water within a hospital might be considered in certain settings where persons are highly susceptible to illness and mortality from *Legionella* infection (e.g., hematopoietic stem cell transplantation units and solid organ transplant units). Also, after an outbreak of legionellosis, health officials agree monitoring is necessary to identify the source and to evaluate the efficacy of biocides or other prevention measures.” p235

Assessment of evidence
"A potential advantage of the environmental surveillance approach is that periodic culturing of water is less costly than routine laboratory diagnostic testing for all patients who have health-care associated pneumonia" P70 "The only types of routine environmental microbiologic sampling recommended as part of a quality-assurance program are a. the biological monitoring of sterilization processes by using bacterial spores and b. the monthly culturing of water used in hemodialysis applications and for the final dialysate use dilution". p104 "Routine testing of the water in a health-care facility is usually not indicated, but sampling in support of outbreak investigations can help determine appropriate infection-control measures. Water-quality assessments in dialysis settings have been discussed in this guideline (see Water, Dialysis Water Quality and Dialysate, and Appendix C)." p109 "Perform assays at least once a month by using standard quantitative methods for endotoxin in water used to reprocess hemodialyzers, and for heterotrophic, mesophilic bacteria in water used to prepare dialysate and for hemodialyzer reprocessing." p16 "No recommendation is offered regarding routine culturing of water systems in health-care facilities that do not have patient-care areas (i.e., PE or transplant units) for persons at high risk for *Legionella spp*. infection." p144

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01 Water safety for healthcare premises. Part B: Operational management.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2014.					

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended:

“Apart from situations where there are taste or odour problems, microbiological monitoring for TVCs is not considered to be necessary. However, many estates management staff continue to test for TVCs notwithstanding any conflict with the requirements of L8 as any obvious changes in monitored levels provide a useful rule of thumb early warning of possible emerging problems.”

“If performed for these purposes, the detection of low TVCs is not necessarily an indication of the absence of *Legionella* but is an indication of the overall water quality and signifies a generally unfavourable environment for bacteria. “

“All microbiological measurements should be approved methods and/or be carried out by the appropriate United Kingdom Accreditation Service (UKAS)-accredited laboratories. Dip slides are not acceptable. “

“The procedures to be followed for sampling are set out in SHTM 04-01 Part C: TVC testing protocol.

“Up to now, in the absence of evidence of healthcare-associated infection, testing (which is complex and expensive) has not been considered necessary (for *legionella*)”

“The infection prevention and control team, however, will need to consider the level of risk before deciding that *Legionella* testing is indicated. For example, testing may be required:

- when storage and distribution temperatures do not achieve those recommended under the temperature control regime and systems are treated with a biocide regime, a monthly frequency of testing for *Legionella* is recommended. This may be reduced as confidence in the efficacy of the treatment regime is established;
- in systems where the control regimes are not consistently achieved, for example temperature or biocide levels (weekly checks are recommended until the system is brought under control);

Assessment of evidence
- when an outbreak is suspected or has been identified; - a Written Scheme is to be prepared indicating all sentinel taps. This is the responsibility of the designer; - on hospital wards with at-risk patients – for example those who are immuno-compromised." "Testing of water for *Pseudomonas aeruginosa* is only required if a very specific reason has been identified such as suspected or confirmed outbreak or a series of sequential cases, as guided by the Responsible Person (*Pseudomonas*)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended:					

Assessment of evidence
"Although Scottish Health Technical Memorandum (SHTM) 04-01 Part B paragraph 9.1 states that routine quality control microbiological testing for TVCs is no longer considered to be necessary (other than where there are taste or odour problems), many estates personnel invariably have them undertaken on a regular basis after acceptance of installations as a 'rule of thumb' indicator by which an abnormal change assists in identifying potential problems at an early stage. This narrative sets out procedures to be followed." On frequency of sampling, the guideline states that "This should be carried out quarterly".

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: “The microbiological examination of water from the healthcare facility environment is necessary both in the routine monitoring of decontamination procedures within the healthcare facility and in the investigation of contamination incidents and outbreaks of healthcare associated infection. For example, regular monitoring of the microbiological quality of renal dialysis water, hydrotherapy water and endoscopy rinse water plays an important role in protecting patients from exposure to potentially infectious waterborne microorganisms. Similarly, microbiological testing of the water system at defined intervals for *Legionella* species helps to ensure that healthcare facilities” water system is well controlled and that water used for the care and management of patients does not pose a risk to those patients and/or staff. Monitoring of water supplying augmented care units for *Pseudomonas aeruginosa* may be required based on risk assessment.” “Therapeutic pools used in healthcare facilities need to be formally managed to ensure that patients utilising these facilities are not exposed to potential pathogens and avoid acquiring a healthcare associated infection. This is achieved by regular maintenance, chemical disinfection and periodic water quality monitoring.” “Water treatment facilities for haemodialysis in healthcare facilities need an associated quality system that accounts for governance, planning, commissioning, installation, operation, maintenance, and water monitoring.” “Monitoring of water supplying an augmented care unit for *Pseudomonas aeruginosa* may be required, based on risk assessment. Water testing is recommended during an outbreak or if surveillance identifies an increased incidence of infection. Water testing may also be indicated following a single invasive *Pseudomonas aeruginosa* infection, if the organism is an unusual pathogen in the augmented care unit. Furthermore, evidence suggests that there is a greater risk of the internal surfaces and components of non-touch or sensor taps becoming contaminated with microorganisms and biofilm in comparison to manually operated taps. Therefore, water testing may be considered by the environmental monitoring committee for augmented care units with sensor taps.”

Assessment of evidence
"Water dispenser, water cooler or filtered water unit taps and associated pipe work are frequently manufactured from plastic materials, which are particularly prone to microbial biofilm contamination. These units and the water they provide should be subject to periodic microbiological testing to ensure good water quality" On Endoscopy units, the guideline stated "The final rinse water utilised should comply with stringent microbiological controls. Periodic testing of the final rinse water is required and remedial actions should be triggered by non-conforming results."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 7592:2022. Sampling for Legionella bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: "Sampling for *legionellae* should routinely be conducted as identified by a *legionella* risk assessment, taking account of, but not limited to: a) the presence of highly susceptible people; and b) ongoing verification of a recommended scheme of control where the potential for legionella growth is identified."

Assessment of evidence
"NOTE 2 While routine sampling for *legionellae* represents one aspect of monitoring the effectiveness of a water treatment programme, it can be useful for auditing control measures and to validate new disinfection regimes." "NOTE 3 Quarterly sampling for the presence of *legionellae* is recommended in HSG274 Part 1 for operating evaporative cooling systems incorporating a cooling tower or evaporative condenser and in HSG282 [17] for commercial spa pools and hot tubs in business premises. For other constructed water systems, such as hot- and cold-water distribution systems, sampling is not normally required unless recommended temperatures are not consistently attained or control methods other than heat are used, or where it is found to be necessary by the risk assessment (see Clause 4) (for example, systems in healthcare premises where there might be patients with increased susceptibility to Legionnaires' disease)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8580-1:2019. Water quality – Risk assessments for *Legionella* control – Code of practice. BSI Standards Publication 2019.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on *Legionella* risk assessment relevant to water systems. It is applicable to any undertaking involving a work activity or premises controlled in connection with a trade, business or other undertaking where there is potential for exposure to water or when water is used or stored in circumstances that could cause a reasonably foreseeable risk of

Assessment of evidence
infection by *Legionella* and contracting legionellosis. The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: It is not normally necessary to take samples for *Legionella* analysis as part of a risk assessment. However, if the assessor decides it will assist in determining risk, sampling should be carried out in accordance with BS 7592. Testing for *Legionella* should be considered if any of the following occur. a) The risk assessor encounters a novel situation and/or piece of equipment perceived to be a potential risk to health. b) There is a failure of, or concerns about, control measures. c) It is necessary to verify the operation of a control regime, particularly if it has recently been changed or implemented and the system is known to have previously been colonized. d) The assessor has reason to doubt the validity of the results of routine tests or has identified areas of concern during the survey. Recommendations for any further sampling should be included in the final assessment report.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8580-2:2022. Water quality Part 2– Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens – Code of practice.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
BSI Standards Publication 2019.					
Assessment of evidence					
"This British Standard gives recommendations and guidance how to carry out risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens whose natura habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment. It does not cover risk assessments for *Legionella spp*.; these are covered in BS 8580-1, or risk assessments for enteric microorganisms derived from human or animal faecal contamination or sewage ingress." The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: "Microbiological surveillance is an essential element of the early identification of water outlet contamination to prevent hospital-acquired infections so the frequency of routine sampling for *PA* and other waterborne pathogens e.g. NTMs should be based on risk assessment and agreement with the WSG. The frequency of microbiological sampling, where there are high-risk patients, should be sufficient for trend analysis to establish evidence-based confidence that control measures remain effective. When establishing trends, sampling should be carried out frequently (for example, monthly). This frequency should be reviewed by the WSG based on sample findings. Where standard methods are not available e.g., for unusual waterborne opportunistic waterborne pathogens, input should be sought from expert microbiologists from national reference laboratories."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Legionella bacteria in hot and cold water systems. 2014.					
Assessment of evidence					
This British document provides "practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999." The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: "*Legionella* monitoring should be carried out where there is doubt about the efficacy of the control regime or it is known that recommended temperatures, disinfectant concentrations or other precautions are not being consistently achieved throughout the system. The risk assessment should also consider where it might also be appropriate to monitor in some high-risk situations, such as certain healthcare premises. The circumstances when monitoring for *legionella* would be appropriate include… high-risk areas or where there is a population with increased susceptibility, eg in healthcare premises including care homes"					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization. *Legionella* and the prevention of legionellosis. WHO 2007.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document "provides guidance on assessment and management of risks associated with potentially hazardous environments, such as cooling towers, pools and spa baths. The document also identifies necessary measures to prevent, or adequately control, the risk of exposure to Legionella bacteria for each particular environment." The following sections are relevant for this research question on whether routine water testing in healthcare settings is recommended: "In hospital wards with high-risk patients, testing for *Legionella* is recommended. The results must be reviewed (HSC, 2000)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part B: Operational management. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This guidance developed by the Department of Health (UK, England) aims to summarise and recommend measures to control waterborne pathogens in healthcare estates (NHS). Appendix D regarding *P. aeruginosa* is relevant for this research question on whether routine water testing in healthcare settings is recommended:					

Assessment of evidence
"D1. *P. aeruginosa* may be present within the water storage, distribution and delivery systems and also in the water supplied to the healthcare facility. D2. The sampling protocol (Appendix E) is intended to help healthcare providers establish whether the water in augmented care units is contaminated with *P. aeruginosa* and, if it is, to help locate its origin and to monitor the efficacy of remedial measures. D14. If test results are satisfactory (not detected), there is no need to repeat sampling for a period of six months unless there are changes in the water distribution and delivery systems components or system configuration (for example, refurbishments that could lead to the creation of dead-legs) or occupancy. D15. However, the WSG could indicate that water sampling is required within six months if there are clinical evidence-based suspicions that the water may be a source of patient colonisation or infection (that is, with *P. aeruginosa* or another potentially waterborne pathogen)." Regarding routine TVC testing, the following paragraphs are relevant: "Where there are taste or odour problems, microbiological monitoring for total viable counts (TVCs) may be considered necessary. However, routine microbiological monitoring for TVCs is not recommended as there is no direct association with TVCs and the presence of waterborne pathogens." "If performed, TVCs may be used to analyse trends. Counts taken before and after disinfection (samples at least 48 hours post-disinfection) can give an indication of the efficacy of a disinfection procedure." "All microbiological measurements should be by approved methods and/or be carried out by United Kingdom Accreditation Service (UKAS)-accredited laboratories for the method being used. Dip slides are not acceptable on hot and cold water systems." Regarding routine *Legionella* testing, the following paragraphs are relevant: "*Legionella* monitoring should be carried out where there is doubt about the efficacy of the control regime or where the recommended temperatures, disinfectant concentrations or other precautions are not consistently achieved throughout the system. The WSG should use risk assessments to determine when and where to test, which may include the following circumstances: …. d. Where there are at-risk patients with increased susceptibility."

Question 13: What are the recommended microbiological limits for healthcare water system-associated organisms?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part A: Design, installation and testing. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"This Scottish Health Technical Memorandum gives comprehensive advice and guidance to healthcare management, design engineers, estate managers and operations managers on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises." The following sections are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings.

"Provided water is supplied from the public mains and its quality is preserved by correct design, installation and maintenance, it can be regarded as microbiologically acceptable for use. It is exceptional, however, for a water supply, either public or private, that is wholly

Assessment of evidence
'potable' to be entirely free from aquatic organisms, and consequently it is important that appropriate measures are taken to guard against conditions that may encourage microbial multiplication"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. TVCs: No given limits for TVCs, instead the document states that 'any obvious changes in monitored levels provide a useful rule of thumb early warning of possible emerging problems.' This suggests that trend analysis is required. Legionella: >100 cfu/litre is provided as requiring action, therefore is the stated limit. Pseudomonas aeruginosa: no limits are provided.

Assessment of evidence
Limits are not provided for any other microorganisms.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. TVC limits: ‘although TVCs are in themselves innocuous the testing procedures are intended to provide an early warning system whereby elevated TVCs should trigger some form of action to determine the identity of the organism and implement the appropriate treatment’. Legionella: <100cfu/ litre.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. “The EU Directive and the Irish Regulations (SI No. 122 of 2014) specify the main microbiological parameters for water for human consumption in colony forming units (CFU) i.e.0 cfu/100 ml coliform bacteria and *Escherichia coli* and 0 cfu/100 ml *enterococci,* and no					

Assessment of evidence

upper limit on other bacterial species, including aerobic heterotrophic bacteria. In addition to the above, the EU Directive does limit the levels of *Pseudomonas aeruginosa* in water offered for sale in bottles or containers to 0 cfu/250 ml and caps the aerobic heterotrophic plate count at 100 cfu /ml"

The document also featured a table titled "Table 5.3: Testing Options and Interpretation of Results for Hot and Cold Water Systems" in which it provided the following values:

- *Legionella* (<100 cfu/l – Satisfactory; >100 <1000 cfu/l – System under review; >1000- cfu/l – Unsatisfactory)
- *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; 1-10 in 100ml – Undesirable; >10 in 100ml – Unsatisfactory)

In "Table 5.4: Testing Options and Interpretation of Results for Renal Dialysis Fluid and Water Used for the Preparation of Dialysis Fluid", the following values are provided:

- Aerobic Colony count (0 - <50/ml – Satisfactory; 50 – 100/ml – Borderline; >100/ml – Unsatisfactory)
- Endotoxin/ml (<0.125 EU/ml – Satisfactory; 0.125 – 0.25 EU/ml – Borderline; >0.25 EU/ml – Unsatisfactory)

In "Table 5.5: Testing Options and Interpretation of Results for Renal Dialysis Ultrapure Fluid and Water used for Preparation of Ultrapure fluid", the following values are provided:

- Aerobic Colony count (<10 in 100ml – Satisfactory; ≥10 in 100ml – Unsatisfactory)
- Endotoxin/ml (<0.03 EU/ml – Satisfactory; ≥0.03 EU/ml – Unsatisfactory)

In "Table 5.5: Testing Options and Interpretation of Results for Endoscopy Final Rinse", the following values are provided:

- Aerobic Colony count (<1 in 100ml – Satisfactory; 1-9 in 100ml – Acceptable provided *P. aeruginosa* not detected; 10 – 100 in 100ml – Unsatisfactory; >100 in 100ml - Unacceptable)
- Environmental *Mycobacteria* (0 in 100ml – Satisfactory; >0 in 100ml – Unsatisfactory)
- *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; >0 in 100ml – Unsatisfactory)
- Endotoxin (>0.25 WU/ml – Unsatisfactory)

In "Table 5.7: Testing Options and Interpretation of Results for Dental Chair Unit Waterline Output Water Samples", the following values are provided:

Assessment of evidence
• Aerobic heterotrophic bacteria count (0 – 500 cfu/ml – Satisfactory; >500 cfu/ml – Unsatisfactory) In "Table 5.8: Testing Requirements and Interpretation of Results for Hydrotherapy Water Samples", the following values are provided: • *Escherichia coli* (0 in 100ml – Satisfactory; >0 in 100ml – Unsatisfactory) • Coliform bacteria (0 in 100ml – Satisfactory; 1 -10 in 100ml – Acceptable; >10 in 100ml – Unsatisfactory) • *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; 1 -10 in 100ml – Borderline; >10 in 100ml – Unsatisfactory; >50 in 100ml – Unacceptable) • Aerobic Colony count (0 - <10/ml – Satisfactory; 10 – 100ml – Borderline; >100/ml – Unsatisfactory) • *Staphylococcus aureus* (0 in 100ml – Satisfactory; >0 in 100ml – Unsatisfactory)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings.

In "Table 3a: Testing requirements and interpretation of results for hydrotherapy pool water samples", the following values were provided:

- *Escherichia coli* (0 in 100ml - Satisfactory; >0 in 100ml – Unsatisfactory)
- Coliform bacteria (0 in 100ml - Satisfactory; 1 - ≤10 in 100ml – Acceptable; >10 in 100ml – Unsatisfactory)
- *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; 1 -10 in 100ml – Borderline; >10 in 100ml – Unsatisfactory; >50 in 100ml – Unacceptable)
- Aerobic Colony Count (0 - <10/ml – Satisfactory; 10 – <100ml – Borderline; >100/ml – Unsatisfactory)
- *Staphylococcus aureus* (0 in 100ml – Satisfactory; >0 in 100ml – Unsatisfactory)
- *Legionella* (<20 in 1L – Satisfactory; 20 – <1000 in 1L – borderline; >1000 in 1L – Unsatisfactory)

In "Table 3b: Testing requirements and interpretation of results for birthing pool water samples", the following values were provided:

- *Escherichia coli* (0 in 100ml - Satisfactory; >0 in 100ml – Unsatisfactory)
- Coliform bacteria (0 in 100ml - Satisfactory; 1 - ≤10 in 100ml – Acceptable; >10 in 100ml – Unsatisfactory)
- *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; 1 -10 in 100ml – Borderline; >10 in 100ml – Unsatisfactory; >50 in 100ml – Unacceptable)
- *Legionella* (<20 in 1L – Satisfactory; 20 – <1000 in 1L – borderline; >1000 in 1L – Unsatisfactory)

In "Table 4: Testing requirements and interpretation of results for hot and cold-water systems", the following values were provided:

- *Legionella* (<100 cfu/l – Satisfactory; ≥100 - <1000 cfu/l – Undesirable; ≥1000 cfu/l – Unsatisfactory)
- *Pseudomonas aeruginosa* (0 in 100ml – Satisfactory; 1 -10 in 100ml – Undesirable; >10 in 100ml – Unsatisfactory)

Assessment of evidence
In “Table 5: Testing requirements and interpretation of results for renal dialysis fluid and water used for the preparation of dialysis fluid”, the following values were provided: • Aerobic Colony Count (0 - ≤50/ml – Satisfactory; >50 – ≤100ml – Borderline; >100/ml – Unsatisfactory) • Endotoxin/ml (<0.125 EU/ml – Satisfactory; >0.125 – ≤0.25 EU/ml – Borderline; >0.25 EU/ml – Unsatisfactory) In “Table 6: Testing requirements and interpretation of results for endoscopy final rinse water”, the following values were provided: Aerobic Colony Count (<1 in 100ml – Satisfactory; 1 – 9 in 100ml - Acceptable; 10 – ≤100 in 100ml – Unsatisfactory; >100 in 100ml - Unacceptable) • Environmental *mycobacteria* (0 in 100ml - Satisfactory; >0 in 100ml – Unsatisfactory) • *Pseudomonas aeruginosa* (0 in 100ml - Satisfactory; >0 in 100ml – Unsatisfactory) • Endotoxin (≤ 30 EU/ml) In “Table 7: Testing requirements and interpretation of results for final rinse water in surgical instrument washer disinfectors”, the following values were provided: • Aerobic Colony Count in final rinse water (<1 in 100ml – Satisfactory; ≥1 in 100ml – Unsatisfactory) • Aerobic Colony Count in other water services supplied to washer/disinfector (<100 in 100ml – Satisfactory; ≥100 in 100ml – Unsatisfactory) • Endotoxin ml (<0.25 EU/ml – Satisfactory; >0.25 EU/ml – Unsatisfactory) In “Table 8: Testing requirements and interpretation of results for dental unit water lines”, the following values were provided: • Aerobic Colony Count in final rinse water (<100ml – Satisfactory; 100 – 200/ml – Acceptable; >200/ml – Unsatisfactory) In “Table 9: Heater cooler unit waters”, the following values were provided: • Environmental mycobacteria (Not detected in 100ml – Satisfactory; Detected in 100ml – Unsatisfactory) • *Legionella* (Not detected – Satisfactory; Up to 1000 cfu/l – Undesirable; ≥1000 cfu/l - Unsatisfactory)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Inkster T, Peters C, Wafer T, et al. Investigation and control of an outbreak due to a contaminated hospital water system, identified following a rare case of *Cupriavidus pauculus* bacteraemia. Journal of hospital infection 2021; 111, 53–64.	Outbreak investigation	**Level 3**	The study aimed to describe the investigation of a waterborne infection outbreak in a new build hospital and the measures taken to control it.	N/A	Number of positive-patient, water and outlet samples; TVC (CFU/ml). Pulsotypes and genotypes of patient and tap water isolates.

Assessment of evidence

This study initially investigated a *Cupriavidus pauculus* bloodstream infection in an immunosuppressed patient which turned into the investigation and control of a contaminated water system in a new build hospital with 22 other patients infected with various other waterborne pathogens in the following few months.

Organisms: *C. pauculus* was the indicator organism. However, further testing detected “over 60 species of Gram-negative bacteria (including *Aspergillus spp*.) and atypical mycobacteria from water and system components”.

Transmission mode: Direct contact with water through showering or splashing likely as all the patients had Hickman lines. Patient to patient transmission ruled out as typing of patient isolates showed that all isolates were unique.

Assessment of evidence
Clinical setting: Paediatric haemato-oncology Unit Source: Water system components Water/Environmental contamination: In a previous outbreak, the sterile aseptic pharmacy unit asked for input from the infection prevention and control team (IPCT) due to elevated TVCs from tap water from two sinks within the unit. The unit (sterile aseptic pharmacy unit) undertook frequent water testing and had prior agreed cut-off levels of <10 cfu/mL at 37°C and, <100 cfu/mL at 22°C. Limitations: iv. Described as one incident categorised in 3 phases which were all separate outbreaks (different organisms) – this makes it slightly unclear. The methods were also not very clearly written especially with respect to typing of the isolates. v. Not all water samples were sent for typing. Neither were multiple colonies selected from each agar plate for typing. Therefore, it is not clear what the exact source was of the patient infections. However, the authors clearly stated isolate from the first Patient matched the water isolate on Pulsed-field gel electrophoresis (PFGE). vi. Combination of control measures makes it difficult to determine which part was responsible for the impact.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in healthcare premises Guidance for PHE	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Teams. 2015.					

Assessment of evidence

This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings.

Regarding elevated *Legionella* counts, then "The algorithm in this guidance begins where *Legionella* counts are greater than 100 cfu/l (colony forming units per litre)".

In "Table 2: Action levels following *Legionella* sampling in hot and cold water systems in healthcare premises with susceptible patients", the following actions were recommended

Not detected or up to 100 cfu/l - In healthcare, the primary concern is protecting susceptible patients, so any detection of *Legionella* should be investigated and, if necessary, the system resampled to aid interpretation of the results in line with the monitoring strategy and risk assessment.

>100 cfu/l and up to 1000 cfu/l – "Either: • if the minority of samples are positive, the system should be resampled. If similar results are found again, review the control measures and risk assessment to identify any remedial actions necessary or • if the majority of samples are positive, the system may be colonised, albeit at a low level. An immediate review of control measures and a risk assessment should be carried out to identify any other remedial action required. Disinfection of the system should be considered."

>1000 cfu/l - The system should be resampled following an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system. Retesting should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control is achieved.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides "practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings.

In Table 2.3 "Actions to be taken following *Legionella* sampling in hot and cold water systems in healthcare premises with susceptible patients",

"Not detected or up to 100 cfu/l - In healthcare, the primary concern is protecting susceptible patients, so any detection of *Legionella* should be investigated and, if necessary, the system resampled to aid interpretation of the results in line with the monitoring strategy and risk assessment.

>100 cfu/l and up to 1000 cfu/l – "Either: • if the minority of samples are positive, the system should be resampled. If similar results are found again, review the control measures and risk assessment to identify any remedial actions necessary or • if the majority of samples are positive, the system may be colonised, albeit at a low level. An immediate review of control measures and a risk assessment should be carried out to identify any other remedial action required. Disinfection of the system should be considered."

Assessment of evidence
>1000 cfu/l - The system should be resampled following an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system. Retesting should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control is achieved.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8554:2015. Code of practice for the sampling and monitoring of hot and cold water services in buildings. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
“This British Standard gives guidance and recommendations for investigative and planned collection of hot and cold water samples during the life of a building, including sampling locations and the selection of laboratory or on-site testing for those samples.” The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. “4.11.2.1 The microbiological monitoring regime should be able to demonstrate that the organisms of interest or microbial indicators are not present, or likely to be present, in numbers contrary to any use-specific guidance. Any changes observed in the microbiological quality

Assessment of evidence
of water might not therefore be relevant to the point of supply at the building curtilage. For example, the absence of a particular organism in water supplied to the building and its appearance in samples within a distribution system should be regarded as a significant change. 4.11.2.2 Similarly, a significant increase in indicator organisms in samples taken within buildings should be regarded as a warning that water quality is deteriorating and that cohabiting opportunistic pathogens, such as *Legionella*, could also be supported in the system. Such changes should trigger exploration of the cause. NOTE For example, a significant increase in TVC counts could indicate failing disinfection efficacy and/or the establishment of biofilms, which could, in turn, lead to the colonization/regrowth of other, previously supressed organisms.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Network. Guideline on the management of Legionella cases, incidents, outbreaks and clusters in the community. Health Protection Network Scottish Guidance 2 (2014 Edition). Health Protection Scotland, Glasgow, 2014.	Guidance	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish document "provides interagency guidelines to aid investigation and management in the event of an incident, cluster and/or outbreak of legionellosis in the community." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. For *Legionella*, it is desirable to control concentrations to no greater than 100 cfu/litre. Specific actions will be triggered at levels above 100 cfu/litre.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings.

Assessment of evidence
"Where the results of sampling/testing indicate that the system has deteriorated, with an increase in microbiological counts, e.g. TVC results in excess of a 2 log difference above that found in incoming water, remedial action should be taken. A pragmatic common sense approach should be adopted, taking into account the need to conserve water, as well as to react to a disinfection need".

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Guidance for Decontamination and testing of Cardiac Heater Cooler Units (HCUs). 2019.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance "sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings. In "Table 4.2.10 Water monitoring result parameters and actions"., the following values are provided. • Total viable count (<100cfu/ 100 ml – Satisfactory; >100cfu/100 ml – Unsatisfactory) • *Legionella spp* (0 – Satisfactory; >0 – Unsatisfactory) • *Mycobacterium chimera* (0 – Satisfactory; >0 – Unsatisfactory)

Assessment of evidence
• *Mycobacterium species* – other than *Chimera* (0 – Satisfactory; >0 – Unsatisfactory) • *Pseudomonas aeruginosa* (0 – Satisfactory; >0 – Unsatisfactory) • Coliforms (0 – Satisfactory; >0 – Unsatisfactory)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). *Legionella* and the prevention of legionellosis. WHO 2007.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document "provides guidance on assessment and management of risks associated with potentially hazardous environments, such as cooling towers, pools and spa baths. The document also identifies necessary measures to prevent, or adequately control, the risk of exposure to *Legionella* bacteria for each particular environment." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings: "The guidance given here relates to general hospital hot and cold-water systems. In high-risk areas, such as transplant centres and intensive care units, water from the outlet should be free of *Legionella* (no colonies detectable in 1 litre of water). If this cannot be achieved within the system then point-of-use filters will be needed at the outlet. Ice should be made either from water that has had *Legionella* removed by filtration, or from heat-sterilized water."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for the interpretation and clinical management of endoscopy final rinse water. 2019	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance “aims to enhance patient safety and reduce risks of decontamination related Healthcare Associated Infection (HAI) by standardising the interpretation of and clinical management of endoscopy final rinse water results nationally, based on available scientific evidence, current practices and an estimation of infection risk within NHSScotland following endoscopic procedures.” The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings:

In “Figure 1: Algorithm for Clinical Management of Endoscopy Final Rinse Water”, the following values are provided:

TVC/P.A. <0 cfu/100ml – Very low risk - Satisfactory

TVC 1 – 9 cfu/100ml – Low risk - Acceptable

TVC 10 – 100 cfu/100ml – Medium risk – Action required

TVC >100 cfu/100ml – High risk – Action required

P.A >1 cfu/100ml – High risk Action required

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Government. The Public Water Supplies (Scotland) Regulations. 2014.	Legislation	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
Table A titled Microbiological Parameters in Schedule 1 provides a value of 0 cfu/100ml for *E. Coli, Enterococci* and coliform bacteria. On wholesomeness of Public water supplies, Part 3, 4(2)(b) states that Water suppled by Scottish Water for human consumption purposes "…must not contain a parameter in Table A or Table B at a concentration or value in excess of or, as the case may be, less than the prescribed concentration or value for that parameter". Table C titled Indicator Parameters in Schedule states that water should have 'no abnormal change' for TVCs in 1ml water sample at 22°C and 37°C.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Walker JT, Bak A, Marsden G et al Final rinse water quality for flexible endoscopy to minimize the risk of post-endoscopic	Guidelines	**AGREE: Recommend**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
infection. Report from Healthcare Infection Society Working Party Journal of Hospital Infection 124 (2022) 79e96					

Assessment of evidence

"The recommendations describe measures that are practicable for minimizing the risk of post-endoscopic infection or pseudo-infection related to final rinse water for flexible endoscopy when used by healthcare workers carrying out or advising on the decontamination of flexible endoscopes." The following section(s) are relevant for this research question on the recommended microbiological limits for waterborne organisms in healthcare settings:

"The Working Party concluded that the above studies provided additional evidence that monitoring of the final rinse water for microbial quality is essential for patient safety. Monitoring can be beneficial when microbial contamination is identified, and appropriate actions are taken to ensure the microbial counts remain within safe limits. When the safe levels are breached, action needs to be taken. This will balance the risk to patients and avoid unnecessary cost and service disruptions. These trigger points may be different depending on the level of risk associated with different types of endoscopy procedures and the type of microorganisms present. It would be pragmatic to expect that the final rinse water is free of waterborne pathogens such as *Pseudomonas aeruginosa*, environmental mycobacteria and *Legionella* pneumophila but that other micro-organisms are only present in small quantities. It appears that the 10 cfu/100 mL threshold for TVC may be difficult to sustain although it may be necessary for some types of endoscope or for high-risk patients"

"Figure 1. Actions required for endoscope washer-disinfectors following the results of final rinse water testing" provides the following values

- TVC <1 cfu/100 mL AND no micro-organisms of significance - Satisfactory
- TVC 1 – 9 cfu/100 mL AND no micro-organisms of significance – Acceptable

Assessment of evidence
• TVC 10 – 100 cfu/100 mL AND no micro-organisms of significance – Unsatisfactory • TVC >100 cfu/100 mL OR micro-organisms of significance >0 cfu/100ml – Unacceptable Relevant recommendations: ER1.1 Monitor the final rinse water for total viable counts weekly (TVC) and test for the presence of environmental *mycobacteria* and *Pseudomonas aeruginosa* quarterly. ER2.3 Collate total viable counts weekly to assess for trends and to determine whether microbial counts are increasing. ER3.1 Following unsatisfactory final rinse water test results (TVC 10-100 cfu/100 mL), do not reprocess high-risk endoscopes in an affected endoscope washer-disinfector until satisfactory or acceptable result is obtained.

Health Facilities Scotland. Scottish Health Technical Memorandum 01-06: Decontamination of thermolabile flexible endoscopes and Transoesophageal echocardiograph (TOE) ultrasound probes in Endoscope Decontamination Units. Part D: Automated	Guidance	**SIGN50 Level 4**	N/A	N/A	N/A

endoscope washer disinfectors. 2023.					
Assessment of evidence					
This guidance states that final rinse water or RO water samples should contain no more than 0.25 EUml-1 bacterial endotoxins.					

Question 14: How frequently should routine water testing be conducted?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). Water safety in buildings. 2011.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This international document provides guidance on "for managing water supplies in buildings where people may drink water; use water for food preparation, washing, showering, swimming or other recreational activities; or be exposed to aerosols produced by water-using devices, such as cooling towers. These uses occur in a variety of buildings, such as hospitals, schools, child-care and aged-care facilities, medical and dental facilities, hotels, apartment blocks, sport centres, commercial buildings and transport terminals." The following sections are relevant for this research question on how frequently routine water testing should be conducted. "The range of chemical parameters and frequency of testing will depend on the source of the water supply."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England (PHE). Examining food, water and environmental samples from	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
healthcare environments. Microbiological guidelines. 2020.					

Assessment of evidence

This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on how frequently routine water testing should be conducted.

"There is no regulation or guidance in the UK regarding the frequency of sample collection from Dental Unit Water Lines (DUWL)."

On *Pseudomonas* testing in augmented care areas, the document states ". It is recommended that water outlets are tested every 6 months or more frequently if results prove to be unsatisfactory."

The document (in Tables 3a - 9) also provides the following guidance on the frequency of water testing for various hazard/ hygiene indicators in different areas of the healthcare environment:

"Table 3a: Testing requirements and interpretation of results for hydrotherapy pool water samples"

- *Escherichia coli* – Weekly
- Coliform bacteria – Weekly
- *Pseudomonas aeruginosa* – Weekly
- Aerobic colony count – Weekly
- *Staphylococcus aureus* – As part of wider investigations only.

Assessment of evidence
• *Legionella* – Quarterly (depending on risk assessment) "Table 3b: Testing requirements and interpretation of results for birthing pool water samples" • *Escherichia coli* – Weekly • Coliform bacteria – Weekly • *Pseudomonas aeruginosa* – Weekly • *Legionella* – Quarterly (depending on risk assessment) "Table 4: Testing requirements and interpretation of results for hot and cold water systems" • *Legionella* – As indicated by risk assessment • *Pseudomonas aeruginosa* – In augmented care wards as indicated by risk assessment "Table 5: Testing requirements and interpretation of results for renal dialysis fluid and water used for the preparation of dialysis fluid" • Aerobic colony count – Monthly (or more frequently if necessary) • Endotoxin/ml – Monthly (or more frequently if necessary) "Table 6: Testing requirements and interpretation of results for endoscopy final rinse water" • Aerobic colony count – Weekly • *Pseudomonas aeruginosa* – Quarterly • Environmental *mycobacteria* – Quarterly • Endotoxin – Not routinely required "Table 7: Testing requirements and interpretation of results for final rinse water in surgical instrument washer disinfectors" • Aerobic colony count (final rinse water – where products are rinsed after the disinfection stage) – Weekly

Assessment of evidence
• Aerobic colony count (Other water services supplied to washer/disinfector) – Not specified • Endotoxin (for washer disinfectors that are used for surgically invasive items or those that come into contact with parenteral solutions) – Annually "Table 8: Testing requirements and interpretation of results for dental unit water lines" • Aerobic colony count at 22°C – As required "Table 9: Heater cooler unit waters" • Environmental mycobacteria - Quarterly • *Legionella* - Monthly

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part B: Operational management. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This guidance developed by the Department of Health (UK, England) aims to summarise and recommend measures to control waterborne pathogens in healthcare estates (NHS). Appendix D regarding *P. aeruginosa* is relevant for this research question on whether routine water testing in healthcare settings is recommended: “D1. *P. aeruginosa* may be present within the water storage, distribution and delivery systems and also in the water supplied to the healthcare facility. D2. The sampling protocol (Appendix E) is intended to help healthcare providers establish whether the water in augmented care units is contaminated with *P. aeruginosa* and, if it is, to help locate its origin and to monitor the efficacy of remedial measures. D14. If test results are satisfactory (not detected), there is no need to repeat sampling for a period of six months unless there are changes in the water distribution and delivery systems components or system configuration (for example, refurbishments that could lead to the creation of dead-legs) or occupancy. D15. However, the WSG could indicate that water sampling is required within six months if there are clinical evidence-based suspicions that the water may be a source of patient colonisation or infection (that is, with *P. aeruginosa* or another potentially waterborne pathogen).” Regarding routine *Legionella* testing, the following paragraphs are relevant: “*Legionella* monitoring should be carried out where there is doubt about the efficacy of the control regime or where the recommended temperatures, disinfectant concentrations or other precautions are not consistently achieved throughout the system. The WSG should use risk assessments to determine when and where to test, which may include the following circumstances: …. d. Where there are at-risk patients with increased susceptibility.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England (PHE). Responding to the detection of *Legionella* in healthcare premises. Guidance for PHE Health Protection Teams. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on how frequently routine water testing should be conducted: "…the frequency and sites for routine environmental sampling and culture for *Legionella* in healthcare facilities should be based on a comprehensive risk assessment and should be part of an overall management strategy."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 7592:2022. Sampling for *Legionella*	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
bacteria in water systems – Code of practice. BSI Standards Publication 2022.					

Assessment of evidence

This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on how frequently routine water testing should be conducted:

“Sampling for the presence of *Legionella*e for the purposes of monitoring the effectiveness of control measures should be undertaken following a site-specific *Legionella* risk assessment and as a supplement to a full physical and chemical monitoring programme. When sampling large or complex sites, the sampling personnel should have a sampling plan containing sufficient details to identify the outlets to be sampled, e.g. a schematic diagram with a unique identifier for each sampling point. When designing a sampling plan, the following should be taken into account:

a) the reason(s) for the choice of sample points;

b) the frequency of sampling;

c) the sample matrix (type of material and system tested);

d) the limit of detection required and sample volume;

e) the analytical/evaluation techniques to be used; and

f) the location of temperature sensor”

“NOTE 2 While routine sampling for *Legionella*e represents one aspect of monitoring the effectiveness of a water treatment programme, it can be useful for auditing control measures and to validate new disinfection regimes.”

Assessment of evidence
"NOTE 3 Quarterly sampling for the presence of *Legionella*e is recommended in HSG274 Part 1 [14] for operating evaporative cooling systems incorporating a cooling tower or evaporative condenser and in HSG282 [17] for commercial spa pools and hot tubs in business premises. For other constructed water systems, such as hot- and cold-water distribution systems, sampling is not normally required unless recommended temperatures are not consistently attained or control methods other than heat are used, or where it is found to be necessary by the risk assessment (see Clause 4) (for example, systems in healthcare premises where there might be patients with increased susceptibility to Legionnaires' disease)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Surveillance Centre 2015.					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on how frequently routine water testing should be conducted:

In “Table 5.3: Testing Options and Interpretation of Results for Hot and Cold Water Systems”, the following details on testing frequency are provided:

- *Legionella* - As indicated by risk assessment
- *Pseudomonas aeruginosa* – “ In augmented care units, if indicated by risk assessment”

In “Table 5.4: Testing Options and Interpretation of Results for Renal Dialysis Fluid and Water Used for the Preparation of Dialysis Fluid” the following details on testing frequency are provided:

- Aerobic Colony Count – Monthly (or more frequently if necessary)
- Endotoxin/ml – Monthly (or more frequently if necessary)

In “Table 5.5: Testing Options and Interpretation of Results from Renal Dialysis Ultrapure Fluid and Water Used for Preparation of Ultrapure Fluid”. the following details on testing frequency are provided:

- Aerobic Colony Count – Monthly (or more frequently if necessary)
- Endotoxin/ml – Monthly (or more frequently if necessary)

Assessment of evidence
In “Table 5.6: Testing Options and Interpretation of Results for Endoscopy Final Rinse”, the following details on testing frequency are provided: • Aerobic Colony Count – Weekly • Environmental *Mycobacteria* – Quarterly • *Pseudomonas aeruginosa* – Optional – consult with microbiologist • Endotoxin – Not routinely required In “Table 5.7: Testing Options and Interpretation of Results for Dental Chair Unit Waterline Output Water Samples”, the following details on testing frequency are provided: • Aerobic heterotrophic bacterial count from waterline output – “At least twice yearly provided effective periodic or residual waterline disinfection protocol in place. Otherwise monthly.” In “Table 5.8: Testing Requirements and Interpretation of Results for Hydrotherapy Water Samples”, the following details on testing frequency are provided: • *Escherichia coli* – Weekly • *Coli*form bacteria – Weekly • *Pseudomonas aeruginosa* – Weekly • Aerobic Colony Count – Weekly • *Staphylococcus aureus* – As part of wider investigations only

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on how frequently routine water testing should be conducted:

"Samples should be: a) appropriate for the specified purpose, i.e. microbiological assessment, chemical analysis or on-site testing; b) sufficient in number to be fully representative of the distribution system, sub-branches (see Note), tanks and cisterns, as well as the condition to be evaluated, e.g. completion of a cleaning process, efficacy of distribution of disinfectant; and c) taken at a frequency which is representative of the time series to be demonstrated, e.g. taking into account the growth rate of the organism when designing the monitoring scheme to check for potential microbiological colonization."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8580-2:2022 Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on how frequently routine water testing should be conducted:

"Microbiological surveillance is an essential element of the early identification of water outlet contamination to prevent hospital-acquired infections so the frequency of routine sampling for PA and other waterborne pathogens e.g. NTMs should be based on risk assessment and agreement with the WSG. The frequency of microbiological sampling, where there are high-risk patients, should be sufficient for trend analysis to establish evidence-based confidence that control measures remain effective. When establishing trends, sampling should be carried out frequently (for example, monthly). This frequency should be reviewed by the WSG based on sample findings. Where standard

Assessment of evidence
methods are not available e.g. for unusual waterborne opportunistic waterborne pathogens, input should be sought from expert microbiologists from national reference laboratories.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). *Legionella* and the prevention of legionellosis. WHO 2007.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document “provides guidance on assessment and management of risks associated with potentially hazardous environments, such as cooling towers, pools and spa baths. The document also identifies necessary measures to prevent, or adequately control, the risk of exposure to *Legionella* bacteria for each particular environment.” The following section(s) are relevant for this research question on how frequently routine water testing should be conducted: “A count of 5 × 105 colony forming units (CFU)/ml in HPC* is an acceptable upper limit for treated tower water in a clean system. If this level of HPC is exceeded, the frequency of testing should be increased to weekly, until control has been re-established.” “The frequency of verification monitoring of control measures for *Legionella* depends on the status of the system: • In water systems treated with biocides, where storage and distribution temperatures are lower than the recommended temperatures, samples should be analysed for *Legionella* on a monthly basis. After a year, test results should be reviewed. The frequency of testing may be reduced when confidence in the efficacy of the biocide regime has been established.

Assessment of evidence
• In systems in which control levels are not being achieved consistently through the treatment regime, more frequent samples for analysis of *Legionella* (e.g. weekly) should be taken until the system is brought back under control. This action may also form part of a corrective action procedure." *HPC – Heterotrophic plate count

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Wilkinson MAC, Holden KL, et al. Tap out: reducing waterborne *Pseudomonas aeruginosa* transmission in an intensive care unit. Journal of Hospital Infection 102 (2019) 75 – 81.	Before and after study	**Level 3**	Installation of new tap outlets (the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa).*	Contamination at the tap before/after installation of 'test taps' (i.e. engineering solution)	Total viable counts of test tap samples (cfu) *P. aeruginosa* cfu
Assessment of evidence					
This study investigated the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa*. They also investigated wether *P. aeruginosa* could be removed from contaminated tap and how often water sampling needed to be done in a setting where contamination of tap outlets with *P. aeruginosa* is high. Organism: *Pseudomonas aeruginosa*					

Assessment of evidence
Transmission mode: Contaminated water outlets Clinical setting: ICUs in a tertiary referral NHS teaching hospital in England On the frequency of routine water testing, the paper stated the following: “The frequency of water testing of tap outlets for *P. aeruginosa* was originally recommended to be six-monthly. This recommendation has since been updated, and a risk assessment approach is now recommended to determine the frequency of water testing. However, there is a lack of evidence in the literature as to the appropriate frequency of testing. We have previously suggested that a six-monthly sampling regimen may result in a number of positives being missed. Indeed, Bayesian models predicted that monthly sampling would enhance the detection rate of *P. aeruginosa* in tap outlets and allow problems to be rectified more promptly.”

Question 15: When should routine water testing frequency be increased?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on when routine water testing frequency should be increased.

“The infection prevention and control team, however, will need to consider the level of risk before deciding that *Legionella* testing is indicated. For example, testing may be required:

- when storage and distribution temperatures do not achieve those recommended under the temperature control regime and systems are treated with a biocide regime, a monthly frequency of testing for *Legionella* is recommended. This may be reduced as confidence in the efficacy of the treatment regime is established;
- in systems where the control regimes are not consistently achieved, for example temperature or biocide levels (weekly checks are recommended until the system is brought under control);”

Assessment of evidence
The document also recommends that if *Legionella* sampling in hot and cold water systems shows *Legionella* bacteria >1000cfu/litre, "The system should be re-sampled and an immediate review of the control measures and risk assessment should be carried out to identify any remedial action, including disinfection of the system. Re-testing should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control has been achieved." "Testing of water for *Pseudomonas aeruginosa* is only required if a very specific reason has been identified such as suspected or confirmed outbreak or a series of sequential cases, as guided by the Responsible Person (*Pseudomonas*)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on when routine water testing frequency should be increased. "Where water quality sampling in a water system confirmed *Legionella* results in excess of 1,000 CFUs/Litre immediate action must be taken and the Consultant Microbiologist and Authorised Person (Water) must be informed and provided with copies of the samples in

Assessment of evidence
writing. They will immediately confirm the necessary actions prior to re-sampling and bringing the water system into use when (acceptable) *Legionella* results are reliably less than 100 CFUs/Litre." "Note: Where continued water system sampling is required, this would be undertaken on a weekly frequency." "Where the results of three consecutive weekly water system samples remained below 100 CFUs/Litre, the Authorised Person (Water) and Consultant Microbiologist would be informed and sampling would revert to a monthly sampling frequency. Where the results of three consecutive monthly Water System samples remained below 100 CFUs/Litre, the Authorised Person (Water) and Consultant Microbiologist would be informed and sampling would revert to a 3-monthly sampling frequency."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler MA, Osman F, Marx Jr J et al. Hospital-acquired *Legionella* pneumonia outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020.	Outbreak investigation (including case-control element)	**Level 3**	The study describes the epidemiological and laboratory investigation of an outbreak of nosocomial *Legionella* pneumonia at The University of Wisconsin Hospital in 2018 despite a long standing copper-silver ionization system.	Molecular genotyping results (WGS) between patient strains and *L. pneumonia* isolated from environmental/water samples were compared to establish link of colonisation/infection	Case-control study: ICU admission, 30-day mortality and 90-day mortality, Demographic data and patient factors, pertinent exposures Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia*		*Legionella* in environmental samples taken from patient rooms and clinical units, molecular type of isolates found.

Assessment of evidence

This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the implementation of changes to the water treatment strategy which caused bypass valves to be opened to incorporate water and potentially sediment, from rarely used plumbing into the system. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters.

Organism: *Legionella* spp.

Transmission mode: Direct (from water system)

Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients.

Source: Hospital water circuit

Control measures: ‘Showering activities were promptly restricted, the hot potable water distribution system was hyper chlorinated with 50-200 ppm free chlorine overnight, and sections were sequentially flushed to remove excess chlorine. The silver-copper ionization system was then returned to its original configuration. Nine days later, point of use filters were installed on showerheads and faucets in the inpatient unit with the majority of cases. Other interventions included removal of the old water heaters and associated dead end water pipes.’

Assessment of evidence
Point-of-use filters: 'point-of-use filters were effective in preventing further *Legionella* infections after showering restrictions were lifted, consistent with previous reports of point-of-use filter effectiveness at trapping *Legionella* organisms. Point of use filters remain in place at our institute as positive environmental samples have continued to occur sporadically though at progressively greater intervals. We plan to continue their use till we have sustained suppression below the level of detection.' It is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Heath Technical Memorandum 04-01: Safe water in healthcare premises: Part B: Operational management. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This UK guidance created by the department of health includes recommendations regarding safe management of water in healthcare premises. Appendix D regarding *P. aeruginosa* is relevant for this research question on when routine water testing frequency should be increased:					

Assessment of evidence
"D14. If test results are satisfactory (not detected), there is no need to repeat sampling for a period of six months unless there are changes in the water distribution and delivery systems components or system configuration (for example, refurbishments that could lead to the creation of dead-legs) or occupancy. D15. However, the WSG could indicate that water sampling is required within six months if there are clinical evidence-based suspicions that the water may be a source of patient colonisation or infection (that is, with *P. aeruginosa* or another potentially waterborne pathogen). D16. If tests show counts of 1 to 10 cfu/100 mL, the WSG should risk-assess the use of water while simultaneously retesting the water outlet. D17. If test results are not satisfactory (>10 cfu/100 mL), further sampling along with an engineering survey of the water system could be used to identify problem areas and modifications that may be implemented to improve water quality. D18. After such interventions, the water should be resampled (see Figure D1 for suggested frequencies)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following sections are relevant for this research question on when routine water testing frequency should be increased: “In the event of a cluster or outbreak, the epidemiological information available at the time should be used to determine the locations where samples are to be collected. As an outbreak proceeds and the investigation progresses, the collated epidemiological and environmental information should be continually reassessed and updated by the outbreak investigation team, and the emphasis of the environmental investigation should reflect this. NOTE 1 Depending on the nature and size of the outbreak, the investigation might centre around or involve a single property or might involve a number of properties within a certain area. Thus, the number of samples to collect is difficult to assess in advance, especially in the early stages of the investigation”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in Healthcare Facilities. Health Protection Surveillance Centre (2015).					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on when routine water testing frequency should be increased:

“Monitoring of water supplying an augmented care unit for *Pseudomonas aeruginosa* may be required, based on risk assessment. Water testing is recommended during an outbreak or if surveillance identifies an increased incidence of infection. Water testing may also be indicated following a single invasive *Pseudomonas aeruginosa* infection, if the organism is an unusual pathogen in the augmented care unit. Furthermore, evidence suggests that there is a greater risk of the internal surfaces and components of non-touch or sensor taps becoming contaminated with microorganisms and biofilm in comparison to manually operated taps. Therefore, water testing may be considered by the environmental monitoring committee for augmented care units with sensor taps.

In “Tables 5.1: Microbiology Testing for Water Systems in the Health Care Environment”, the guidance states that testing frequency for “Healthcare facility hot and cold water system in augmented care units” and “Healthcare facility hot and cold water system” and “Dental chair unit waterline output water” is to be determined by risk assessment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides "practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999." The following sections are relevant for this research question on when routine water testing frequency should be increased:

"*Legionella* monitoring should be carried out where there is doubt about the efficacy of the control regime or it is known that recommended temperatures, disinfectant concentrations or other precautions are not being consistently achieved throughout the system. The risk assessment should also consider where it might also be appropriate to monitor in some high risk situations, such as certain healthcare premises. The circumstances when monitoring for *Legionella* would be appropriate include:

- water systems treated with biocides where water is stored or distribution temperatures are reduced. Initial testing should be carried out monthly to provide early warning of loss of control. The frequency of testing should be reviewed and continued until such a time as there is confidence in the effectiveness of the regime;
- water systems where the control levels of the treatment regime, e.g. temperature or disinfectant concentrations, are not being consistently achieved. In addition to a thorough review of the system and treatment regimes, frequent testing, eg weekly, should be

Assessment of evidence
carried out to provide early warning of loss of control. Once the system is brought back under control as demonstrated by monitoring, the frequency of testing should be reviewed”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). *Legionella* and the prevention of legionellosis. WHO 2007.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document “provides guidance on assessment and management of risks associated with potentially hazardous environments, such as cooling towers, pools and spa baths. The document also identifies necessary measures to prevent, or adequately control, the risk of exposure to *Legionella* bacteria for each particular environment.” The following sections are relevant for this research question on when routine water testing frequency should be increased: “In systems in which control levels are not being achieved consistently through the treatment regime, more frequent samples for analysis of *Legionella* (e.g. weekly) should be taken until the system is brought back under control (see Chapter 3). This action may also form part of a corrective action procedure.”

Question 16: Where should routine water samples be taken from (which outlets, how many samples)?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part A: Design, installation and testing. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on where (and how many) water samples should be taken from: "Water samples should be taken from selected areas within the distribution system."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:

“As a minimum, samples should be taken as follows:

- From the cold water storage and the furthermost outlet from the tank, on every loop;
- From the calorifier flow, or the closest tap to the calorifier, and the furthermost tap on the hot water service circulating system;
- Additional samples should be taken from the base of the calorifier where drain valves have been fitted;
- Additional random samples may also be considered appropriate where systems are known to be susceptible to colonisation”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:

“Samples should be taken from:

- inlet and outlet at cold water storage tanks;
- incoming main, close to meter, where facilities exist to do so;
- possible stagnant areas within tanks pending rectification of any identified problem;
- beginning, mid-point and end of cold distribution system (i.e. sentinel outlets);
- special supplies to kitchens, pharmacies, etc;
- calorifier outlet;
- nearest hot water tap to calorifier;

Assessment of evidence
• most distant hot water tap from calorifier (i.e. sentinel outlet); • return to calorifier; • typical samples from heated circulating water." On "Sampling Swimming, Spa and Hydrotherapy Pool Water", the guidance stated "The following sampling procedure should be followed from a number of sample points and from the balance tank (and swab samples from inside/behind any jets)…"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are					

Assessment of evidence

currently lacking." The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:

"Higher counts will be found in water which is stagnant or stationary for long periods, e.g. tanked supplies, dead legs, infrequently used parts of buildings. It is therefore important to use a risk-based approach to the selection of appropriate sampling points, and to collect sufficient volumes of water to enable adequate assessment of the water quality."

On the "Procedure for sampling swimming, spa and hydrotherapy pool water (based on Pool Water Treatment Advisory Group, 2017)", the guidance states thus, "Normally a single sample of pool water is taken. The most appropriate site for taking a single sample from a pool is where the water velocity is likely to be at its lowest and away from fresh water inlets or outlets. Depending on the size of the pool, it may be advisable to take samples from other sites to establish whether there are "dead spots" in the water circulation. During investigations of poor water quality, it is recommended that a sample is taken from the balance tank and skimmers, and that swabs are taken from inside/behind any jets and from the lid or cover for the pool if used… If both routine testing parameters and *Legionella* are required, then separate 1 litre and 500 ml samples should be collected."

"On Procedure for sampling water for Pseudomonas testing in augmented care areas (based on Department of Health, 2013b)", the publication states, "The water outlets to be sampled should be those that supply water that has direct contact with patients, used to wash staff hands or used to clean equipment that will have contact with patients as determined by local risk assessment. It is recommended that water outlets are tested every 6 months or more frequently if results prove to be unsatisfactory. Water samples should be taken during a time of low or no use (at least 2 hours or preferably longer without use). The first water delivered from the outlet (i.e. pre-flush) should be used for routine monitoring, according to the method described in 'Procedure for Sampling Tap Water' (points v - vii). For follow-up samples, pre- and post-flush samples should be collected (i.e. an initial, pre-flush sample should be taken as described above; the tap should then be run for 2 minutes and a second post-flush sample taken)."

On "Procedure for sampling water for *Legionella* testing (based on British Standards Institution, 2008)", the guidance states "During investigations, sampling must not be carried out in isolation but should be done in conjunction with a review of the risk assessment, up-to-date schematics of the water systems, a review of previous monitoring results (both microbiological and temperature) and a review of current control measures. Sampling must be carried out based on the perceived risk. For example, water should be sampled from the areas where *Legionella* are likely to multiply, such as the warmest parts of a cold system, the coolest parts of a hot system or areas where

Assessment of evidence
there is low usage/ stagnation. Where there are several floors in the building under investigation, flow and return temperatures should be taken on each floor and to and from the calorifier or other heat source. Further details of appropriate sampling points are given in Approved Code of Practice and Guidance: L8 (Health and Safety Executive, 2013)." On "Renal unit waters and dialysis fluids", the document states "Samples should be taken from points expected to have the highest bacterial load, such as the end of the distribution loop or the last machine in a dead-end system... If the sample is to be collected from a tap used solely for sampling, ensure that this has been appropriately sanitised as described in 'Procedure for Sampling Tap Water'" On "Endoscopy/washer disinfector final rinse waters", the guidance states "The exact procedure will vary from one model to another, but in general, the machine should be run on a special cycle that allows the cycle to be stopped in the rinse phase and a sample collected via a sterile sampling tube. If this is not feasible, use a sampling point on the machine, disinfect the sampling point with 70% alcohol and run approximately 500 ml rinse water to waste before aseptically collecting at least 100 ml (and preferably 400 ml) in a sterile container." On "Heater cooler units", the paper states "A volume of 100 ml per sample is suggested if only an environmental mycobacteria test is required. However, 500 ml is more appropriate if tests for a range of different parameters are to be undertaken."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in healthcare premises Guidance for PHE Health Protection Teams.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
2020.					

Assessment of evidence

This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:

"Routine sampling results are the starting point of the algorithm in Figure 1; the frequency and sites for routine environmental sampling and culture for *Legionella* in healthcare facilities should be based on a comprehensive risk assessment and should be part of an overall management strategy."

"A degree of contamination at the periphery of a water system with *Legionella* is almost inevitable. Presence of *Legionella* may represent poor use of an outlet or the presence of materials that promote biofilm formation. In addition, sampling through a thermostatic mixer valve (TMV) will also have an impact on the microbiological results and their interpretation."

On "Further investigation" in the Assurance checklist, the document states "As a guide, sampling should be carried out from cold water tanks, hot and cold outlets, sentinel sites (e.g, those most distal from the hot and cold supply and those in other 'high risk' areas – should have been identified from schematic). Particularly sample from outlets less likely to be used e.g an assisted toilet."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 7592:2022. Sampling for *Legionella* bacteria in	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
water systems – Code of practice. BSI Standards Publication 2022.					

Assessment of evidence

This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:

“Where an existing sampling plan has been developed and agreed as suitable by the RP and/or WSG, the schematic diagrams are helpful in identifying the location of the sample points. Samplers should liaise with the authorized person (see HTM 00 or national equivalent), RP and/or WSG representative to ensure they understand the rationale and policy for sampling and resampling prior to taking samples. On new sites or where there is no WSP (see BS 8680) or sampling plan a site survey should be carried out, taking BS 8554 into account, which should then be submitted for approval by the RP/WSG. Following commissioning of new or refurbished systems, the number and location of samples to be taken to verify that systems are not contaminated should be included within the commissioning brief and pre-agreed with the RP/WSG.”

“Whether samples are collected for routine purposes or as part of outbreak or other investigations, the sampling plan should indicate that samples be collected, wherever possible, from locations considered most likely to contain the highest numbers of *Legionella*e or which pose the greatest risk from exposure. Any available data, including the as-fitted plans, schematic drawings and site staff systems knowledge, should be used to identify sample locations. A simple room plan or site/system schematic should be prepared, clearly showing the points sampled to enable later resampling and/or identification by parties other than the original sampler. NOTE Temperature monitoring can be an important factor in the risk assessment process to determine appropriate sampling points. For example, samples collected from the warmest point in a cold-water system, or the coolest part of a hot-water system, or areas of low biocide level, are likely to pose the greatest risk of *Legionella*e growth and survival of *Legionella*e”

Assessment of evidence
“Potable water cisterns should not be opened for sampling as this can introduce contamination, especially when removing the lid. Instead, the sample should be taken from either a dedicated sample valve or the nearest outlet to the cistern. NOTE In exceptional circumstances, e.g. outbreak investigations, it might be necessary to sample a drinking water storage tank.”
“For routine monitoring purposes, only pre-flush samples should be taken and, where possible, these should be taken from unmixed outlets. Pre-flush samples should be taken with no disinfection or adjustment of devices or inserts to obtain a reflection of the water as it is used. NOTE 1 Post-flush samples are not suitable for routine monitoring”
“If it is necessary to differentiate between local and systemic colonization following a positive result, post-flush, disinfected-outlet samples should be collected in addition to the pre-flush samples to support the determination of whether the system itself or components, such as TMVs, are colonized, as opposed to outlets, and to determine that the numbers of *Legionella*e within the system are controlled. NOTE 4 Adequate, consistent temperature control or secondary disinfection usually reduces the risk of growth or multiplication of *Legionella*e in a system. However, one area where growth and multiplication of *Legionella*e are likely to occur is within the components of a TMV, TMT and the outlet”
“Whenever possible, when post-flush samples are required these should be collected from individual taps, rather than mixer taps so that the samples are representative of the water flowing around the system and do not just contain localized contamination of the outlet(s).”
“when sampling water closet cisterns or non-potable water storage cisterns, the biofilm should be collected at the interface from the surface between the water line and atmosphere, or a small amount of water may be drained from the cistern, and the sample collected from just below the normal water-line mark. NOTE 1 Maximum growth of biofilms usually occurs at the water-air interface around the normal fill line or around objects at the surface such as float valves. NOTE 2 Specialized monitoring devices are built into some water systems, particularly evaporative cooling water systems, to monitor biofilm development. These devices, usually comprising a section of piping or conduit material, can be plumbed into water systems, via side-stream connections, which can then be isolated by appropriately placed valves to facilitate sampling. The devices can incorporate studs of known surface area, which can be aseptically removed for subsequent analysis of the biofilm growing on them. The studs that are removed are then replaced with new sterile studs, and the water flow resumed by reopening the valves; care is needed with interpretation as their very presence alters flow patterns within the system where they are inserted.”

Assessment of evidence
On sampling “Cold-water outlets”, the guidance states “Cold-water samples should be collected at outlets close to, but downstream of, each cistern. In addition, for each water system a sample should be collected at an outlet at the furthest point (in terms of pipe length) downstream from each cistern. Samples should also be collected from any areas indicated by the risk assessment. NOTE Cold-water outlets regularly used for routine monitoring are often referred to as “sentinel taps or outlets”. For each fitting, a pre-flush sample should be collected. The fitting should not be disinfected prior to sampling. The temperature of the water should be recorded after the sample has been collected.” “To gain a representative overview of domestic hot-water systems, water samples should be collected from sentinel outlets and representative taps on a rotational basis (see HSG274 Part 2 [18]): a) the tap (in terms of pipe length) nearest to the calorifier outlet; b) the tap furthest removed (in terms of pipe length) from the calorifier on the distribution system; and c) the tap (in terms of pipe length) nearest to the return to the calorifier. Showers or taps with mixers should not be used as sentinel outlets, unless in a healthcare setting, for determining/sampling the hot water system. NOTE 1 However, if the overall control at the outlets is being monitored, sampling of showers and mixer outlets might be appropriate. In multi-loop systems, samples should be collected to represent each of the subordinate/secondary and tertiary loops. NOTE 2 Many large circulating hot-water systems have additional loops consisting of a smaller bore pipe branching from the flow leg of a principal loop to supply a group of outlets and connecting back to the return leg. The smaller bore loops are the subordinate (secondary) loops and the larger loops are the principal loops. Large and complex systems, e.g. in hospitals, often have localized loops that feed only one or two outlets, and these are known as tertiary loops. Additional samples should be collected from outlets of particular concern as indicated by a risk assessment or by temperature monitoring. NOTE 3 As already noted, post-flush samples provide information on the colonization of bacteria within the whole system and pre-flush samples provide information on the degree of control at the outlets. If indicated by the risk assessment or to determine whether control measures downstream of the TMV or mixer are effective, mixer outlet samples should be collected. NOTE 4 Samples from mixer taps are not necessarily representative of the whole system.” The document also provided guidance on sample sites for different parts of the water system. Header cisterns – “Cisterns feeding the domestic hot-water system should be sampled where necessary. NOTE These cisterns might be for the incoming mains-water supply feeding water-softening systems that then supply further cisterns before entering hot-water systems.

Assessment of evidence
All cisterns should, where possible, be sampled on the opposite side to the incoming supply or where the turnover of water within the tank is at its lowest." Water-softening systems – "When a water-softening system is fitted, a sample should be collected immediately downstream of the equipment. Ideally, there should be a sampling point specific for this purpose." Expansion vessels – "Expansion vessels should only be sampled if they are not of the flow-through type or not installed in the vertical orientation and not located so that the length of the connecting pipework is kept to a minimum or are identified by the risk assessment. NOTE 1 Where there is no drain valve, assistance might be required to take samples. Expansion vessels contain a bladder which is conducive to biofilm growth, so these should be sampled through the drain valve when investigating colonized systems or during outbreak investigations" Storage calorifier drain-off point – "These samples can be potentially hazardous, as *Legionellae* have often been found in storage calorifier drain-off points and water might be at high pressure and/or at high temperature. Additionally, storage calorifier drain cocks often corrode and might snap off when an attempt is made to open them. Storage calorifier drain-off points should only be sampled if specifically indicated by the risk assessment or RP/WSG and the results should be interpreted with caution." Point of use/instantaneous heaters – "If the design of the heater incorporates stored water at a temperature that promotes *Legionella* proliferation, the manufacturers' recommendations should be followed in respect to hygiene maintenance and sampling for *Legionellae* should be carried out whenever the risk management plan has been compromised. Where practicable, point of use (POU) and instantaneous water heaters should be sampled following their longest period of inactivity under normal operating procedures, i.e. prior to use on a Monday morning if the building is unoccupied over the weekend." Hot-water storage cisterns/buffer vessels – "Hot-water storage cisterns/buffer vessels are usually associated with plate heat exchangers (3.27) or solar heating systems and should be sampled if the storage temperature is below 60 °C, which is not compliant with HSG274 Part 2. If the temperature is 60 °C or above, the vessels should be sampled as storage calorifiers" Tap samples – "Pre-flush samples should be collected from designated tap outlets or those tap outlets furthest removed (in terms of pipe length) from the cisterns or incoming supply. NOTE Samples might also need to be collected from outlets in areas of particular concern. Samples should be collected at sentinel outlets, i.e. those closest to, but downstream of, each cistern or calorifier and those furthest away

Assessment of evidence
(in terms of pipe length). Samples may also be collected from any areas indicated by the risk assessment or as requested by the RP or WSG. For each location, a pre-flush sample should be collected. The temperature of the water obtained in accordance with 7.6 should be recorded after the sample has been collected by inserting the thermometer into the flow of water, or in an additional sample, collected in a separate container intended for this purpose." Showers – "Most bacterial colonization within showers occurs in the region of the outlet, including mixer valves, shower heads and any flexible hoses. The problem for the sampler is to collect the sample that is representative of the water to which the user is exposed whilst avoiding the risk of splashing and aerosol production during sampling. In showers operating correctly and fitted with fail-safe thermostats, the process of turning the tap on always results in a mixture of hot and cold water issuing from the tap, as cold water is automatically released into the shower head first. With other showers, there might be a variable mixture of hot and cold water. When sampling showers, care should be taken to minimize splashing and aerosol production." Evaporative cooling systems – "Post-flush samples should be collected from designated sample valves that have been disinfected. Samples should be collected at locations that correspond (at the time sampled) to the highest risk – the highest numbers of *Legionella*e occur in circulating water just after the pumps have been switched on. Thus, if possible, samples should be collected shortly after pumps have initially been switched on. If samples of the supply water are required, they should be collected either from the float valve at the inlet to the cooling tower pond or from the header cistern. If a water-softening system is incorporated into the system, samples of softened water and water that has not been softened should be collected." Cooling circuit with cooling towers – "Ideally, a sample valve should be fitted on the return service to the cooling tower, located near to the heat source, for example, just after the refrigerator condenser. If no such sample valve is available, one should be fitted. Samples should not be collected from the drain valve as part of a routine monitoring programme, as any sample collected might not be representative of the circulating water. Samples should be collected, if possible, when the biocide is at its lowest concentration (if not continuously dosed) and there is a maximum potential number of *Legionella*e present, for example: a) when recirculating pumps have just been started; b) at the time after which any biocidal activity has ceased, and immediately prior to the next biocide addition; and c) just before any dilution of the water takes place either by automatic or manual operation." Evaporative condensers – "Samples should only be collected, shortly after switching off the recirculating pump, from the pond at the point furthest removed from the cold-water inlet or a dedicated sample point. Alternatively, a dedicated sample valve in the recirculating line can

Assessment of evidence
be used but should be disinfected before sampling. In other respects, the recommendations of 7.9.3 should be followed. NOTE Condensers using softened make-up waters often have a buffer cistern as part of the circuit. Samples should not be collected when make-up water is entering the system." On the number of samples to collect during outbreak or other investigations, the document states "Depending on the nature and size of the outbreak, the investigation might centre around or involve a single property or might involve a number of properties within a certain area. Thus, the number of samples to collect is difficult to assess in advance, especially in the early stages of the investigation."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8554:2015. Code of practice for the sampling and monitoring of hot and cold water services in buildings. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
"This British Standard gives guidance and recommendations for investigative and planned collection of hot and cold water samples during the life of a building, including sampling locations and the selection of laboratory or on-site testing for those samples." The following section(s) are relevant for this research question on where (and how many) water samples should be taken from:					

Assessment of evidence
“Sampling points should be designated according to the sampling plan, and indicated on a schematic diagram of the water system in the sampling plan. Each outlet being sampled should be representative of the potential water quality change being investigated. The sampling plan should identify equipment that best represents the risk being investigated, e.g. equipment that constitutes a significant risk of infection because it produces an aqueous aerosol, or where there is the potential for ingress, stagnation and biofilm build-up.” “Where it is feasible to carry out long-term periodic monitoring, the sampling plan should require sampling from both fixed and randomly selected points for each batch of samples to enable both trending of results and increased coverage of the whole system. NOTE A single sample location might not be representative of a dynamic system where use patterns vary spatially and over time.” “To indicate the relative risk of poor water quality from an outlet and the system, both pre-flush (see Clause 5) and post-flush (see Clause 6) samples should be taken. Whenever possible, samples should be collected from individual taps, rather than mixer taps, as this ensures that the samples are representative of the hot or cold system, rather than a combination of both.” On “Re-sampling before occupancy”, “he sampling plan should include samples from the incoming mains water (as close to the building inlet as possible), cisterns, hot water storage vessels and outlets as indicated in the risk assessment. NOTE Good practice in an unoccupied building is for these not to be filled until the building is occupied, i.e. bypassed so that only mains is used until there is the need for stored water.” On “Sampling during incident investigations”, the standards state, “The planning of sampling for incident investigation should only be undertaken by competent and experienced people with a detailed knowledge of the building and any plant that is implicated in the water quality deviation. The sampling plan design should ensure that changes in water quality can be identified at any and all critical points from where the water enters the building to the outlets. NOTE Such sampling might need to be more intense than that conducted for routine monitoring, involving the collection of more samples. Depending on the nature of the incident under investigation there is likely to be a range of organisms and system-specific water quality criteria to be assessed, so the precise sampling needs should be assessed and documented in the sampling plan. NOTE Specialist techniques might be required for the assessment of the cleanliness of the outside of a tap in a hospital intensive care unit, or for *Legionella* sampling of a showerhead (see BS 7592).” On “Common sampling points”, the Standards provide the following:

Assessment of evidence
Water supply points with removable hoses and devices – “Any pre-flush sample should be taken directly through the outlet in accordance with Clause 5, after which the outlet should be disconnected and cleaned. The orifice should also be sampled. The outlet should then be reconnected to the hose/device, and another sample taken if verification of the clean is required.” Domestic hot and cold water outlets – “NOTE 1 Sink and basin taps provide the majority of sample locations for hot and cold water services in typical buildings Where a risk assessment for Legionnaires’ disease indicates that there is a need to sample for *Legionella* bacteria, samples should be collected from locations indicated by the risk assessor. NOTE 2 Additional samples may be collected from outlets of particular concern showing discolouration or other concerns. NOTE 3 Outlets regularly used for routine monitoring include “sentinel taps”. These are chosen to be representative of the system condition. In a simple cold water system, the sentinel points are typically the tap furthest (far sentinel) and the tap nearest (near sentinel) to the supply or storage tank (see HSG274 Part 2)” Cold water cisterns and hot water storage vessels – “NOTE Sampling these points could be useful for investigative purposes.” Storage calorifier drain-off point – “Storage calorifier drain-off points should only be sampled if specifically indicated by the sampling plan, and where it is safe to do so. NOTE A visual clarity check is required by HSG274 Part 2. When taking microbiological samples, the outside and inside surfaces of the outlet side of the drain valve should be disinfected. Any pipework connected to the drain should be removed, if possible, before disinfecting the valve. The drain valve should then be opened for a few seconds in order to rinse out any remaining disinfectant from the valve. If there is insufficient space to place a sample container under the outlet to collect the sample, then clean, sterile silicone rubber tubing can be attached to the drain valve. The visual appearance of the water, for example the presence of rust deposits, sediment or corrosion products, should be noted in order to facilitate the assessment of the cleanliness of the calorifier” Water closet cisterns – “Water closet cisterns (flush toilets) should only be sampled as part of an investigation or if a risk assessment indicates that this is necessary.” Showers and thermostatically-controlled outlets – Samples from mixer taps are not likely to be representative of the whole system or of hot or cold water quality. Showers or thermostatic mixing valve (TMV) outlets with mixers should not be used as sentinel outlets, but might be the most likely to develop localized problems, so pre-flush outlet sampling can be informative. “Pre-flush sampling of showerheads is a useful indicator of conditions and should be conducted when indicated in a risk assessment or specified in a sample plan, or to determine whether control measures are effective.”

Assessment of evidence
Dedicated sampling points not intended for use by building occupants – “Water softeners: the sampling operative should have access to the feed water and the softened water before any other plant, and the sampling points should be suitable for sampling for non-microbiological and microbiological purposes.” “Carbon filters for removing disinfection residuals: where activated carbon treatments are applied for the necessary depletion of chlorine, chloramine or chlorine dioxide, for example before treatment of water by reverse osmosis, dedicated sampling points should be available to check the efficacy of the carbon bed in order to assess the need for replacement/ regeneration or amendment of contact time through the bed. Such sampling points might also be required for microbiological samples” “Special (medical) devices – Sampling of special (medical) devices should be conducted in accordance with the applicable part of BS 15883 and CFPP 01-06 [N2]” Expansion vessels – Where it is suspected that an expansion vessel holding water above 20 °C is harbouring bacteria, the supply valve should be closed and a sample taken from an appropriate outlet representative of the water in the vessel.”. Point-of-use (POU)/instantaneous heaters – “A point-of-use/instantaneous heater should only be sampled where the need for this is indicated by the risk assessment or investigation of a complaint. NOTE 2 Samples may be pre-flush or post-flush, though post-flush samples are likely to have reduced temperatures due to the limited water volume present. Post-flush samples are therefore more likely to demonstrate the water quality of the cold water supplied to the water heater, and this type of sampling might be more relevant for water heaters which have limited use and whose supply line might be stagnant.” Incoming supply – “Sampling of water entering the building should be included in the scope of any routine sampling or investigation of water quality issues within the building. The results should form the baseline against which results obtained elsewhere in the building can be compared. The sample should be obtained from the first available cold water outlet on the incoming supply, which may be a sink or basin tap or a dedicated sampling point provided for the purpose.” On collecting biofilm samples using outlet (pre-flush) sampling techniques, the standards state “When sampling a water closet cistern or water storage cistern, the biofilm should be collected at the interface between the water and atmosphere, or a small amount of water may be drained from the cistern and the sample collected from just below the normal water-line mark. Maximum growth of biofilms usually occurs at the water-air interface around the normal fill line. To facilitate quantification of *Legionella*e, a sterile template should be used so

Assessment of evidence
that a known surface area is sampled." It also stated that "In the case of showerheads and pipes, if accessible, biofilms can also be sampled from their inside surfaces by means of a swab. The entire surface should be swabbed to maximize repeatability." This guidance also informs on the sampling methodology.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on where (and how many) water samples should be taken from: "Samples should be: a) appropriate for the specified purpose, i.e. microbiological assessment, chemical analysis or on-site testing; b) sufficient in number to be fully representative of the distribution system, sub-branches (see Note), tanks and cisterns, as well as the condition to be evaluated, e.g. completion of a cleaning process, efficacy of distribution of disinfectant; and c) taken at a frequency which

Assessment of evidence
is representative of the time series to be demonstrated, e.g. taking into account the growth rate of the organism when designing the monitoring scheme to check for potential microbiological colonization. NOTE Further guidance on sampling is given in BS EN ISO 5667-3, BS ISO 5667-5, BS EN ISO 19458 and BS 7592. The following are examples of sampling frequencies and distances for distribution networks, where samples would be taken from each branch and at suitable intervals along the run of pipe: • 1 sample for pipes up to 100 m in length and ≥25 mm inner diameter; • 1 sample per 250 m for pipes ≤75 mm inner diameter; • 1 sample per 500 m for pipes ≤150 mm inner diameter; and • 1 sample per 1 000 m for pipes >150 mm inner diameter” “Where alternative temporary supplies are used during construction, or at other necessary times of deployment, sampling should be conducted in accordance with BS ISO 5667-21.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
NSS Health Facilities Scotland & Health Protection Scotland. NHS Lothian - Royal Hospital for Children and Young People & Department of Clinical Neurosciences – NHS National Services Scotland –	Guidance review	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
NHS National Services Scotland – Review of: Water, Ventilation, Drainage and Plumbing Systems. Scottish Government, 2019.					
Assessment of evidence					
NHS National Services Scotland (NSS) received a commission from Scottish Government to undertake an external series of checks, led by Health Facilities Scotland (HFS) and Health Protection Scotland (HPS), to ensure that the relevant technical specifications and guidance applicable to the new hospital have been followed and are being implemented. It provides some information regarding how many samples should be taken. Within this document, it was commented that 'only' 5% of the total outlets in the hospital were sampled at commissioning.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre (2015).					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on where (and how many) water samples should be taken from:

“It may be appropriate to sample water from sensor taps to ensure they are being adequately maintained.”

“The main strategy for sampling is to take the first sample of water (pre-flush) delivered from a tap at a time of no use (at least 2 hours or preferably longer) or, if that is not possible, during a time of its lowest usage. This will normally mean sampling in the early morning, although a variety of use patterns may need to be taken into account. A 500mL container is recommended and this should be filled almost to the brim ie 500mLs.”

Question 17: When should water samples from further back in the system be taken?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aspelund AS, Sjöström K, Liljequist BO et al. Acetic acid as a decontamination method for sink drains in a nosocomial outbreak of metallo-b-lactamase-producing *Pseudomonas aeruginosa*. Journal of Hospital Infection 94 (2016) 13 – 20.	Outbreak investigation	**Level 3**	To describe a nosocomial outbreak of *Pseudomonas aeruginosa*-MBL associated with hospital sink drains and to evaluate acetic acid as a decontamination method.	Molecular typing (PFGE) results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared.	Minimum inhibitory concentration (MIC), Minimum bactericidal concentration (MBC), Minimum biofilm eradication concentration (MBEC). PFGE typing results.

Assessment of evidence

This study describes “a prolonged outbreak of metallo-b-lactamase-producing *P. aeruginosa* (Pae-MBL) associated with sink drains and propose a previously unreported decontamination method with acetic acid.”

Organism: *Pseudomonas aeruginosa*

Transmission mode: Indirect contact; (likely splashing of the water in the sink or similar).

Clinical setting: 3 Wards at a University Hospital in Sweden

Assessment of evidence
Source: Sink drains (and further down in the pipes). Control measures: The initial response was the replacement of contaminated sinks. In one ward where the sinks could not be immediately replaced, acetic acid was poured once weekly into colonized sink drains. Acetic acid treatment was terminated when all sinks and plumbing's were changed as it was believed that the bacteria reservoir had been eliminated. However, the bacterium reappeared in 3 sinks after a mean time of 13 weeks, but without any positive clinical sample. Culturing the drainpipes going into the wall indicated a reservoir further down. "As acetic acid treatment of colonized sinks had previously shown promising results in ward 1, acetic acid treatment of Pae-MBL-positive sinks was restarted. Since the finding of an initial positive culture in one colonized sink, all control cultures have been negative. However, two drainpipes in the wall remained positive even after 10 weeks of acetic acid treatment." To completely eradicate Pae-MBL growth, the two colonized drainpipes "were flushed with hot water (90°C) directly into the pipe in the wall for 5 minutes with high pressure". Sink drain, siphon and pipes to the wall were changed at the same time, but one of the pipes became Pae-MBL positive again after five weeks. Following this recurrence, all patient bathroom sinks were treated with acetic acid. Patients were also asked to observe 'sink rules' such as "not keeping toothbrushes or toiletries on the sink brim". PFGE typing of the 12 isolates from patients and seven isolates from sinks showed identical or closely related band patterns. *Pseudomonas aeruginosa* was found in 4/9 drainpipes that were cultured after replacement of the sinks, indicating a reservoir further down the pipes.

Question 18: Who should water test results be reported to?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on who water test results should be reported to.

"Where water quality sampling in a water system confirmed (acceptable) *Legionella* results less than 100 CFUs/Litre – the Authorised Person (Water) would be informed and provided with copies of the samples in writing and associated record keeping. The Authorised Person (Water) would provide interpretation (with the Consultant Microbiologist when and where required) on the results and confirm if any actions are required."

"Where water quality sampling in a water system confirmed *Legionella* results in excess of 100, but less than 1,000 CFUs/Litre – the Authorised Person (Water) and Consultant Microbiologist must be informed and provided with copies of the samples in writing. The Consultant Microbiologist would provide interpretation on the results and confirm the necessary actions prior to bringing the water system into use."

Assessment of evidence
"Where water quality sampling in a water system confirmed *Legionella* results in excess of 1,000 CFUs/Litre immediate action must be taken and the Consultant Microbiologist and Authorised Person (Water) must be informed and provided with copies of the samples in writing. They will immediately confirm the necessary actions prior to re-sampling and bringing the water system into use when (acceptable) *Legionella* results are reliably less than 100 CFUs/Litre."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. The control of *Legionella*, hygiene, 'safe' hot water, cold water and drinking water systems Part E: Alternative materials and filtration. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This document “covers the policy, design, commissioning, operation and maintenance requirements for the installation of domestic hot and cold water (DHCW) services systems throughout NHSScotland premises.”. The following section(s) are relevant for this research question on who water test results should be reported to. “Water samples should be obtained from appropriate points in the system after each recharging. Potability analysis of these samples of water should be carried out by the Public Analyst, or an approved independent body, and the contractor should supply a full set of the analysis to the site supervisor for approval before the system is put into use.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires’ disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British document provides “practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999.” The following section(s) are relevant for this research question on who water test results should be reported to.					

Assessment of evidence
"These Regulations require employers, where they have five or more employees, to record the significant findings of their risk assessment and the steps taken to prevent exposure to substances hazardous to health. Employers are also required to keep suitable records of examinations, tests and repairs of control measures." "An assessment of the risk must be carried out and those appointed under paragraph 48 must record the significant findings and ensure appropriate records are kept. This should include any groups of employees identified as being particularly at risk and the steps taken to prevent or control risks. If the employer has less than five employees there is no statutory duty to write anything down, but it may be useful to keep a written record of what has been done." "Records should include details about: (a) the appointed responsible person(s) for conducting the risk assessment, managing, and implementing the written scheme; (b) any significant findings of the risk assessment; (c) the written scheme and its implementation; (d) details about the state of operation of the water system, i.e in use/not in use; (e) the results of any monitoring inspection, test or check carried out, and the dates." "These records should be retained throughout the period they are current and for at least two years afterwards. Retain records of any monitoring inspection, test or check carried out, and the dates, for at least five years." "To ensure that precautions continue to be applied and that adequate information is available, where there are five employees or more, you must keep a record of the assessment, the precautionary measures, and the treatments. All records should be signed, verified or authenticated by those people performing the various tasks assigned to them."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
healthcare premises Guidance for PHE Health Protection Teams. 2015.					

Assessment of evidence

This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on who water test results should be reported to.

"In most instances, the HPT should only be informed (and advice sought) when critical points are reached, for example, where there is a lack of *Legionella* control after application of routine measures, an augmented care area is affected, or a suspected nosocomial case linked to the premises is identified."

The day to day management of water systems in healthcare premises is the responsibility of the organisation and is usually undertaken by Estate Departments, often in conjunction with infection control teams. There should be an established Water Safety Group that meets regularly to review management strategies, incidents, any sampling results and actions to be taken.

Critical points on when HPT are to be contacted are provided in "Figure 1: Risk assessment algorithm for the public health response to the detection of *Legionella* by health protection teams."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8680:2020. Water quality – Water safety plans – Code of practice. BSI Standards Publication 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document "gives gives recommendations and guidance for the development of a water safety plan (WSP) for all types of premises and undertakings with water systems which can pose a risk to those exposed, either from the water itself, aerosols derived from it or the surrounding environment, and where a WSP is particularly recommended within existing national guidance, such as in healthcare." The following section(s) are relevant for this research question on who water test results should be reported to.

"The WSP should also ensure that the WSG is aware of what the risk assessment should cover, to ensure only personnel with the skills and competence carry out and review the assessment to ensure it is fit for purpose. The report from the risk assessor should be produced within the agreed timescale and format, be concise and reflect and prioritize all identified risks. The WSP should include processes to ensure the associated hazards, potential hazardous events and preventative measures to control the hazard are identified. The WSG should have an understanding of the factors to be included in the risk assessment and there should be competent support for the WSG to ensure that risk assessments are fit for purpose, especially if there are any gaps identified in risk assessors' knowledge."

"The WSG should assess the potential use of a log book system, which may be electronic or printed, as a way of keeping all relevant documentation in one easily accessible place to assist in the assessment, implementation and audit of WSPs."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 8554:2015. Code of practice for the sampling and monitoring of hot and cold water services in buildings. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"This British Standard gives guidance and recommendations for investigative and planned collection of hot and cold water samples during the life of a building, including sampling locations and the selection of laboratory or on-site testing for those samples." The following section(s) are relevant for this research question on who water test results should be reported to.

"Site record sheets should list all test results obtained, including those listed in 4.5.1.3c), and disinfection residuals (taken concurrently with the microbiological samples)."

"A water analysis is of limited value if it is unaccompanied by detailed information about the sample, so the source of the sample and the conditions under which it was collected should be recorded and a suitable record attached to the bottle immediately after filling."

"The results of any on-site analyses carried out should also be included in a report with the sample. Labels and forms should be completed at the time of sample collection. The sampling operative should never move on to another task before completing all documentation at a site."

NOTE Some laboratories are using only electronic systems with direct input into lab systems."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on who water test results should be reported to.

“A risk assessment of the water distribution system in a healthcare facility is a legislative requirement. A water safety plan (WSP) approach, incorporating a risk assessment, is outlined in the World Health Organisation (WHO) document Water Safety in Buildings, 2011.”

“The latest HPS/HFS Guidance on *Pseudomonas aeruginosa* – advice for augmented care units, also recommends that a Water Safety Group (WSG) commissions and develops a WSP which includes a risk assessment. The key steps of a WSP, including a risk assessment, are outlined below.”

“Key steps of a Water Safety Plan for a Healthcare Facility

- establish an Environmental Monitoring Committee (or equivalent);
- document and describe the entire water distribution system including schematic diagrams;

Assessment of evidence
• carry out a hazard analysis and risk characterisation, assessing likelihood and impact; • assess the risks pertaining to all water, water systems, water uses, routes of exposure and patient risk groups; • assess incoming source water quality and composition; • identify and evaluate existing control measures; • identify and implement additional control measures; • carry out scalding risk assessments; • enter ongoing risks onto the facility's risk register and manage appropriately; • monitor and audit control measures; • ensure maintenance is carried out in line with current recommendations; • maintain an up-to-date hygiene logbook; • develop written policies and procedures; • develop a contingency plan for major disruptions to the incoming water supply;

Question 19: How should routine water test results be interpreted?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking."

Testing requirements and interpretations of results are provided in Tables 3a to 9 for a variety of sample types collected from the hospital environment. The following section is relevant for this research question on how routine water test results should be interpreted.

"In addition to the tests shown in Tables 2 to 12, a range of further microbiological tests may be carried out, and advice given regarding interpretation of results through discussion with the microbiologists at the local laboratory. Advice on the interpretation of results should be sought from a microbiologist with experience of the healthcare environment."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 8554:2015. Code of practice for the sampling and monitoring of hot and cold water services in buildings. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"This British Standard gives guidance and recommendations for investigative and planned collection of hot and cold water samples during the life of a building, including sampling locations and the selection of laboratory or on-site testing for those samples" The following section(s) are relevant for this research question on how routine water test results should be interpreted.

"When interpreting the results, reference should be made to the sampling plan. NOTE 1 The interpretation of results requires that sufficient detail is obtained at the time of sampling. In some cases, such as sampling for *Legionella*, additional test parameters, such as the temperature and biocide levels at the time of sampling, might be required. Appropriate statistical considerations are detailed in Annex B. NOTE 2 When a sample of water is taken for analysis, irrespective of the volume sampled and tested, the results only reflect the quality of the sampled water and not the whole body of water. Individual sample results do not reflect the whole system and might be difficult to interpret, particularly microbiological samples where contamination could be intermittent. Regular sampling from predefined sample points combined with random sampling gives a better indication of microbiological risk and, when carried out for trend analysis, also indicates deviations from the norm and, possibly, a failure in disinfection or a post-disinfection contamination event. NOTE 3 Examination of data allows managers to adjust their interpretation of the building's performance and to assess any trends that contribute to changes in identified risks. NOTE 4 There are limitations in the conclusions that can be drawn from any single sample. Multiple samples might be

Assessment of evidence
required to give confidence in the interpretation of the condition of the system (i.e. the indication that action is required), e.g. the baseline noise, background condition. Baseline noise, in this context, is the random variability (combination of the sampling variability and the variability of parameter occurrence)." "NOTE 5 The use of such techniques allows data users to respond to changes that give early warning of critical conditions developing, rather than reacting to information that requires urgent action. " "When monitoring sentinel outlets, the time of sampling should reflect the conditions following the longest period of system stagnation to highlight the greatest risk of water quality impairment. NOTE Such an approach ensures that latent risks are not masked by a monitoring regime which only returns favourable results because sampling occurs at periods of high water throughput." On Non-microbiological parameters, the document states "An accurate record of any relevant conditions, e.g. temperature or water turnover, should be made at the time of sampling to provide the information needed to permit assessment of the overall impact of the building's use and function on the quality of water." On Microbiological parameters, it states "Samples should be collected coincidently with on-site tests for disinfection residuals to ensure that the water management regime efficacy can be interpreted with the greatest degree of confidence."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected.

See Table 5.3/5.4/5.5 for interpretations of test results in different occasions (Hot and cold water systems, Endoscopy, renal dialysis, hydrotherapy, dental units). The following section(s) are relevant for this research question on how routine water test results should be interpreted.

“Pre-flush and post-flush water samples may be indicated depending on the nature of the outbreak and/ or the purpose of the sampling. If contamination is detected, compare the pre- and post-flush bacterial counts. A substantially higher bacterial count in the pre-flush sample, compared with the post-flush, should direct remedial measures towards the tap and associated pipework and fittings near to that outlet. A higher bacterial count in the post-flush sample than in the pre-flush sample suggests stagnation in the water system and inadequate flushing. A similar bacterial count in pre-flush and post-flush samples indicates that attention should focus on the whole water supply, storage and distribution system.”

Assessment of evidence
"All laboratories carrying out environmental water testing should be accredited for the methods used and participate in appropriate external proficiency schemes." "Laboratory testing requirements for different water samples and interpretation of results must be in accordance with international standards"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides "practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999." The following section(s) are relevant for this research question on how routine water test results should be interpreted. "Monitoring results to determine appropriate action levels, depending on whether colonisation is local to an outlet or more widespread within the water system, should be interpreted by a competent person. To establish if the circulating hot water or the distributed cold water is under control, samples should be taken from separate hot and cold water outlets which are not blended. This will ensure the sample is

Assessment of evidence
representative of the water flowing around the system and not just of the area downstream of the mixing valve. Monitoring of hot and cold water systems where TMVs are fitted needs careful consideration to ensure the results are interpreted in the context of the conditions in place at the time of sampling.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides guidance “on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages.” The following section(s) are relevant for this research question on how routine water test results should be interpreted. “Where the results of sampling/testing indicate that the system has deteriorated, with an increase in microbiological counts, e.g. TVC results in excess of a 2 log (see WHO [25]) difference above that found in incoming water, remedial action should be taken. A pragmatic common sense approach should be adopted, taking into account the need to conserve water, as well as to react to a disinfection need.”

Assessment of evidence
"Where *Pseudomonas aeruginosa* or Coliform bacteria are present, the sampling point should be cleaned externally, flushed and retested. If positive results persist, investigation into the cause(s) should be extended with a view to repeating the disinfection process"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on how routine water test results should be interpreted. "NOTE 1 It would also be beneficial to record the temperature of the water immediately after taking the sample, which will be useful for the interpretation of the results." "NOTE 2 If the hot water has not reached 50 °C (55 °C in healthcare) after 1 min or < 20 °C after 2 min for cold water, it is useful for interpretation of results to know how long it took to reach the required temperatures"

Assessment of evidence
“For routine monitoring purposes, only pre-flush samples should be taken and, where possible, these should be taken from unmixed outlets. Pre-flush samples should be taken with no disinfection or adjustment of devices or inserts to obtain a reflection of the water as it is used.”
“NOTE 1 Post-flush samples are not suitable for routine monitoring.”
“NOTE 2 Pre-flush samples allow for the determination of the colonization of a particular outlet. This is the type of sample that is most representative of the risk to individuals and is the only sample necessary. In healthcare the WSG may wish that pre-flush samples are taken from showers and mixed outlets with TMVs as these represent the highest risk to patients.”
“NOTE 3 Detection of Legionellae in a sample collected from an outlet which has not been disinfected does not discriminate between outlet or system contamination, so further sampling of either mixed or unmixed outlets would be necessary with and without outlet disinfection.”
“If it is necessary to differentiate between local and systemic colonization following a positive result, post-flush, disinfected-outlet samples should be collected in addition to the pre-flush samples to support the determination of whether the system itself or components, such as TMVs, are colonized, as opposed to outlets, and to determine that the numbers of *Legionella*e within the system are controlled.”
“NOTE 4 Adequate, consistent temperature control or secondary disinfection usually reduces the risk of growth or multiplication of Legionellae in a system. However, one area where growth and multiplication of Legionellae are likely to occur is within the components of a TMV, TMT and the outlet.”
“Whenever possible, when post-flush samples are required these should be collected from individual taps (see 7.4.2 and 7.4.3), rather than mixer taps so that the samples are representative of the water flowing around the system and do not just contain localized contamination of the outlet(s).”
“Hot water feeding the mixer should be held at a temperature greater than 50 °C (55 °C in healthcare), then mixed with cold water to a set point, usually variable only on the unit itself. This results in a blend of hot water with cold water, so results should be interpreted with this in mind.”
“During investigations, or when routine testing has indicated that there is a problem, post-flush samples might be required from showers in addition to pre-flush samples. In such circumstances, care should be taken in the interpretation of the results of tests returned from post-

Assessment of evidence
flush samples as it is almost impossible to ensure that any *Legionellae* detected in the post-flush sample were not derived from biofilms that can exist in the shower head, hose and mixing valve components. *NOTE 3 However, comparison of the relative numbers of bacteria detected in the pre-flush and post-flush samples can provide an indication of the likely location of the contamination, i.e. at the periphery of the system (shower head, hose or mixing valve) or further upstream in the supply pipework, but interpretation of the results of these tests is likely to require specialist input."*

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 8680:2020. Water quality – Water safety plans – Code of practice. BSI Standards Publication 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document "gives recommendations and guidance for the development of a water safety plan (WSP) for all types of premises and undertakings with water systems which can pose a risk to those exposed, either from the water itself, aerosols derived from it or the surrounding environment, and where a WSP is particularly recommended within existing national guidance, such as in healthcare." The following section(s) are relevant for this research question on how routine water test results should be interpreted. "The WSP should include processes to ensure the sample, when analysed, represents the water at the time of sampling, e.g. by the addition of biocide neutralizing agents where available, and identifies the background information required to ensure that repeat samples can be taken from the exact location and that the additional information required to allow results to be meaningfully interpreted is available.

Assessment of evidence
NOTE 3 Supporting information could include whether the sampling point has been used prior to sampling, the timing of dosing and concentration of biocides, pH, temperature, turbidity, pool bather load, etc”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). *Legionella* and the prevention of legionellosis. WHO 2007.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document “provides guidance on assessment and management of risks associated with potentially hazardous environments, such as cooling towers, pools and spa baths. The document also identifies necessary measures to prevent, or adequately control, the risk of exposure to *Legionella* bacteria for each particular environment.” The following section(s) are relevant for this research question on how routine water test results should be interpreted. “To date, no direct relationship has been established between the risk of infection and the number of *Legionella* detected in a water system using the generally adopted culture method. Recovery of *L. pneumophila* by culture is poor because: • *Legionella* exist with other background heterotrophic bacteria; therefore, the sample needs to be treated with heat or acid to repress the growth of non-*Legionella* bacteria on the culture media • antibiotics need to be added to the culture medium for *Legionella* growth • other *Legionella* species that do not cause legionellosis produce colonies on the medium, as does *L. pneumophila* • the culture technique often fails to detect some other disease-causing *Legionella* species (e.g. *L. bozemanii* and *L. micdadei*) • residual disinfectant in the system may affect the cultivation of *Legionella*e

Assessment of evidence
• if the sample collection bottles do not contain a neutralizing agent, *Legionella* may be killed (Wiedenmann, Langhammer & Botzenhart, 2001). These uncertainties and differences in susceptibility of *Legionella* populations make it difficult to interpret the colony count values for *Legionella* in relation to disease risk. However, culture results, together with the percentage of samples containing *Legionella*, provide useful information about the degree of amplification of *Legionella* in a system. A high degree of amplification results in a higher exposure, which may be related to a higher infection risk.”

Question 20: What are the water testing requirements following a positive water test result (in the absence of clinical cases)?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This English guidance document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases).

In "Table 4: Testing requirements and interpretation of results for hot and cold-water systems", the following follow-up actions were provided:

- *Legionella*
  - <100 cfu/l – Satisfactory – "No action; system under control"

Assessment of evidence
- ≥100 - <1000 cfu/l – Undesirable – (a) If only one or 2 samples are positive, system should be resampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions (b) If the majority of samples are positive, the system may be colonised, albeit at a low level, with *Legionella*. Disinfection of the system should be considered but an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required. - ≥1000 cfu/l – Unsatisfactory) – "The system should be re-sampled and an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system." • *Pseudomonas aeruginosa* - 0 in 100ml – Satisfactory – "No action; system under control" - 1 -10 in 100ml – Undesirable – "Re-test and refer back to those responsible for the Water Safety Plan to determine what actions may be required." - >10 in 100ml – Unsatisfactory – "Investigate cause and put corrective actions in place. Re-sample after 3 weeks."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in healthcare premises Guidance for PHE Health Protection Teams. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases). "There should be an established Water Safety Group that meets regularly to review management strategies, incidents, any sampling results and actions to be taken." In "Table 2: Action levels following *Legionella* sampling in hot and cold water systems in healthcare premises with susceptible patients", the document recommends the following actions following test results for *Legionella* bacteria. Not detected or up to 100 cfu/l – "In healthcare, the primary concern is protecting susceptible patients, so any detection of *Legionella* should be investigated and, if necessary, the system resampled to aid interpretation of the results in line with the monitoring strategy and risk assessment." >100 cfu/l and up to 1000 cfu/l – "Either: (a) if the minority of samples are positive, the system should be resampled. If similar results are found again, review the control measures and risk assessment to identify any remedial actions necessary or (b) if the majority of samples are positive, the system may be colonised, albeit at a low level. An immediate review of control measures and a risk assessment should be carried out to identify any other remedial action required. Disinfection of the system should be considered." >1000 cfu/l – "The system should be resampled following an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system. Retesting should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control is achieved."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part B: Operational management. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This guidance developed by the Department of Health (UK, England) aims to summarise and recommend measures to control waterborne pathogens in healthcare estates (NHS).

Appendix D regarding *P. aeruginosa* is relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases):

“D16. If tests show counts of 1 to 10 cfu/100 mL, the WSG should risk-assess the use of water while simultaneously retesting the water outlet (see Figure D1 and Note below).”

Figure D1 shows a summary of suggested water sampling and testing frequencies and in case of a positive test, remediation is recommended and retesting at 3 days and when tests are negative, testing again after 2 weeks and after 4 weeks is recommended.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part A: Design, installation and testing. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"This Scottish Health Technical Memorandum gives comprehensive advice and guidance to healthcare management, design engineers, estate managers and operations managers on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises." The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases).

"After disinfection, microbiological tests for bacteria colony counts at 37°C and coliform bacteria, including Escherichia coli, should be carried out under the supervision of the infection prevention control team to establish that the work has been satisfactorily completed. Water samples should be taken from selected areas within the distribution system. The system should not be brought into service until the infection control team certifies that the water is of potable quality"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases).

"Where necessary, hot and cold water services should be cleaned and, in the following situations, disinfected in accordance with BS EN 806-4 and BS 8558:…" "This should be done following water sampling results that indicate evidence of microbial contamination of the water system; g) during or following an outbreak or suspected outbreak of legionellosis linked to the system".

"To confirm effective disinfection, any required microbiological samples should be taken between two and seven days after the system is treated. Samples taken immediately after a disinfection process might give false negative results."

"Where *Pseudomonas aeruginosa* or Coliform bacteria are present, the sampling point should be cleaned externally, flushed and retested. If positive results persist, investigation into the cause(s) should be extended with a view to repeating the disinfection process."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases).

Tables 5.3, 5.4, 5.5 and 5.6 recommends actions following positive results in different occasions (Endoscopy, renal dialysis, hydrotherapy, dental units). For hot and cold water system, the guidance recommends the following:

Assessment of evidence
Legionella (>100 but <1000 cfu/l): “Re-sample and review control programme.” *Legionella* (>1000 cfu/l): “If only a minority of samples are positive, the system should be re-sampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions. If the majority of samples are positive, the system may be colonised. Disinfection of the system should be considered and an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required.” *Pseudomonas aeruginosa (*1-10 in 100ml*):* ”Re-test and refer back to those responsible for the Water Safety Plan to determine what actions may be required.” *Pseudomonas aeruginosa* (>10 in 100ml): “Investigate cause and put corrective actions in place. Re-sample after 3 weeks.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases).					

Assessment of evidence
"For routine monitoring purposes, only pre-flush samples should be taken and, where possible, these should be taken from unmixed outlets. Pre-flush samples should be taken with no disinfection or adjustment of devices or inserts to obtain a reflection of the water as it is used." "NOTE 1 Post-flush samples are not suitable for routine monitoring" "NOTE 2 Pre-flush samples allow for the determination of the colonization of a particular outlet. This is the type of sample that is most representative of the risk to individuals and is the only sample necessary." "In healthcare the WSG may wish that pre-flush samples are taken from showers and mixed outlets with TMVs as these represent the highest risk to patients." "NOTE 3 Detection of *Legionella*e in a sample collected from an outlet which has not been disinfected does not discriminate between outlet or system contamination, so further sampling of either mixed or unmixed outlets would be necessary with and without outlet disinfection." "During investigations, or when routine testing has indicated that there is a problem, post-flush samples might be required from showers in addition to pre-flush samples. In such circumstances, care should be taken in the interpretation of the results of tests returned from post-flush samples as it is almost impossible to ensure that any *Legionella*e detected in the post-flush sample were not derived from biofilms that can exist in the shower head, hose and mixing valve components."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Part B: Operational management. 2014.					
Assessment of evidence					
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on the water testing requirements following a positive water test result (in the absence of clinical cases). The document provides for the following actions to be taken following positive results: >100 but <1,000 – “Either: If only one or two samples are positive, system should be re-sampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial action to be taken. Or: If the majority of the samples are positive, the system may be colonised with *Legionella*. Disinfection of the system should be considered, but an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required.” >1000 – “The system should be re-sampled and an immediate review of the control measures and risk assessment should be carried out to identify any remedial action, including disinfection of the system. Re-testing should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control has been achieved”					

Question 21: What action(s) (remedial and/or clinical) should be taken following a positive water test result (in the absence of clinical cases)?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM,Chinn RYW, Arduino MJ et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). American Society for Healthcare Engineering/American Hospital Association; 2004.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). "*Legionella* spp. are ubiquitous and can be isolated from 20%–40% of freshwater environments, including man-made water systems. In health-care facilities, where *Legionella*e in potable water rarely result in disease among immunocompromised patients, courses of remedial action are unclear. Scheduled microbiologic monitoring for *Legionella*e remains controversial because the presence of *Legionella*e is not necessarily evidence of a potential for causing disease. CDC recommends aggressive disinfection measures for cleaning and maintaining devices known to transmit *Legionella*e, but does not recommend regularly scheduled microbiologic assays for the bacteria." "Health-care facilities use at least two general strategies to prevent health-care associated legionellosis when no cases or only sporadic cases have been detected. The first is an environmental surveillance approach involving periodic culturing of water samples from the hospital's potable water system to monitor for *Legionella* spp. If any sample is culture-positive, diagnostic testing is recommended for all patients with health-care associated pneumonia." "The second strategy to prevent and control health-care associated legionellosis is a clinical approach, in which providers maintain a high index of suspicion for legionellosis and order appropriate diagnostic tests (i.e., culture, urine antigen, and direct fluorescent antibody [DFA] serology) for patients with health-care associated pneumonia who are at high risk for legionellosis and its complications. The testing of autopsy specimens can be included in this strategy should a death resulting from healthcare–associated pneumonia occur. Identification of one case of definite or two cases of possible healthcare–associated Legionnaires disease should prompt an epidemiologic investigation for a hospital source of *Legionella* spp., which may involve culturing the facility's water for *Legionella*. Routine maintenance of cooling towers, and use of sterile water for the filling and terminal rinsing of nebulization devices and ventilation equipment can help to minimize potential sources of contamination."

Assessment of evidence
"A potential advantage of the environmental surveillance approach is that periodic culturing of water is less costly than routine laboratory diagnostic testing for all patients who have health-care associated pneumonia. The primary argument against this approach is that, in the absence of cases, the relationship between water-culture results and legionellosis risk remains undefined."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following sections are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). The document provides the following for "Action following *Legionella* sampling in hot and cold water systems:" ">100 but <1000 – Either: If only one or two samples are positive, system should be re-sampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial action to be taken. Or: If the majority of the

Assessment of evidence
samples are positive, the system may be colonised with *Legionella*. Disinfection of the system should be considered, but an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required." ">1000 – The system should be re-sampled and an immediate review of the control measures and risk assessment should be carried out to identify any remedial action, including disinfection of the system. Re-testing should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control has been achieved."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This English guidance document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases).

Assessment of evidence
In “Table 4: Testing requirements and interpretation of results for hot and cold water systems”, the document provides the outline of actions (including some remedial actions) for different testing parameters (hazard/ hygiene indicator) and microorganisms. On *Legionella*, the document states the following if the result is ≥100 – <100: (a) If only one or 2 samples are positive, system should be resampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions (b) If the majority of samples are positive, the system may be colonised, albeit at a low level, with *Legionella*. Disinfection of the system should be considered but an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
World Health Organization (WHO). Water safety in buildings. 2011.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This international document provides guidance on “for managing water supplies in buildings where people may drink water; use water for food preparation, washing, showering, swimming or other recreational activities; or be exposed to aerosols produced by water-using devices, such as cooling towers. These uses occur in a variety of buildings, such as hospitals, schools, child-care and aged-care facilities, medical and dental facilities, hotels, apartment blocks, sport centres, commercial buildings and transport terminals.” The following sections are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). “As part of remediation following a contamination event, the entire distribution system, including water-using devices, PoU and end-of-pipe devices will need to be fl ushed and possibly disinfected or decontaminated. Treatment systems such as water softeners, deionizers and

Assessment of evidence
filtration systems will need to be regenerated, backwashed or recommissioned before being returned to service. Small PoU filters could harbour contamination and may need replacing.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in healthcare premises Guidance for PHE Health Protection Teams. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This English guidance “describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises”. The following section(s) are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). In “Table 2: Action levels following *Legionella* sampling in hot and cold water systems in healthcare premises with susceptible patients”, the following actions were recommended (This was referenced to HTM 04-01 Part B(Operational Management):

Assessment of evidence
Not detected or up to 100 cfu/l - In healthcare, the primary concern is protecting susceptible patients, so any detection of *Legionella* should be investigated and, if necessary, the system resampled to aid interpretation of the results in line with the monitoring strategy and risk assessment. >100 cfu/l and up to 1000 cfu/l – "Either: • if the minority of samples are positive, the system should be resampled. If similar results are found again, review the control measures and risk assessment to identify any remedial actions necessary or • if the majority of samples are positive, the system may be colonised, albeit at a low level. An immediate review of control measures and a risk assessment should be carried out to identify any other remedial action required. Disinfection of the system should be considered." >1000 cfu/l - The system should be resampled following an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system. Retesting should take place a few days after disinfection and at frequent intervals thereafter until a satisfactory level of control is achieved.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases).

Cleaning and disinfection

"7.1 Where necessary, hot and cold water services should be cleaned and, in the following situations, disinfected in accordance with BS EN 806-4 and BS 8558:

a) on completion of a new water installation or refurbishment of a hot and cold water system;

b) on installation of new components, especially those which have been pressure-tested using water by the manufacturer (see the manufacturer's instructions);

c) where the hot and cold water is not used for a prolonged period and has not been hygiene-flushed as recommended, or the control measures have not been effective for a prolonged period (this could be as little as two or three weeks), depending on the ambient temperature, condition of the water system, potential for exposure to aerosols and the susceptibility of users considered in a site-specific risk assessment;

d) on routine inspection of the water storage cisterns where there is evidence of significant contamination or stagnation;

e) if the system or part of it has been substantially altered or accessed for maintenance purposes that might introduce contamination;

f) following water sampling results that indicate evidence of microbial contamination of the water system;

g) during or following an outbreak or suspected outbreak of legionellosis linked to the system; or

h) where indicated by the site risk assessment."

"To confirm effective disinfection, any required microbiological samples should be taken between two and seven days after the system is treated. Samples taken immediately after a disinfection process might give false negative results."

Assessment of evidence
"Where the results of sampling/testing indicate that the system has deteriorated, with an increase in microbiological counts, e.g. TVC results in excess of a 2 log (see WHO [25]) difference above that found in incoming water, remedial action should be taken. A pragmatic common sense approach should be adopted, taking into account the need to conserve water, as well as to react to a disinfection need." "Where Pseudomonas aeruginosa or Coliform bacteria are present, the sampling point should be cleaned externally, flushed and retested. If positive results persist, investigation into the cause(s) should be extended with a view to repeating the disinfection process." "Where *Legionella* is identified following disinfection, the system should be reassessed as defined in HSG 274 Part 2 [23], Table 2.2, and the disinfection should be repeated if assessed appropriate." On "Remedial actions after monitoring indicates problem", the documents states the following: - "The nature and cause of the problem should be fully investigated and understood before appropriate remedial measures are defined. For example, some taste and odour issues might be due to material issues, e.g. copper corrosion or reaction to some disinfection materials" - "Remedial cleaning and disinfection should be appropriate to the nature and cause of the problem. Where system disinfection fails to remove established biofilm, consideration should be given to removal of affected pipes and fittings for cleaning or for continuous supplementary dosing. In extreme cases, pipes and fittings, etc., should be replaced."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases).

In "Table 5.3: Testing Options and Interpretation of Results for Hot and Cold Water Systems", the document provides the following actions following an unsatisfactory result for *Legionella* (>1000 cfu/l)

- "If only a minority of samples are positive, the system should be re-sampled. If a similar count is found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions."
- "If the majority of samples are positive, the system may be colonised. Disinfection of the system should be considered and an immediate review of control measures and risk assessment should be carried out to identify any other remedial action required."

The table also provides the following for *Pseudomonas aeruginosa:*

Assessment of evidence
- *Pseudomonas aeruginosa (*1-10 in 100ml*):* ”Re-test and refer back to those responsible for the Water Safety Plan to determine what actions may be required.” - *Pseudomonas aeruginosa* (>10 in 100ml): “Investigate cause and put corrective actions in place. Re-sample after 3 weeks.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires’ disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides “practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999.” The following sections are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). “Table 2.2 gives guidance on action to take if *Legionella* is found in the water system. However, for healthcare premises with vulnerable patients, the action levels and recommended actions in Table 2.3 should be considered.” The recommended actions from Table 2.2 are presented as follows:

Assessment of evidence
>100 cfu/l and up to 100 – "Either: - If the minority of samples are positive, the system should be resampled. If similar results are found again, a review of the control measures and risk assessment should be carried out to identify any remedial actions necessary or - If the majority of samples are positive, the system may be colonised, albeit at a low level. An immediate review of the control measures and risk assessment should be carried out to identify any other remedial action required. Disinfection of the system should be considered" >1000 cfu/l – "The system should be resampled and an immediate review of the control measures and risk assessment carried out to identify any remedial actions, including possible disinfection of the system. Retesting should take place a few days after disinfection and at frequent intervals afterwards until a satisfactory level of control is achieved."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens - Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases). In Paragraph 3.33, the document states that the Water safety group (WSG) is a "multidisciplinary group of people formed to undertake the commissioning, development and ongoing implementation and management of the water safety plan (WSP) with the skills and responsibility for ensuring that the water is safe at the point of use for all uses and all users of water within buildings. NOTE 1 It also advises on the remedial actions required when water systems or outlets are found to be contaminated and the risk to susceptible persons is increased." "The assessor should check that the records and drawings are accurate including monitoring and surveillance records and verify that any remedial actions and control measures identified within the *Legionella* risk assessment have been implemented and validated and that there have been no changes since that assessment which could have had an adverse effect on water safety. These include, for example, changes in control measures, water usage, alterations to the system including the addition of any relevant equipment, patient susceptibility, relocation of patient beds and equipment used for patient treatment."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Heath Technical Memorandum 04-01: Safe water in healthcare premises:	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Part B: Operational management. 2016.					

Assessment of evidence

"This Health Technical Memorandum (HTM) gives comprehensive advice and guidance to healthcare management, design engineers, estate managers, operations managers, contractors and the supply chain on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises. It is equally applicable to both new and existing sites." The following section(s) are relevant for this research question on action(s) (remedial and/or clinical) that should be taken following a positive water test result (in the absence of clinical cases).

In Figure 4, the document provides the following actions to be taken with positive *Legionella* results for pre-flush samples as follows:

Legionella from detection to 100 cfu/l – "The detection limit for *Legionella* by culture methods was historically 100cfu/L, at present laboratories may be able to report to levels of 20cfu/L or less. This can cause confusion over what level should bring about corrective actions. The primary concern is protecting susceptible patients, so any detection of *Legionella* should be investigated and, if necessary, the system resampled to aid interpretation of the results in line with the monitoring strategy and risk assessment"

100 – less than 1000 – "Action required

• Identify remedial actions, Investigate:–

- Usage frequency
- Outlet for corrosion and scale
- local heat gain, o Local Dead ends
- Cross flow between hot and cold and vice versa,
- Localised failure of the HWS return

Assessment of evidence

• It may be appropriate to immediately resample to indicate if initial remedial actions have been effective. The locations should then be resampled after 3 to 6 months to confirm any actions taken have remained effective.

In addition to the above, and if the outlet is served by a TMV:

- Review the need for the TMV taking into account the relative risks of scalding. Remove the TMV if considered appropriate
- If the TMV is to remain, clean and disinfect the TMV, the outlet and the strainers on both cold and hot feeds.
- Identify any flexible hoses (particularly after the TMV) and consider replacement, avoiding the use of flexible hoses where practicable"

Appendix D also provides the following guidance on "what to do if a contamination problem is identified"

a. "Inform the WSG and hold a focused incident control meeting (for example, IPC team, estates and clinical staff) to ensure patient safety is prioritised and to formulate an action plan.
b. If a water outlet has been taken out of service because of contamination with P. aeruginosa, continue daily flushing while the outlet is out of normal use to prevent water stagnation and exacerbation of the contamination.
c. Where practical, consider removal of flow straighteners. However, the removal of flow straighteners may result in splashing and therefore additional remedial action may need to be taken. If they are seen to be needed, periodically remove them and either clean/disinfect or replace them. Replacement frequency should be verified by sampling/swabbing.
d. Splashing can promote dissemination of organisms, resulting in basin outlets becoming heavily contaminated. If splashing is found to be a problem, investigate the causes.
e. Hand-washing should be supplemented with the use of an antimicrobial hand-rub.
f. To prevent water stagnation, check for infrequently used outlets – assess frequency of usage and if necessary remove infrequently used outlet(s). For example, the provision of showers in areas where patients are predominantly confined to bed, and the resultant lack of use, could lead to stagnation.

Assessment of evidence
g. Check connections to mixing taps to ensure that the supply to the hot connection is not supplied from an upstream TMV. In a hot water service, a dead-leg will exist between the circulating pipework and hot connection of a fitting such as a mixing tap. In the case of cold water services, sometimes there will be no draw-off from any part of the system and the entire service is in effect a dead-leg. To minimise the stagnation of water in a cold water system, it can be beneficial to arrange the pipework run so that it ends at a frequently used outlet. A dead-leg may also exist when a TMV is installed upstream of a mixing tap (see Figure D3). Depending on the activities of the room in which the tap is located, cold water may never be drawn through the pipe between the cold water connections of the mixing valve and mixing tap.
h. Risk-assess the water system for redundant pipework and dead-legs (for example, where water is supplied to both the cold water outlet and a TMV supplying an adjacent blended water outlet, as such cold water outlets in augmented care units may be infrequently used). When removing outlets, the branch hot and cold water pipes should also be cut back to the main distribution pipework in order to eliminate redundant pipework.
i. Assess the water distribution system for non-metallic materials that may be used in items such as inline valves, test points and flexible hoses. They should be replaced according to the guidance in safety alert DH (2010) 03 – 'Flexible water supply hoses'.
j. All materials in contact with water should have been assessed and shown they are appropriate for the intended purpose and should not leach chemicals that provide nutrients that support microbiological growth. Materials should also be compatible with the physical and chemical characteristics of water supplied to the building. Flexible pipes should only be used in exceptional circumstances (for example, where height adjustment is necessary as in installations such as rise-and-fall baths and hand-held showers).
k. POU filters, where they can be fitted, may be used to provide water free of P. aeruginosa. Where fitted, regard filters primarily as a temporary control measure until a permanent solution is developed, although long-term use of such filters may be required in some healthcare applications. Where POU filters are fitted to taps, follow the manufacturer's recommendations for renewal and replacement and note that the outer casing of a POU filter and the inner surface can become contaminated. There should be sufficient activity space once a POU filter has been fitted.
l. In certain circumstances, the WSG may decide it is necessary to carry out a disinfection of the hot and cold water distribution systems that supply the unit to ensure that contaminated outlets are treated. See chapter 2 of HSG274 Part 2 for guidance on how to carry out the disinfection procedure. Note that with respect to P. aeruginosa, hyperchlorination is not effective against established

Assessment of evidence
biofilms. Consider replacing contaminated taps with new taps; however, there is currently a lack of scientific evidence to suggest that this will provide a long term solution.”

Question 22: Is routine environmental testing for healthcare water system-associated organisms recommended?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on whether routine environmental testing for waterborne organisms is recommended.

"Cleaning of the hospital environment is essential to protect patients from hospital acquired infections and must be carried out according to current guidelines. Care facilities must carry out risk assessment of the healthcare environment, document cleaning tasks and monitor the effectiveness of cleaning. These guidelines use visual inspection only as a measure of cleanliness (British Standards Institution, 2014). Routine sampling of environmental surfaces in healthcare environments is therefore not usually indicated. It may, however, be required in

Assessment of evidence
order to identify an environmental source of infection/contamination, to demonstrate efficacy of disinfection or cleaning procedures or as a research tool. It is essential that careful thought is given to the nature and purpose of the sampling and whether quantitative or qualitative results are needed. Diluents and isolation media should be appropriate for the isolation of the specific organisms sought. In some cases, it may be necessary to consider the need for controls or sampling over time to establish a baseline."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Guidance for Decontamination and testing of Cardiac Heater Cooler Units (HCUs). 2019.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance "sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results." The following section(s) are relevant for this research question on whether routine environmental testing for waterborne organisms is recommended. It provides the following points on air testing: • "Air samples should be taken fortnightly for each HCU and tested for Mycobacterium as long as air and water test results remain within parameters.

Assessment of evidence
• Mycobacterium cultures take eight weeks to process however subsequent samples should continue to be taken and submitted whilst results are awaited. This allows clear identification of time if required a look back exercise if positive results are reported.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM,Chinn RYW, Arduino MJ et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). American Society for Healthcare Engineering/American Hospital Association; 2004.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on whether routine environmental testing for waterborne organisms is recommended. “Microbiologic sampling of air, water, and inanimate surfaces (i.e., environmental sampling) is an expensive and time-consuming process that is complicated by many variables in protocol, analysis, and interpretation. It is therefore indicated for only four situations. The first is to support an investigation of an outbreak of disease or infections when environmental reservoirs or fomites are implicated epidemiologically in disease transmission.” “The second situation for which environmental sampling may be warranted is in research. Well-designed and controlled experimental methods and approaches can provide new information about the spread of health-care associated diseases” “The third indication for sampling is to monitor a potentially hazardous environmental condition, confirm the presence of a hazardous chemical or biological agent, and validate the successful abatement of the hazard.” “The fourth indication is for quality assurance to evaluate the effects of a change in infection-control practice or to ensure that equipment or systems perform according to specifications and expected outcomes.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
waterborne pathogens — Code of practice. BSI Standards Publication 2022.					

Assessment of evidence

"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on whether routine environmental testing for waterborne organisms is recommended.

"Microbiological surveillance is an essential element of the early identification of water outlet contamination to prevent hospital-acquired infections so the frequency of routine sampling for PA and other waterborne pathogens e.g. NTMs should be based on risk assessment and agreement with the WSG. The frequency of microbiological sampling, where there are high-risk patients, should be sufficient for trend analysis to establish evidence-based confidence that control measures remain effective. When establishing trends, sampling should be carried out frequently (for example, monthly). This frequency should be reviewed by the WSG based on sample findings."

"Assessors need to have the skills and competencies needed to identify the factors leading to the ingress, colonization and growth of these specific pathogens and be aware that such infections can originate not just from water distribution systems and the surrounding environment, but also specialized systems and associated equipment, such as within dental practices, decontamination units, hydrotherapy pools, etc. and also the above ground waste water systems, e.g. drains and associated environment."

"The ultimate aim of both clinical and environmental surveillance is to reduce healthcare associated infections. A number of key stages should be in place to verify surveillance is effective, including microbiological sampling from both patients and the environment, appropriate laboratory testing and typing followed by collection, validation, analysis and interpretation of data."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Responding to the detection of *Legionella* in healthcare premises Guidance for PHE Health Protection Teams. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This English guidance "describes situations where HPTs should be contacted, and the extent of involvement that can be expected of HPTs where *Legionella* counts are detected in the hot and cold water systems (excludes cooling towers) of healthcare premises". The following section(s) are relevant for this research question on whether routine environmental testing for waterborne organisms is recommended. "…the frequency and sites for routine environmental sampling and culture for *Legionella* in healthcare facilities should be based on a comprehensive risk assessment and should be part of an overall management strategy."					

Question 23: Are there any specific actions required if an outlet tests positive pre-flush but negative post-flush?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from					

Assessment of evidence

water sources is suspected. The following sections are relevant for this research question on whether specific actions are required if an outlet tests positive pre-flush but negative post-flush.

"Pre-flush and post-flush water samples may be indicated depending on the nature of the outbreak and/ or the purpose of the sampling. If contamination is detected, compare the pre- and post-flush bacterial counts. A substantially higher bacterial count in the pre-flush sample, compared with the post-flush, should direct remedial measures towards the tap and associated pipework and fittings near to that outlet. A higher bacterial count in the post-flush sample than in the pre-flush sample suggests stagnation in the water system and inadequate flushing. A similar bacterial count in preflush and post-flush samples indicates that attention should focus on the whole water supply, storage and distribution system"

"If *P. aeruginosa* has been found in a pre-flush sample, take a second paired set of samples. The first would be a pre-flush sample as before. Then run the tap for two minutes and take a second identical post-flush sample. Bacteria in this second sample (termed post-flush) are more likely to originate further back in the water system. A substantially higher bacterial count in the pre-flush sample, compared with the post-flush, should direct remedial measures towards the tap and associated pipework and fittings near to that outlet. A similar bacterial count in pre-flush and post-flush samples indicates that attention should focus on the whole water supply, storage and distribution system. A more extensive sampling regimen should be considered throughout the water distribution system, particularly if that result is obtained from a number of outlets"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Heath Technical Memorandum 04-01: Safe water in healthcare premises:	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Part B: Operational management. 2016.					
Assessment of evidence					
This UK guidance created by the department of health includes recommendations regarding safe management of water in healthcare premises. Appendix D regarding *P. aeruginosa* and chapter 10 regarding testing for *Legionella* both mention that "positive pre-flush samples tend to be an indicator of local conditions and if detected will often require Post-flush samples in order to determine that the contamination is local and not systemic. Positive post-flush samples (or multiple positive samples) may be an indication that the whole water systems is contaminated and that controls are not effective."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides guidance “on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages.” The following section(s) are relevant for this research question on whether specific actions are required if an outlet tests positive pre-flush but negative post-flush. “To confirm effective disinfection, any required microbiological samples should be taken between two and seven days after the system is treated. Samples taken immediately after a disinfection process might give false negative results”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on whether specific actions are required if an outlet tests positive pre-flush but negative post-flush. “For routine monitoring purposes, only pre-flush samples should be taken and, where possible, these should be taken from unmixed outlets. Pre-flush samples should be taken with no disinfection or adjustment of devices or inserts to obtain a reflection of the water as it is used.

Assessment of evidence
NOTE 1 Post-flush samples are not suitable for routine monitoring. NOTE 2 Pre-flush samples allow for the determination of the colonization of a particular outlet. This is the type of sample that is most representative of the risk to individuals and is the only sample necessary. In healthcare the WSG may wish that pre-flush samples are taken from showers and mixed outlets with TMVs as these represent the highest risk to patients. NOTE 3 Detection of Legionellae in a sample collected from an outlet which has not been disinfected does not discriminate between outlet or system contamination, so further sampling of either mixed or unmixed outlets would be necessary with and without outlet disinfection. If it is necessary to differentiate between local and systemic colonization following a positive water result, post-flush, disinfected-outlet samples should be collected in addition to the pre-flush samples to support the determination of whether the system itself or components, such as TMVs, are colonized, as opposed to outlets, and to determine that the numbers of *Legionellae* within the system are controlled. 6.2 Biocide neutralizing agents COMMENTARY ON 6.2 When present, biocides continue to exert their action and be effective after the sample has been taken. The purpose of the sample is to enable the presence, or absence, of potentially infective Legionellae to be determined at the time of sampling, and not at some time after the biocide has continued to be effective. Allowing the biocide to continue its action after the sample has been collected might result in lower counts or false negative results and be unrepresentative of the safety of the system at the time of sampling. If biocides are known or suspected to be present, sterile bottles containing suitable neutralizers should be used to stop the action of the biocide at the time of collection. Where neutralizing agents are used, these should be known to have no biocidal or inhibitory effect on the recovery of *Legionellae*.”

Question 24: Are there any recommended methods for the removal of healthcare water system contamination?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
de Jonge E, de Boer MGJ, van Essen HER et al. Effects of a disinfection device on colonization of sink drains and patients during a prolonged outbreak of multidrug – resistant *Pseudomonas aeruginosa* in an intensive care unit.	Outbreak investigation	**Level 3**	The aim of this study was to study the influence of installing disinfecting devices on sink drains on colonization of sinks and patients in a Dutch ICU during a prolonged outbreak of multidrug-resistant *P. aeruginosa.*	Isolated cultures of multidrug-resistant *P. aeruginosa.* before and after the 'intervention' (installation of disinfecting devices)	Proportion of sinks colonised with MDR-PA. Proportion of patients colonised with MDR-PA. Presence of MDR-PA in samples taken from ICU patients per 1000 admission-days.

Assessment of evidence

The study was described as a 'two-armed intervention trial' with disinfecting devices installed in sink drains in ICU A and new conventional PVC plastic siphons installed in sink drains in ICU B and described the effects on sink and patient colonisation.

The disinfection device aims to decontaminate waste water in the siphon basin by applying repeated heating (to at least 85C) and electromechanical vibration. The study reported that installation of the devices in ICU A resulted in a decrease in colonisation of patients in the subunit from 4.8 to 2.1 per 1000 admission days while colonisation of sink "almost disappeared". Patient colonisation dropped further

Assessment of evidence
to between 0 and 0.2 per 1000 patient days when the devices were installed in both subunits (ICU A and B). These devices appeared to be successful at decreasing the colonisation rates of sink drains however they were not 100% effective; some sink drains occasionally tested positive for MDR-PA. This suggests that other components/distal regions of the sink plumbing remained colonised. Organism: MDR *Pseudomonas aeruginosa* Transmission mode: Contaminated water system Clinical Setting: ICU in a Dutch University Medical Centre (A tertiary and teaching hospital) Source: Sink drains Control Measures: Installation of disinfecting devices on sink drains. Limitations: • No randomisation or blinding. • There seemed to be a cross-contamination between both ICU A and B. • Colonisation was used as an outcome rather than infection

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM,Chinn RYW, Arduino MJ et al. Guidelines for environmental infection control in health-care facilities. Recommendations	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). American Society for Healthcare Engineering/American Hospital Association; 2004.					

Assessment of evidence

These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on recommended methods for the removal of waterborne organisms from a contaminated outlet.

“The primary disinfectant for both cold and hot water systems is chlorine. However, chlorine residuals are expected to be low, and possibly nonexistent, in hot water tanks because of extended retention time in the tank and elevated water temperature. Flushing, especially that which removes sludge from the bottom of the tank, probably provides the most effective treatment of water systems. Unlike the situation for disinfecting cooling towers, no equivalent recommendations have been made for potable water systems, although specific intervention strategies have been published. The principal approaches to disinfection of potable systems are heat flushing using temperatures 160°F–170°F (71°– 77°C), hyperchlorination, and physical cleaning of hot-water tanks. Potable systems are easily recolonized and may require continuous intervention (e.g., raising of hot water temperatures or continuous chlorination). Chlorine solutions lose potency over time, thereby rendering the stocking of large quantities of chlorine impractical.”

Assessment of evidence
"Some hospitals with hot water systems identified as the source of *Legionella* spp. have performed emergency decontamination of their systems by pulse (i.e., one-time) thermal disinfection/superheating or hyperchlorination. After either of these procedures, hospitals either maintain their heated water with a minimum return temperature of 124°F (51°C) and cold water at <68°F (<20°C) or chlorinate their hot water to achieve 1–2 mg/L (1–2 ppm) of free residual chlorine at the tap." "Additional measures (e.g., physical cleaning or replacement of hot-water storage tanks, water heaters, faucets, and shower heads) may be required to help eliminate accumulations of scale and sediment that protect organisms from the biocidal effects of heat and chlorine. Alternative methods for controlling and eradicating *Legionella*e in water systems (e.g., treating water with chlorine dioxide, heavy metal ions [i.e., copper/silver ions], ozone, and UV light) have limited the growth of *Legionella*e under laboratory and operating conditions." "Additional filtration of potable water systems is not routinely necessary. Filters are used in water lines in dialysis units, however, and may be inserted into the lines for specific equipment (e.g., endoscope washers and disinfectors) for the purpose of providing bacteria-free water for instrument reprocessing. Additionally, an RO unit is usually added to the distribution system leading to PE areas."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aspelund AS, Sjöström K, Liljequist BO et al. Acetic acid as a decontamination method for sink drains in a nosocomial outbreak of metallo-b-lactamase-producing	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Minimum inhibitory concentration (MIC), Minimum bactericidal concentration (MBC), Minimum biofilm eradication concentration (MBEC), genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa. Journal of Hospital Infection 94 (2016) 13 – 20					
Assessment of evidence					
This study describes “a prolonged outbreak of metallo-b-lactamase-producing P. *aeruginosa* (Pae-MBL) associated with sink drains and propose a previously unreported decontamination method with acetic acid.” Organism: *Pseudomonas aeruginosa* Transmission mode: Indirect contact; (likely splashing of the water in the sink or similar). Clinical setting: Three different wards at a University Hospital in Sweden Source: Sink drains (and further down in the pipes). Control measures: The initial response was the replacement of contaminated sinks. In one Ward where the sinks could not be immediately replaced, acetic acid was poured once weekly into colonized sink drains. Acetic acid treatment was terminated when all sinks and plumbing’s were changed as it was believed that the bacteria reservoir had been eliminated. However, the bacterium reappeared in 3 sinks after a mean time of 13 weeks, but without any positive clinical sample. Culturing the drainpipes going into the wall indicated a reservoir further down. “As acetic acid treatment of colonized sinks had previously shown promising results in ward 1, acetic acid treatment of Pae-MBL-positive sinks was restarted. Since the finding of an initial positive culture in one colonized sink, all control cultures have been negative. However, two drainpipes in the wall remained positive even after 10 weeks of acetic acid treatment.” To completely eradicate Pae-MBL growth, the two colonized drainpipes “were flushed with hot water (90°C) directly into the pipe in the wall for 5 minutes with high pressure”. Sink drain, siphon and pipes to the wall were changed at the same time, but one of the pipes became Pae-MBL positive again after five weeks. Following this recurrence, all patient bathroom sinks were treated with acetic acid. Patients were also asked to observe ‘sink rules’ such as “not keeping toothbrushes or toiletries on the sink brim”.					

Assessment of evidence
PFGE typing of the 12 isolates from patients and seven isolates from sinks showed identical or closely related band patterns Limitations: “The reinforcement of ‘sink rules’ may have affected the outcome”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Rogues AM, Boulestreau H, Lasheras A et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit. Journal of Hospital Infection (2007) 67, 72 – 78.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonisation of *Pseudomonas aeruginosa* in a French ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of colonisation.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
Pseudomonas aeruginosa was found in tap water samples in patients’ rooms more than in other tap water in the unit. Half of the environmental isolates of *P. aeruginosa* derived from colonised patients and did not stem from a central source in the supply mains. Carriage happened by patients (source). Both water-related and non-water related strains appeared to have spread in half of the instances.					

Assessment of evidence
Organism: *Pseudomonas aeruginosa* Transmission mode: Carriage by patients, and indirect from tap water Source: Contaminated water systems Control measures: The following interventions were carried out: • Twice monthly chlorine disinfection (aqueous solution (4.5%) of sodium hypochlorite injected into taps with a 60mL syringe for 15 minutes. • Aerators were also removed every two weeks, immersed and brushed in a detergent-disinfectant solution. • Hand disinfection with alcohol – based solution between patient contacts • Exclusive use of bottled water for enteral nutrition and administration of drugs through gastric pipes. • Use of sterile water for mouth care. • Removal of defective flexible bronchoscope which was contaminated with an epidemic strain after manual reprocessing. • P. aeruginosa was found in 34 out of 180 (18.8%) samples before and in 22 of 288 (7.6%) after disinfection was implemented (P < 0.01).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jolivet S, Couturier J, Vuillemin X et al. Outbreak of OXA-48-producing *Entero bacterales* in a haematological ward associated with an	Outbreak investigation (including case-control element)	**Level 3**	The study reports the epidemiological and microbiological investigations carried out to control a large and protracted outbreak caused by	Phylogenetic properties of isolates and epidemiologic links between patients and environmental sources.	Number of clinical cases with OXA-48-producing Enterobacterales infection or colonisation in the haematological ward. Contamination/

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
uncommon environmental reservoir, France, 2016 – 2019. Euro Surveill. 2021;26(21):pii≡2000118			OXA-48 CPE, mostly *Citrobacter freundii.*		growth of CPE in environmental samples. Antimicrobial resistance and typing.

Assessment of evidence

Organisms: A total of 78 OXA-48 CPE were detected including *C. freundii*, *E. coli*, *K. pneumoniae*, *Klebsiella oxytoca*, *Enterobacter cloacae*, *Citrobacter koseri*, *Enterobacter aerogenes, Hafnia alvei*, *Kluyvera cryocrescens*, *Citrobacter amalonaticus*, *Morganella morganii*, and *Raoultella ornithinolytica.*

Transmission mode: Indirect contact (toilet splashback)

Clinical setting: Hematological ward in a French hospital

Source: Toilet rims

Control measures: “Following the identification of the toilets as a potential source of the outbreak, intensive toilet cleaning with descaling and bleaching (initially daily, then weekly) was implemented. Afterwards, 23 environmental samples were taken (including 21 toilet rims and two drains), and only one toilet remained positive for OXA-48-producing *C. freundii*. This toilet was successfully re-decontaminated by performing a single additional cleaning and bleaching. In August 2018, all toilets bowls and tanks in two units with environmental CPE-positive samples were replaced by rimless toilets. Rimless toilets are easier to clean and reduce the risk of limescale deposits. After implementation of the environmental measures, the incidence of new CPE cases declined, and only two unrelated CPE cases” causes of which remain undetermined.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. The control of *Legionella,* hygiene, 'safe' hot water, cold water and drinking water systems. Part D: Disinfection of Domestic Water Systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document summarises the disinfecting agents and their pros and cons for use in healthcare premises water systems. This was in response to the concerns raised by the Health Facilities Scotland (HFS) Scottish Engineering and Technology Advisory Group regarding a lack of information and guidance on the addition of chemicals to water in healthcare premises. In response to this, a Short-Life Working Group was formed and this eventually became the National Water Services Advisory Group.

The following sections are relevant for this research question on recommended methods for the removal of waterborne organisms from a contaminated outlet.

Assessment of evidence
“When considering the most suitable method of disinfection for a healthcare facility a number of parameters have to be taken into consideration, factors to be considered include the condition of estate, the health of the occupants, the quality of the public water supply, finance, and the availability of resources to implement a particular regime” The disinfection systems reviewed in this document are: • Heat and flush; • Continuous chlorination; • Chlorine dioxide; • Ultra Violet light (UV); • Copper silver ionisation; • Silver catalysed hydrogen peroxide; • Ozone and chloramines” The pros and cons of the following disinfecting agents are reviewed: • Chlorine • Chloramine (monochloramine) • Chlorine Dioxide • Ozone • Silver Catalysed Hydrogen Peroxide • Silver/copper ionisation • UV

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on recommended methods for the removal of waterborne organisms from a contaminated outlet:

“Central absolute bacteria filters: These filters are installed as close to the heat source/calorifier outlet as possible. The filters range in size from 0.2 to 0.65 micron. They operate by continuously cleaning the system and assist in preventing the build-up of deposits at final outlets.

Assessment of evidence

They are generally protected upstream by either a 1 or 5 micron particulate filter and in some circumstances by a strainer upstream of that. The pressure drop and/or flow-rate through the filter should be monitored via the Building Management System (BMS). Provided they are installed as close to the heat source/ calorifier outlet as possible and in accordance with supplier/manufacturer specifications and UK HTM 04-01, they may be a cost effective method to reduce system particulate and sediment levels."

"Intelligent water management systems (IWMS): Intelligent water management systems should be encouraged particularly in new build projects. A life cycle costing appraisal will determine their value for money (VFM) at the design stage. Retrofitting may not be economically viable. Alternately, elements of an IWMS can be installed and linked to the existing BMS on site. Such elements include water meters, temperature sensors, tank level water sensors, control valves, balancing valves, biocide level sensors and pressure drop sensors. A number of companies provide packaged solutions which address these aspects. Some of these packaged intelligent systems provide preventive measures that assist in avoiding stagnation in the water system. They can also reduce personnel and operating costs, for example, through controlled flushing measures carried out in an efficient manner. Overall these systems provide for better water quality management, enabling better control, monitoring, recording and communication, all of which are essential elements of a water management system in a healthcare facility. However, the water distribution system's pipework must be configured appropriately to work with IWMS."

In "Table 3.6: Secondary disinfection methods applied to healthcare facility water distribution systems", the document provided the following methods for disinfection based on a systematic review:

- Systemic Continuous – Temperature control regime, Chlorine dioxide, Monochloramines, Copper – silver ionisation, Electrochemically activated water
- Systemic intermittent – Thermal disinfection (superheat and flush), Shock hyperchlorination, Shock chlorine dioxide, Silver catalysed hydrogen peroxide
- Focal Continuous – UV, Ozone

"Systemic disinfection methods aim to disinfect the entire distribution system including distal outlets. Focal disinfection methods disinfect only a portion of the distribution system acting at the point of application with no residual effect. Continuous secondary disinfection

Assessment of evidence
methods that may be employed in healthcare facilities may not respond effectively to sudden unanticipated significant contamination of the incoming water supply due to major disruptions or repairs.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakade J, Nakamura Y, Katayama Y, et al. Systematic active environmental surveillance successfully identified and controlled the *Legionella* contamination in the hospital. J Infect Chemother. 2023;29(1):43-47. doi:10.1016/j.jiac.2022.09.010	Surveillance study	**Level 3**	This surveillance study was performed after a patient acquired *Legionella* infection to identify and control the *Legionella* contamination. Resampling was done 1, 2 and 3 months after implementation of control measures (disinfecting by increasing heat, increasing chlorine and increasing water pressure) and results were negative.	N/A	Sample location, water temperature, chlorine concentration(ppm), Legionella counts (CFU/100ml).

Assessment of evidence

This surveillance study was performed after a patient acquired *Legionella* infection. The authors state that the patient infection must be nosocomial as on day 18 high fever started and *Legionella* was confirmed 28 days after admission. Samples were taken from the bathrooms of the patient as well as bathrooms on different floors that connected to the same plumbing, in total 47 water samples were taken and *Legionella* was confirmed in 16 of the 47 samples (3/5 from patient bathroom and 13/42 from connected bathrooms).

However, it is not confirmed by genotyping/serotyping that the strains found in water samples were matching the patient strains and thus it could be possible that *Legionella* was acquired elsewhere (in rare cases the incubation period can take up to 20 days according to ECDC).

Organism: *Legionella*

Transmission mode: not confirmed

Source: not confirmed (either faucets/shower heads or inside the plumbing of the circulation)

Control measures: Increase of water temperature (from 65C to 70C), increase of chlorine concentrations, increase of water pressure. *Legionella*-positive water tap was replaced with a new one. For the parts those are difficult for being replaced, such as water plumbing around bathtub for the accessible bathing, plumbing was flushed by hot water of 45C Celsius for 15 min followed by 60C Celsius for 3 min for 3 consecutive days. In addition, water taps and plumbing were flushed more than 15 min once a week on a regular basis after cleaning and disinfecting.

Limitations:

- No genotyping performed, thus not known whether the isolates (patient and all environmental isolates) were identical strains.
- Not confirmed if case was nosocomial. Patient used bathroom on 5th floor and 7th floor, and both were positive for *Legionella* afterwards, but not known if the patient was the source or if the water was the source.
- Single patient case.
- Not clear whether *Legionella* was contaminated only in faucets/shower heads or inside the plumbing of the circulation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aumeran C, Paillard C, Robin F, et al. *Pseudomonas aeruginosa* and *Pseudomonas putida* outbreak associated with contaminated water outlets in an oncohaematology paediatric unit. Journal of Hospital Infection. 2007 Jan 1;65(1):47-53.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* and *Pseudomonas putida* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *P. aeruginosa* and *P. putida* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antibiogram and genotyping results.

Assessment of evidence

No further cases were identified after implementation of control measures.

Organism: *Pseudomonas aeruginosa* and *Pseudomonas putida*

Transmission mode: not confirmed

Clinical setting: haematology paediatric unit

Source: contaminated water outlets

Control measures: water network was chlorinated, and disposable seven-day filters were fitted on all taps and showers. Due to the deleterious effects of chlorination on the water network and the cost of the weekly filter change, a water loop producing microbiologically

Assessment of evidence
controlled water was installed. In addition, the concentration of the detergent disinfectant was increased and refillable sprayers were replaced with ready-to-use detergent disinfectant solution for high-risk areas.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler M. A., Osman F., Marx J. J., et al. Hospital-acquired *Legionella pneumonia* outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020	Outbreak investigation (including case-control element)	**Level 3**	An epidemiological and laboratory investigation of a hospital-acquired *Legionella pneumonia* outbreak at of The University of Wisconsin Hospital. Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia*	Molecular genotyping results (WGS) between patient strains and *L. pneumonia* isolated from environmental/water samples were compared to establish link of colonisation/infection	Case-control study: ICU admission, 30-day mortality and 90-day mortality, Demographic data and patient factors, pertinent exposures Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of *Legionella* in environmental samples taken from patient rooms and clinical units,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
					molecular type of isolates found.

Assessment of evidence

This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the implementation of changes to the water treatment strategy and it is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters.

Organism: *Legionella pneumonia*

Transmission mode: Direct (from water system)

Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients.

The case-control study showed that being a current smoker, having showered during admission and being on prescribed steroids prior to admission were the strongest predictors for acquiring Legionella disease during the outbreak.

Source: hospital water circuit

Control measures: Showering activities were promptly restricted, water distribution system was hyperchlorinated with 50-200 ppm free chlorine overnight, POU filters were installed on showerheads and faucets. Other interventions included removal of the old water heaters and associated dead end water pipes.

Limitations: Case-control element only had 13 cases which is very low to make proper statements on risk factors.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Brulet A, Nicolle M, Giard M et al. Fatal nosocomial *Legionella pneumophila* infection due to exposure to contaminated water from a washbasin in a hematology unit. Infect Control Hosp Epidemiol 2008; 29:1091.	Case report	**Level 3**	This paper describes a case of fatal nosocomial legionellosis after documented washbasin water contamination in a hospital in France.	Molecular typing results (PFGE) between patient isolates and *L. pneumophila* isolated from water samples were compared.	Genetic relatedness

Assessment of evidence

Comparison of patient isolate (2 cases) and water samples by PFGE. High levels of *L. pneumophila* serogroup 5 and serogroup 1 were detected in the potable hot water of every shower sample, ranging from 350 to 165,000 colony-forming units (cfu)/L. The unit's wing inlet and outlet (ie, the places from where the water starts and returns, respectively) were also contaminated (900 and 3,400 cfu/L, respectively). Tap water in patient room had 1,500 cfu/L.

Organism: *Legionella pneumophila* serogroup 5

Setting: haemato-oncology unit, France.

Transmission mode: (unclear, possibly direct ingestion and/or aspiration)

Source: Water system

Assessment of evidence
Control measures: Flexible shower hoses removed. Hot water reheated to 58'C and hyperchlorinated twice a week, monthly Legionella screening instituted, filters on all outlets. Taps changed to simple mixer valves that did not have volumes of standing water. The hyperchlorination and water reheating alone were unsuccessful. No organisms found in water once filters were installed. Genetic relatedness: "*L. pneumophila* serogroup 5 isolates from the cold wash-basin water matched the patient's isolate and the isolate from an earlier case by genotyping with pulsed-field gel electrophoresis (PFGE)"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ashraf M S, Swinker M, Augustino K L, et al. Outbreak of *Mycobacterium mucogenicum* bloodstream infections among patients with sickle cell disease in an outpatient setting. Infection Control and Hospital Epidemiology. 2012 35 (11): 1132-1136.	Outbreak investigation	**Level 3**	The aim of this study was to investigate 4 cases of M. mucogenicum bloodstream infection.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, typing results.

Assessment of evidence
All 4 patients had ports for intravenous medication. Tap water from 2 taps grew *Mycobacterium* species including *M. gordonae*, *M. szulgai*, *M, mucogenicum*, *M. kansasii*). Rep-PCR typing; isolate from tap water from tap with an aerator matched the patient ATCC strains for *M. mucogenicum* with more than 93% similarity. Organism: *Mycobacterium mucogenicum.* Transmission mode: Intravenous flushes performed on the sink counter from a saline bag that was hanging throughout the day over the sink, instead of using prefilled saline flushes; this is a non-sterile field. The same sink also used for handwashing. Clinical setting: Outpatient haematology clinic, United States of America. Source: Hospital water supply. Control measures: All aerators removed from taps, staff educated on aseptic procedures away from sinks and need for prefilled saline flushes. No mention of chlorination/other control methods of the actual water system.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker A. W., Lewis S. S., Alexander B. D. et al. Two-phase hospital-associated outbreak of *Mycobacterium abscessus*: Investigation and mitigation.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium abscessus* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	XbaI pulsed-field gel electrophoresis (PFGE) of patient and environmental isolates of *Mycobacterium abscessus.*	Incident rate, positive cultures, molecular fingerprinting.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Clinical Infectious Diseases, 64 (7), 902-911, 2017.					

Assessment of evidence

Organism: *Mycobacterium abscessus*

Transmission mode: tap water to patient. Possibly cardiac heater cooler units in cardiac patients.

Clinical setting: Acute hospital – ICU/ OR, North Carolina US. New addition added (ICU, OR). Lung transplant recipients represented 51% of cases during phase 1. Other cases included cardiac surgery (13%), cancer (7%). hematopoietic stem cell transplantation (7%). Phase 2 cases were 13 patients that had undergone cardiac surgery; one was respiratory colonisation, 12 developed extrapulmonary invasive disease

Source: Low flow rates within the hospital addition's water circuit and a redundant hot water circulation system may have led to amplification of NTM in the addition's water supply over time. These conditions contributed to low chloramine levels and water temperatures favorable for *M. abscessus* growth.

Control measures: Sterile water protocol (sterile water for oral care, speech therapy assessments, enteral tube flushes, respiratory therapy, consumption and bathing (until surgical sites were well healed)) for all lung and heart transplant patients, ICU patients, and patients with disrupted gastrointestinal tracts. The new protocol for the cardiac heater cooler units (HCUs) included daily water changes with sterile water and daily disinfection with hydrogen peroxide, in addition to intermittent bleach-based disinfection. We also directed HCU exhaust away from the surgical field. Replacement of all existing HCUs with new HCUs only used sterile water in these machines. Water flushing throughout both the cold water and recirculating hot water systems; removal or adjustment of water flow restrictors, aerators, and a redundant hot water tank; and decreasing the percentage of recirculating hot water that bypassed heat exchangers. Additionally, point-of-use 0.2-µm water filters were installed at OR scrub sink faucets. Complete eradication of *M. abscessus* and associated biofilms from hospital tap water and plumbing infrastructure was not realistic given the environmental persistence of NTM.

Assessment of evidence
Limitations: The case definition did not differentiate colonization from invasive infection, because of the inherent difficulties in making this clinical distinction, especially in lung transplant patients. Could not conclusively prove the heater cooler units were the source but it was the most plausible explanation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Durojaiye OC, Carbarns N, Murray S et al. Outbreak of multidrug-resistant *Pseudomonas aeruginosa* in an intensive care unit. Journal of Hospital Infection 78 (2011) 152–159.	Outbreak report	**Level 3**	This paper reports a nosocomial outbreak of MDR strains of *P. aeruginosa* among 10 patients in a renovated adult ICU in a hospital in the United Kingdom.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
All the 10 samples collected from the taps, water outlets and water supply to the sinks in the unit grew 300 cfu/100 mL of multidrug-resistant *P. aeruginosa*. Organism: *Pseudomonas aeruginosa* Clinical setting: ICU, Wales. Transmission mode: Unknown. Possible patient-patient indirect transmission as well as environmental.

Assessment of evidence
Source: Contaminated taps (newly installed sensor taps) Control measures: All sinks in the unit decommissioned and portable sinks using bottled water were arranged. All sensor taps in the unit were replaced with conventional non-sensor mixer taps – repeated sampling showed no further contamination and no more cases. Monthly water sampling continued. Limitations: No details of time from admission to positive test. Genetic relatedness: Isolates from the water samples showed three different strains of *P. aeruginosa*, two of which matched the strains isolated from patients (variable number tandem repeat).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tofteland S, Naseer U, Lislevand JH et al. A Long-Term Low-Frequency Hospital Outbreak of KPC-Producing *Klebsiella pneumoniae* Involving Intergenus Plasmid Diffusion and a Persisting Environmental Reservoir. PLoS ONE 8(3): e59015	Outbreak report	**Level 3**	This paper reports the investigation of the molecular characteristics of a long-term, low frequency outbreak of blakpc-2 in a hospital in Norway.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness Antimicrobial susceptibility

Assessment of evidence
Sink drains and taps supplying water to dialysis machines were sampled. PGFE/MLST analysis of isolates were carried out. KPC-producing bacteria were detected in 4/19 environmental locations in the ICU-A (sink drains in room 5, 6, 9, and the rinsing room). Organism*: K. pneumoniae* ST258 Clinical setting: Surgical/medical ICU, Norway. Transmission: Patient negative on admission because positive 5 days post admission, was admitted to room vacated by positive patient; room sink drain was positive. Matching pulsotypes for all these isolates. Source: Environmental reservoir (sink drains) and patients Control measures: Active surveillance on admission. The sinks and sink traps were decommissioned and the connecting pipe elbows were disinfected using a chlorine disinfectant before new sinks and sink traps were installed. Monthly environmental screening of these positive locations was then undertaken. Several sinks continued to be positive, but no further patient cases. Genetic relatedness: “PFGE and MLST typing revealed that 14 *K. pneumoniae* isolates from both patients and the environment, including the three bla$_{KPC}$-negative *K. pneumoniae* UTI-isolates, belonged to two clonally related pulsotypes (A1 and A2), that by MLST were typed to ST258”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
La Forgia C, Franke J, Hacek DM, et al. Management of a multidrug-resistant *Acinetobacter baumannii* outbreak in an intensive care unit using novel	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Acinetobacter baumannii* outbreak in an ICU (including finding the source) and to determine the	Genomic DNA of the clinical isolates were genetically analysed using restriction endonuclease analysis (REA) and compared with one another to determine	Number of positive samples, sample type, restriction endonuclease analysis (REA).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
environmental disinfection: a 38-month report. American journal of infection control. 2010 May 1;38(4):259-63.			impact of infection prevention and control measures.	whether they were genetically related.	

Assessment of evidence

Organism: *Acinetobacter baumannii*

Transmission mode: Indirect transmission

Clinical setting: ICU, United States of America

Source: Single outbreak source was identified. sink trap that likely represented source and reservoir.

Control measures: contact isolation of all MDR *A baumannii*–positive patients, education of nursing staff on the epidemiology of MDR *A baumannii*, increased training on the importance of hand hygiene, introduction of alcohol-based hand hygiene solution into each patient room, and observations of environmental cleaning in the ICU.

Bleaching protocol successfully decontaminated the reservoir and eliminated the MDR *A baumannii* infections.

Flushing regime: The sink flushing protocol was devised as follows. Once per day for the first week, and then once per week thereafter until October 2008 (when the ICU was demolished for remodelling), 10 gallons of water were first run into each plugged sink in every location in the ICU, including in each patient room and the family waiting area. This was followed by slowly pouring 1 gallon of bleach into the water, avoiding splashing. Health care workers performing this task wore protective goggles as well as rubber gloves. Once all of the sinks were filled, the plugs of all sinks were pulled simultaneously, thereby flushing the sink drain piping with the bleach solution. This protocol was continued throughout the observation period.- Subsequently, 5 additional cultures of the involved sink were negative over the next 30 days, as well as 6 months later. Early after initiation of the bleaching protocol, from March 2005 to September 2005, only 2

Assessment of evidence
patients were culture-positive for *A baumannii*. One of these patients was colonised with an unrelated clone and the other was colonised with the epidemic clone. The patient with the epidemic clone had been hospitalized in the ICU before initiation of the bleaching protocol. Before this intervention, 18 patients over 10 months were infected or colonised with *A baumannii*. After the intervention, this decreased to 19 patients over 28 months, a statistically significant difference in rate (P<0.01).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hong KB, Oh HS, Song JS et al. Investigation and Control of an Outbreak of Imipenem-resistant *Acinetobacter baumannii* Infection in a Pediatric Intensive Care Unit. Pediatr Infect Dis J 2012;31: 685–690.	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of imipenem-resistant *Acinetobacter baumanii* in a paediatric ICU in a Children hospital in Korea.	Molecular typing results (multilocus sequence typing) between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
Environmental samples were obtained from mechanical ventilator devices, respiratory equipment, bed rails, side tables, blood pressure cuffs, door handles, intravenous stands, keyboards, water taps and sinks. Contaminated shallow sink with high water pressure created splashing onto surrounding areas; staff were using towels to soak this up. Organism: *Acinetobacter baumannii*

Assessment of evidence
Setting: Paediatric ICU, Korea. Transmission route: Unknown Source: Sink drain a reservoir, cannot rule out patient-patient transmission (patient as a source) Control measures: Patient and nurse cohorting, active surveillance on admission, contaminated sink was replaced; following this the rate of colonisation decreased. Genetic relatedness: Multilocus sequence typing analysis linked environmental samples from sink drain and that sink tap water to patient cases.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wendel AF, Kolbe-Busch S, Ressina S et al. Detection and termination of an extended low-frequency hospital outbreak of GIM-1-producing *Pseudomonas aeruginosa* ST111 in Germany.	Outbreak report	**Level 3**	This paper describes an outbreak of an extensively drug-resistant GIM-1-carrying *Pseudomonas aeruginosa* Strain in a tertiary care hospital in Germany from 2002-2013.	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
American Journal of Infection Control 43 (2015) 635-9					

Assessment of evidence

A total of 199 environmental specimens were collected (pre+post flush water samples, reusable hair washbasins, sink drains, sink basins, sink counter – all taken before cleaning). The outbreak strain was detected in 6 sink drains (5 patients rooms, 1 service room) and 1 inflatable hair washbasin. Not found in tap water. Five out of 24 patients had a clinical infection, remainder were colonised.

Organism: *Pseudomonas aeruginosa*.

Setting: ICU, Germany.

Transmission mode: Likely indirect and direct, however cannot rule out patient-patient transmission.

Source: Sink drains as a reservoir; cannot rule out patient-patient transmission.

Control measures: Use of water from patient room sinks for patient-related procedures was forbidden. Reusable hair washbasins removed. Clean materials not stored near sinks. All water traps on the ward were exchanged and disinfected but follow up sampling 1 year later revealed a persistently colonised wastewater system, and control measures focused on stopping transmission from the sink to patient No further detections in the year after.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Vergara-Lopez S, Dominguez MC, Conejo MC et al. Wastewater drainage system as an occult	Outbreak report	**Level 3**	This paper describes the investigation of a protracted nosocomial clonal outbreak of a	Molecular typing results between patient strains and environmental strains isolated from	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
reservoir in a protracted clonal outbreak due to metallo-b-lactamase-producing *Klebsiella oxytoca.* Clin Microbiol Infect 2013; 19: E490–E498			multidrug resistant IMP-8 producing *Klebsiella oxytoca* (MDRKO) in a Spanish Hospital.	environmental/water samples were compared to establish a link of infection.	

Assessment of evidence

42 patients colonised (n=28) or infected (n=14). The average time between admission and acquisition of MDRKO was 8 days (IQR,6-37), 16 days (12-17) and 14 (9–40) days in waves 1, 2, and 3, respectively (p 0.22).

A urinary catheter removed from a colonised patient and a stethoscope used with that patient yielded MDRKO. Sampling of sinks, drainpipes and traps, was carried out. Samples from room S6 were positive: MDRKO cultured from every pipe, trap and drainage grille sample taken; samples from the faucet or overflow grille were negative. Samples from the pipe connecting S6 and S7 were also positive.

Organism: *Klebsiella oxytoca*

Setting: Surgical/medical ICU, Spain

Transmission: Unconfirmed.

Source: Sink drains/drainage pipes as reservoir, patients also a source.

Control measures: Chemical dosing of the whole water system (a standard annual practice) did not eradicate the outbreak. Sink 6 and its drain system were permanently removed and the drain system of S7 was replaced. Then, a decision to isolate wastepipe 5, which S5 and S7 still drained into. Thus, the complete horizontal drainage system of S5 and S7 was replaced and connected up to wastepipe 4. Shut-off valves were also installed to each sink drainage system. Since then, a disinfection of the drainage system was performed twice a week

Assessment of evidence
using ‘Biguanid’ (quaternary ammonium compound) at 1.6% for 30 min (through closing the valves), followed by opening the valves and running hot water (70°C) for 5 min. Three and 6 months after the end of the outbreak, transversal screening studies of both patients and the environment were carried out and all were negative. No new cases since. Genetic relatedness: Selected isolates from waves 3 and 4 and all the environmental samples were studied for the presence of blaIMP-8 and molecular relatedness by PFGE profile. Every strain studied carried blaIMP-8 and they showed the same PFGE profile as previous isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Seara N, Oteo J, Carrillo R et al. Interhospital spread of NDM-7-producing Klebsiella pneumoniae belonging to ST437 in Spain. International Journal of Antimicrobial Agents 46 (2015) 169–173	Outbreak report	**Level 3**	This paper describes an interhospital spread of carbapenem-resistant *Klebsiella pneumoniae* (CRKP) producing NDM-7 carbapenemase across three hospitals in Spain.	Molecular typing result between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 7 cases across 3 different hospitals (4 infected, 3 colonised) were categorised as HAI according to CDC definition (supported by admission screening). The median duration from admission to detection of CRKP in these 7 patients was 32 days (range, 21–44 days). Presence of NDM-7 producing *K. pneumoniae* in the traps of the shower and sink. Organism: *Klebsiella pneumoniae* Setting: 3 different hospitals (An acute tertiary hospital, an acute rehabilitation care hospital and a secondary center that provides medical and surgery support to all other hospitals in the Madrid hospital network), Spain. Transmission: Unconfirmed. Source: Sink/shower drain as reservoir for some cases Control measures: Active surveillance at admission following first case. cleaning of the sink and shower with sodium hypochlorite, vaporisation of the inner trap with a steam cleaner for 1 min, and pouring 0.1% sodium hypochlorite, 0.1% sodium hydroxide and 0.1% C12–C16 alkyl dimethyl amine oxide down the drain. 2 months later NDM-producing *K. pneumoniae* was still present in the sink trap and consequently the trap was replaced. Genetic relatedness: PFGE indicated that all CRKP isolates were closely related; MLST showed that all of the isolates belonged to ST437, a single-locus variant of ST11. 5 patients had no overlap of stay but had stayed in same room – this room had colonised sink and shower traps.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leung GHY, Gray TJ, Cheong EYL, et al. Persistence of related bla-IMP-4 metallo-beta-	Outbreak report	**Level 3**	This paper describes the investigation undertaken in a six - year persistent bla-IMP-4 metallo-beta-lactamase (MBL)	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
lactamase producing Enterobacteriaceae from clinical and environmental specimens within a burns unit in Australia - a six-year retrospective study. Antimicrobial Resistance and Infection Control 2013, 2:35			producing Enterobacteriaceae within a separately confined hospital burns unit in a tertiary hospital in Australia.		

Assessment of evidence

23 patients, with clinical infection in 7 (2 bacteremias, 2 CVC tip infections, 3 wound infections).

Assessment of evidence: The only environment shared between patients was the shower and bathroom facilities.

Organism: *Enterobacter clocae* (most commonly detected organism), *Klebsiella pneumoniae, Enterobacter aerogenes, Klebsiella oxytoca.*

Clinical setting: Burns unit, Australia.

Source: Sink and shower drains identified as reservoirs and potential source for some transmissions. Patients may have been initial source.

Transmission: Unclear, however likely both direct and indirect.

Control measures: Monthly and then bi-monthly environmental sampling (bathroom facilities and plumbing including shower drains, ensuite room sink drains). Regular physical cleaning of drains (plumbers had to unscrew sink traps) to remove biofilm and additional cleaning with double-strength phenolic disinfectant (Phensol), later changed to chlorine-based product (Chlor-clean). Point prevalence

Assessment of evidence
environmental screening was carried out and the outbreak organism was identified - this led to monthly routine screening (pre and post cleaning) including patient rooms, shared equipment, plumbing, sink drains etc. This was downgraded to bi-monthly and remained in place. Despite both regular environmental surveillance and disinfection, environmental reservoirs remained.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrobial Resistance and Infection Control (2017) 6:24	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a teaching hospital in Belgium.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission).

Assessment of evidence
Sink drain in this room was positive, as was every other isolation room on the unit. Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc). Organism: Enterobacteriaceae Clinical setting: ICU, Belgium. Transmission mode: Unconfirmed. Source: Sink drain as reservoir (and likely source for some patients). Control measures: daily disinfection of the sinks with a glucoprotamine product was implemented; sinks were dedicated to 'clean work' (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere. Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Wilkinson MAC, Holden KL et al. Tap out: reducing waterborne *Pseudomonas aeruginosa*	Before and after study	**Level 3**	Installation of new tap outlets (the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa).*	Contamination at the tap before/after installation of 'test taps' (i.e. engineering solution)	Total viable counts of test tap samples (cfu) *P. aeruginosa* cfu

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
transmission in an intensive care unit. Journal of Hospital Infection 102 (2019) 75-81					
Assessment of evidence					
This study investigated the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa*. They also investigated wither *P. aeruginosa* could be removed from contaminated tap and how often water sampling needed to be done in a setting where contamination of tap outlets with *P. aeruginosa* is high. Organism: *Pseudomonas aeruginosa* Transmission mode: Contaminated water system Clinical setting: ICUs in a tertiary referral NHS teaching hospital in England Source: Colonised tap outlet Control measures: New taps installed that can be removed, dismantled and disinfected in a benchtop thermal washer-disinfector. Prior to the intervention, 30% of the outlets were positive at any one time and WGS suggested that least 30% transmission from water to patient. Since installation, weekly sampling of the new tap outlets has been negative for P. aeruginosa, and the number of P. aeruginosa clinical isolates has fallen by 50%. The regression model used to analyse ICU A alone suggested that the only important intervention was the fitting of the new taps. Holistic measures – revised tap-cleaning method, disposal of patient waste water into a sluice or marcerator after addition of absorbent gel sheets. Limitations: The other IPC measures ('holistic masures') were implemented at the same time as the installation of the new taps which makes it difficult to ascertain whether the decrease in *P. aeruginosa* was due to the installation of the new taps.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tissot F, Blanc DS, Basset P, et al. New genotyping method discovers sustained nosocomial *Pseudomonas aeruginosa* outbreak in an intensive care burn unit. Journal of hospital infection. 2016 Sep 1;94(1):2-7.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental (water and tap) samples, genotyping (DLST).

Assessment of evidence

Contamination of the hydrotherapy equipment by DLST 1-18 was the confirmed source of the present outbreak, as this clone was not recovered from any other locations of other ICUs, except for the sink trap of a single room of the neighbouring unit.

Pseudomonas aeruginosa has the ability to survive on wet surfaces allowing widespread contamination of hospital environments in damp area (sinks, traps and pipes). Once PA is established within these environments, PA may persist for months within a unit, allowing continuous transmission to patients.

Organism: *Pseudomonas aeruginosa*

Transmission mode: contaminated environment; however three patients infected with DLST 1-18 had no direct contact with the burn unit or the hydrotherapy room. One patient was hospitalized in the neighbouring unit at the same time and in a bed next to patient 11,

Assessment of evidence
suggesting patient-to-patient transmission. For two patients, no epidemiological link was found, suggesting another unrecognized route of transmission. Clinical setting: ICU – burn unit. Source: environmental contamination (outbreak strain recovered from floor traps, shower trolleys, and shower mattress in the hydrotherapy room). The plastic board under the shower mattress remained wet until re-use for the next patient, thus allowing growth of P. aeruginosa in this moist environment, as confirmed by environmental sampling. Shower trolleys were disinfected with a glucoprotamin-based solution without leaving enough time for this agent to act efficiently. Damaged areas of shower mattresses had been repaired with rubber patches, which were shown to contain P. aeruginosa. Control measures: corrective infection control measures were implemented, including (i) revision of the disinfection protocol of the shower trolley and mattress, (ii) drying of wet surfaces on shower mattress after disinfection, (iii) replacement of all damaged shower mattresses, and (iv) reinforcement of disinfection of sink traps of all rooms of the burn unit by pouring 1 L of bleach down all sinks daily. The incidence of P. aeruginosa recovered from clinical samples in the ICU decreased from 44.7 per 1000 admissions in 2011 to 35.6 in 2012. Limitations: a series of control measures were implemented hence cannot trace back which of those stopped the transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Knoester M, De Boer MG, Maarleveld JJ, et al. An integrated approach to control a prolonged outbreak of multidrug-resistant *Pseudomonas*	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of multidrug resistant (MDR) *Pseudomonas aeruginosa* in the Netherlands (including finding the source) and to	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of	Number of positive samples, patient characteristics and exposure factors, sample type, genotyping results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa in an intensive care unit. Clinical Microbiology and Infection. 2014 Apr 1;20(4):O207-15.			determine the impact of infection prevention and control measures. Patients that acquired the outbreak strain were also enrolled in a case-control study to investigate risk factors for acquiring MDR *P. aeruginosa*.	infection. For the case-control study, the exposure factors were compared between cases (ICU patients that acquired the outbreak strain) and control (ICU patient who tested at least three times negative for the outbreak strain during the follow-up period.)	

Assessment of evidence

Two cluster occurred during this outbreak. A common source was found for one the clusters. Two contaminated faucet aerators were identified. Cross-transmission by medical staff might have occurred as nr of new cases decreased after improvement of IPC measures. Presence of drains were not evaluated; this has frequently been identified as a source of infection.

The case-control part of the study identified that patients who are admitted to ICU subunit I, surgery prior to or during admission and those being warmed-up with the warm-air blanker are independently associated with MDR-PA positivity.

Organism: *P. aeruginosa*

Transmission mode: interpatient transmission by medical staff. (indirect contact)

Clinical setting: ICU

Assessment of evidence
Source: no common source was found. Control measures: Contaminated taps and all tap aerators in ICUs 1-4 replaced in December 2011; a new maintenance protocol was implemented in January 2012 requiring replacement of all tap aerators 4 times per year on all ICUs. Chlorination of sink drains 3 times per week from February 2011 to August 2011 was ineffective. Audit of care-related procedures, cleaning procedures and hygiene measures on ICU. Re-education of ICU staff on hygiene protocols. Implementation of new tracheostomy care protocol. Ban on sharing equipment between patients. Control samples taken in February 2012 were negative.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schneider H, Geginat G, Hogardt M, et al. *Pseudomonas aeruginosa* outbreak in a pediatric oncology care unit caused by an errant water jet into contaminated siphons. The Pediatric infectious disease journal. 2012 Jun 1;31(6):648-50.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results (RAPD-PCR and single-nucleotide polymorphism–type *P. aeruginosa* microarray).

Assessment of evidence
Contaminated aerosols may have emerged from the siphon at every water use. Patients could have acquired infection with the outbreak clone due to inhalation of contaminated aerosols (patients B and C), via smear infection with water drops directly from the water tap (patients B and C) or through horizontal transmission from contaminated persons such as staff or family members (patient A). Organism: *Pseudomonas aeruginosa* Transmission mode: Aerosolisation, indirect contact Clinical setting: pediatric oncology care unit (POCU) Source: contaminated siphons. Control measures: New taps installed across unit to avoid direct water flow into the sink. In 2 isolation rooms, taps replaced with BIOREC taps that allow continuous physical disinfection (heat and ultraviolet) and electromechanical cleaning of the siphons inner wall. Patients and staff were obliged to rinse the water taps with running hot water preceding every water use. POU filters installed on all outlets. Taps in isolation rooms remained negative. Other taps became positive again. No clinical cases in the 2 years after the outbreak.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Amoureux L, Riedweg K, Chapuis A, et al. Nosocomial Infections with IMP-19− Producing *Pseudomonas aeruginosa* Linked to	Outbreak investigation	**Level 3**	The aim of this study was to investigate a IMP-19-producing *Pseudomonas aeruginosa* outbreak in France and to find the source.	Molecular genotyping results between clinical strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to	Number of positive samples, sample type, genotyping results (pulsotypes by PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Contaminated Sinks, France. Emerging Infectious Diseases. 2017 Feb;23(2):304.				determine the source of the outbreak.	
Assessment of evidence					
An environmental investigation was carried out in a hospital. >100 environmental samples were collected. Water samples were collected from different faucets (nursing room, medication preparation rooms, and rooms of some patients). Sink and shower drains were also sampled as well as toilets. The 7 clinical isolates belonged to 3 distinct genotypes A, B, and C. Of the 7 environmental isolates of *P. aeruginosa* we identified, 6 belonged to the same genotype as clinical isolates (genotype A). The diversity of species found and genetic structures involved with *bla*IMP-19 indicated that the environmental contamination occurred a long time ago. Organism: *P. aeruginosa* Clinical setting: Haematology department, France Source: Contaminated sinks Control measures: After patient 7 died of sepsis, all drains in the ward were replaced. Replacing the drains did not eradicate the biofilm in the plumbing system. The decision was made to completely rebuild the ward.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hota S, Hirji Z, Stockton K, et al. Outbreak of multidrug-resistant	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas*	Molecular genotyping results between patient strains and *P.*	Number of positive samples, sample type, genotyping results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa colonization and infection secondary to imperfect intensive care unit room design. Infection Control & Hospital Epidemiology. 2009 Jan;30(1):25-33.			*aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	*aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	

Assessment of evidence

Typing was performed using PFGE. This study shows the importance of proper designs of sinks as well as room designs.

Transmission of outbreak organism to patients by means of fluorescent marker testing was visually demonstrated.

Organism: *Pseudomonas aeruginosa*

Transmission mode: probably through contamination of the area where sterile procedures and medication preparation were performed through the splash of drain contents.

Clinical setting: intensive care unit or transplant units of a tertiary care hospital

Source: hand hygiene sink drains

Control measures: Sink were renovated, as follows: traps were replaced; new faucet spouts were installed that did not flow directly into the drain, thereby minimizing splashback; water flow pressure was decreased; a barrier was installed between the sinks and adjacent preparatory areas; and patient care materials were moved more than 1 m from sinks. A 7% accelerated hydrogen peroxide gel was poured into sink drains and left for 5 minutes; sink surfaces, including the interior of faucet spouts, were exposed to a 1: 16 dilution of the

Assessment of evidence
same product for 5 minutes. Gooseneck faucets, drain strainers, and tap covers were submerged in 250 cc accelerated hydrogen peroxide 7% solution (diluted 1:16) for 5 minutes; sink bowls were wiped with accelerated hydrogen peroxide 0.05% wipes.The use of contact precautions (wearing of gowns and gloves by healthcare workers and single room isolation of the patient) for all colonized or infected cases; staff education. Environmental screening more than 1 year after the termination of the outbreak showed that the organism persisted in many drains; however, only 1 new infection was identified on the previous outbreak unit. Limitation: control measures part of bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gbaguidi-Haore H, Varin A, Cholley P, et al. A Bundle of Measures to Control an Outbreak of *Pseudomonas aeruginosa* Associated with P-Trap Contamination. Infect Control Hosp Epidemiol. 2018;39(2):164-169. doi:10.1017/ice.2017.304	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas aeruginosa* outbreak in France including finding the source and to report on the bundle of control measures.	Molecular typing of ESBL- or MBL-producing isolates (patient vs environmental isolates) using pulsed-field gel electrophoresis (PFGE) and multilocus sequence typing (MLST).	Incident rate, infected/colonised patient characteristics, positive cultures (patient and environmental), molecular genotyping.

Assessment of evidence
Overall, 11 patients were colonised or infected with ST235 and 10 patients with ST111. Organism: *Pseudomonas aeruginosa* Clinical setting: Haematology unit, France Source: likely reservoir of the outbreak organism were the P-traps and lower plumbing. Acquisition of the 2 outbreak strains was mainly associated with 2 specific rooms where the environment was contaminated. Control measures: Included (1) a global clinical audit and a reminder on recommendations of hand disinfection opportunities, (2) excreta management, (3) use of gloves, (4) recall of cleaning practices, (5) discontinuation of faeces discharge in the toilets, and (6) removal of hand showers for rinsing the toilets. After the first results of environmental sampling, all taps and all drains of sinks and toilets were replaced. New water outlets were equipped with lockable P-traps and disposable point-of-use water filters that were changed monthly. A bleach solution (water with 2.6% active chlorine) as poured twice weekly into the blocked P-traps to allow a contact time of 15 minutes before rinsing with water. An additional measure was implemented in April 2014: P-traps were changed at patient discharge whenever a patient stay exceeded 1 week. However, the effect of these measures is not included in the study, these are just mentioned in the discussion section. Authors witnessed a recolonization of the new P-traps in rooms hosting patients who were not colonised by the epidemic strains, suggesting that *P. aeruginosa* stayed in the main pipe and recontaminated the P-traps. This explains how the pathogen contaminated new P-traps and drains of rooms hosting patients negative for *P. aeruginosa.*

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Weng MK, Brooks RB, Glowicz J, et al.t Outbreak investigation of *Pseudomonas aeruginosa* infections	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of *Pseudomonas aeruginosa* in the US (incl finding the source) and to	Molecular typing result between patient strain and environmental strain isolated from environmental/water samples were	Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in a neonatal intensive care unit. American Journal of Infection Control 2019; 47: 1148-1150.			determine the impact of infection prevention and control measures.	compared to establish a link of infection.	

Assessment of evidence

Outbreak report: Molecular typing confirmed reservoir in sink plumbing and possible hospital water as source. Potential transmission routes from contaminated breast milk, bathing, incubators. Humidifier reservoirs of incubators were filled with tap water, despite manufacturer instructions recommending distilled water. Parents cleaned reusable breast pump equipment in sinks that were also used for handwashing and other medical purposes.

Organism: *Pseudomonas aeruginosa*

Transmission mode: Contaminated water systems

Clinical setting: NICU, United States of America

Source: Not confirmed, taps/sinks as reservoirs.

Control measures: Hyperchlorination of hospital water with calcium hypochlorite at 200 parts per million (ppm) for 2 hours. Supplemental hypochlorite added at municipal water intakes yielded residual chlorine levels of 2ppm at distal sites until a monochloramine system was installed. Although hyperchlorination reduced post-filter water samples HPCs to <3 CFU/mL, P. aeruginosa was still cultured from first-catch faucet water samples from 3 of 5 NICU faucets sampled. Preparation of breast milk/infant formula outwith splash zones, bathing neonates in sterile water, following manufacturer instructions for breast pump equipment drying and incubator water. Plumbing proximal to NICU sinks was replaced. POU filters installed on all sinks taps. No additional cases (active surveillance on admission) over 1 year after implementation of recommended control measures.

Assessment of evidence
Limitations: Not all patient isolates were available for typing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhang Y, Zhou H, Jiang Q, et al. Bronchoscope-related *Pseudomonas aeruginosa* pseudo-outbreak attributed to contaminated rinse water. American Journal of Infection Control. 2020 Jan 1;48(1):26-32.	Outbreak investigation	**Level 3**	The aim of this study was to investigate an increase in *Pseudomonas aeruginosa* isolated from bronchoalveolar lavage fluid of patients (including finding the source) and to determine the impact of infection prevention and control measures.	Contamination rates of *P aeruginosa* to establish link of infection.	Number of positive samples, sample type, typing results (multilocus sequencing and PFGE).

Assessment of evidence
The contamination source could not be conclusively determined. MRCE was suspected as the contamination source. Only one clinical isolate was linked to a strain derived from a bronchoscope. Organism: *P. aeruginosa* Transmission mode: indirect contact. Clinical setting: bronchoscopy unit

Assessment of evidence
Source: sink connecting tube was implicated as the source of *P aeruginosa* contamination to bronchoscopes. Control measures: A series of control measures were implemented: faucets of rinsing sink were disinfected and replaced; filter devices for air and rinsing water were replaced as well as drainpipes; high-level disinfection flush of water supply pipes of MRCE was performed with trichloroisocyanuric acid (Lionser, Zhejiang, China); and the water inlet pipes were replaced. However, the combination of all of these measures did not prevent the detection of *P aeruginosa* from bronchoscopes, rinsing water, and connecting tube of MRCE. Finally, all the sink connecting tubes of MRCE were replaced, and no *P aeruginosa* were subsequently recovered from MRCE and bronchoscopes cleaned in this equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B et al. *Pseudomonas aeruginosa* Outbreak in a Neonatal Intensive Care Unit attributed to Hospital Tap Water. Infection control & hospital epidemiology. 2017 Jul;38(7):801-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence
PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient. Organism: *Pseudomonas aeruginosa* Transmission mode: Unclear, however it was noted that washing hands with infected water may have contributed. Clinical setting: Newly built community-based hospital, 28-bed neonatal intensive care unit in the United States of America. Source: Tap water Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model. They were reinstated after cases appeared again. Case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured. Outbreak was considered over after substantial reduction of P. aeruginosa in water samples was achieved and no new cases were reported. Limitations: Due to the size of the NICU, matching of cases and controls using a ratio greater than 1:1, matching by NICU admission date, or multivariable modelling could not be done.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bukholm G, Tannæs T, Kjelsberg AB, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a multidrug-resistant *Pseudomonas*	DNA fingerprinting results (AFLP) between clinical strains and	Number of positive samples, sample type, DNA

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
An outbreak of multidrug-resistant *Pseudomonas aeruginosa* associated with increased risk of patient death in an intensive care unit. Infection Control & Hospital Epidemiology. 2002 Aug;23(8):441-6.			*aeruginosa* outbreak in Norway (including finding the source) and to determine the impact of infection prevention and control measures.	*Pseudomonas aeruginosa* isolated from environmental/water samples were compared to determine the source of the outbreak.	fingerprinting results (AFLP).

Assessment of evidence

Outbreak eventually stopped after implementation of the pasteurization procedure for water taps and use of sterile water for drugs and food.

Organism: *Pseudomonas aeruginosa*

Transmission mode: indirect transmission

Clinical setting: ICU

Source: tap water

Control measures: Contact isolation regimens were implemented in rooms with contaminated patients, change of AB policy. Pasteurisation of the water taps was implemented; staps were heated to 75 C for 60 minutes once every week. No new infections recorded after tap pasteurisation.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Engelhart S, Krizek L, Glasmacher A et al. *Pseudomonas aeruginosa* outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment. Journal of Hospital Infection (2002) 52: 93-98	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *P. aeruginosa* associated with contamination of surface cleaning equipment in a hematology-oncology unit in a hospital in Germany.	Molecular typing (PFGE) result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

A total of 6 Cases identified as nosocomial infection as per CDC guidance. *P. aeruginosa* was isolated from six of 133 (4.5%) `sanitary equipment' samples (taps, 2; washbasin drains, 2; shower water, 1; tap water, 1), and from eight of 40 (20.0%) `surface cleaning equipment' samples (cleaning cloths, 4; mops, 2; cleaning solutions, 2) from both cleaning trolleys. None of 36 samples from dry environmental surfaces yielded *P. aeruginosa.* All water samples were pre-flush.

The environmental isolates (11) belonged to seven different PFGE types, two of which (i.e., PFGE types A and C) were identical with the PFGE types of the clinical isolates.

Organism: *Pseudomonas aeruginosa*

Clinical setting: Haemato-oncology unit, Germany.

Assessment of evidence
Transmission mode: unconfirmed (cleaning equipment may have been a vehicle for environmental transmission in the unit) Source: Sinks/taps/showers as reservoirs (and potential source) but cannot rule out patient as source for transmission Control measures: filters fitted to showers and taps, regular disinfection of sink drains using peroxide disinfectant, re-adoption of disinfectants rather than detergents for patients immediate environment. One further case in the following 6 month period. Genetic relatedness: “Genotypic analysis by pulsed-field gel electrophoresis showed different patterns for all (N = 6) of the patient isolates, however, two of the patient isolates were identical in comparison with environmental isolates from cleaning equipment (four samples) and sanitary equipment (one sample).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ambrogi V, Cavalie L, Mantion B, et al. Transmission of metallo-b-lactamase-producing *Pseudomonas aeruginosa* in a nephrology-transplant intensive care unit with potential link to the environment.	Outbreak report	**Level 3**	This study reports on a cluster of five cases of infection with metallo-beta-lactamase producing *P. aeruginosa* in a nephrology-transplant ICU in France.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection 92 (2016) 27-29					

Assessment of evidence

Genetic relatedness: All 5 clinical strains showed the same antibiotype (sensitive only to colistin), possessed bla_{vim-2} genes expressing VIM-2 carbapenemase and were genetically indistinguishable. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). No water contamination in any other areas of hospital.

Organism: *Pseudomonas aeruginosa*

Clinical setting: Nephrology transplant ICU, France.

Transmission mode: Unknown (authors hypothesised that HCWs touching taps when washing hands may have cross-transferred from patients).

Source: Sinks as reservoirs and potential source

Control measures: Replacement of sinks/taps with ones that have a larger space between the tap and the basin. ABHR use reinforced and regular flushing of outlets instigated (presumably had not been happening before). No new cases detected after taps replaced.

Limitations: no details on how the water samples were taken or if this extended beyond just tap water samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Regev-Yochay G, Smollan G, Tal I, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *OXA-48–producing Serratia marcescens* in the ICU in Israel	Molecular typing results between patient strains and *S. marcescens* isolated from	Number of patients with CPE infection/colonisation and their clinical characteristics,

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sink traps as the source of transmission of OXA-48–producing *Serratia marcescens* in an intensive care unit. Infection Control & Hospital Epidemiology. 2018 Nov;39(11):1307-15.			(including finding the source) and to determine the impact of infection prevention and control measures.	environmental/water samples were compared.	environmental samples (source, results and number of isolates), typing results (PFGE).

Assessment of evidence

Extensive control measures were put in place and carried out, but contamination of sinks seemed to be recurring. Using a combined intervention (including educational component, reducing environmental contamination load) the outbreak was contained 12 months after the start of the outbreak.

Organism: CPE, *S. marcescens* (OXA-48–producing *S. marcescens*)

Transmission mode: indirect contact of the sinks

Clinical setting: ICU

Source: sink

Control measures: enhanced control measures were undertaken, including increased hand hygiene observations as well as educational sessions. Thorough cleaning of all surfaces and medical devices with 1,000 PPM sodium hypochlorite and quaternary ammonium, accordingly, was carried out. After identification of the sink as the source of transmission: 2 main measures were carried out: (1) sink-trap decontamination efforts and (2) an educational intervention enhancing specific infection control measures and focusing on the sink as a

Assessment of evidence
source of transmission. All sink traps were replaced, water supply was treated according to Legionella protocol (heating and hyper chlorination of the main water tank and terminal points for 12 hours with free residual chlorine (20–30 mg/L). Although there was continuous growth of S. marcescens in some of the sink traps in the ICU for >11 months, transmission to patients ceased.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Umezawa K, Asai S, Ohshima T, et al. Outbreak of drug-resistant *Acinetobacter baumannii* ST219 caused by oral care using tap water from contaminated hand hygiene sinks as a reservoir. American Journal of Infection Control. 2015 Nov 1;43(11):1249-51.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a drug-resistant *Acinetobacter baumannii* outbreak in Japan (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared to determine the source of the outbreak.	Number of positive samples, sample type, genotyping results (rep-PCR and MLST).

Assessment of evidence
Not clear how contamination occurred. It is possible that it happened from HCW. Also by amplification in outlet. Authors suggest oral care using contaminated tap water as the transmission route.

Assessment of evidence
Organism: *Acinetobacter baumannii* Transmission mode: unknown Clinical setting: emergency intensive care unit Source: colonization in water systems Control measures: use of all 10 hand hygiene water sinks was prohibited. The sinks, automatic taps, tubes, and hot and cold water mixture unit were replaced. Cleaning of the water tap was added to the daily sink cleaning routine. On day 26, the method of oral care was changed to a waterless technique, performed by wiping the teeth and gingiva with a swab after moistening the tissue with sterile water (dry oral care) under the guidance of a dental hygienist. Up to that time, conventional oral care had been performed by nurses using a toothbrush, toothpaste, and tap water while suctioning (wet oral care). No infection detected in the routine active surveillance cultures of any patients over the next 6 months. Limitation: combined control measures were implemented, therefor not able to pinpoint which of those was responsible for the control of the outbreak.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lv Y, Xiang Q, Jin YZ, et al. Faucet aerators as a reservoir for Carbapenem-resistant *Acinetobacter baumannii*: A healthcare-	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Acinetobacter baumannii* (including finding the source) and to determine the impact of infection	Molecular typing results between patient strains and *Acinetobacter baumannii* isolated from environmental/water samples were compared	Number of positive samples, sample type, typing results

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
associated infection outbreak in a neurosurgical intensive care unit. Antimicrobial Resistance and Infection Control 2019; 8 (1) (no pagination).			prevention and control measures.		

Assessment of evidence

Typing results found that the outbreak strain was only found in the faucet aerator of the dining room, used by HCWs. The faucet aerator may have acted as a reservoir for bacteria in the outbreak, and contamination of the faucet aerator might have occurred from splashes originating from handwashing by the healthcare workers (HCWs).

Organism: Carbapenem-resistant *Acinetobacter baumannii* (CRAB)

Transmission mode: Possible transmission from the contaminated tap to the patient via contaminated HCW hands – not confirmed.

Clinical setting: Neurosurgical intensive care unit (NSICU) in a tertiary hospital in China.

Source: Unknown (could have been municipal water, pipeline, or hands of medical staff). Faucet aerator was a likely reservoir – see limitations.

Control measures: Intensive infection control measures (strengthening hand hygiene measures, isolation, fluorescent labelling to control cleaning, aerosolized hydrogen peroxide to carry out terminal disinfection, contact precautions, cessation of unnecessary transfer of patients, retraining of staff on emergency response to HAI) and environmental microbial sampling were implemented immediately, but their effects were poor. Use of all faucet aerators in the NSICU was then stopped. Following the emergency response process, an outbreak control team was established including an infection control officer, bacteriologists, cleaning staff, NSICU doctors, and nurses.

Assessment of evidence
Limitations: the sampling was carried out AFTER control measures were implemented, therefore may not have represented what was present at the time of infection/colonisation. Hands of HCWs were not sampled after washing under the contaminated faucet, therefore there is a lack of direct evidence to support the stated mode of transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Livni G, Yaniv I, Samra Z, et al. Outbreak of *Mycobacterium mucogenicum* bacteraemia due to contaminated water supply in a paediatric haematology-oncology department. Journal of Hospital Infection, 70; 253-258, 2008.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Mycobacterium mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Mycobacterium mucogenicum* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (RAPD).

Assessment of evidence
Organism: *Mycobacterium mucogenicum* Source: Contaminated automatic water tap. Clinical setting: Paediatric haemato-oncology Cultures of the water specimens from the two automatic/sensor faucets out of three tested yielded *M. mucogenicum*. No microorganism was identified in specimens from the regular (manual) faucet or the ice machine. The outbreak was caused by two different *M. mucogenicum* clones (identified by RAPD); one of them was traced to an automatic water faucet. Free chlorine concentrations during the six-month study period measured <0.1 ppm intermittently at the taps on the seventh-floor ward, whereas levels in the lower floor and basement were appropriate (0.1-0.5 ppm). chlorine levels measured periodically from two to six months later (starting April 2000) were in the normal range. Control measures: Contaminated automatic/sensor taps changed to manual taps. Surveillance cultures taken one month and six months later were negative, however it's not clear if this was due to the control measures or because the chlorine levels had returned to acceptable levels.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baird, S.F., Taori, S.K., Dave, J., et al. Cluster of non-tuberculous mycobacteraemia associated with water supply in a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a cluster of CVC-associated NTM bacteraemia over a 10-month period in a haemato-oncology unit at the Western General Hospital in	N/A	Number of positive samples, sample type and species.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
haemato-oncology unit. Journal of Hospital Infection, 79; 339-343. 2011.			Edinburgh and to determine the impact of infection prevention and control measures.		

Assessment of evidence

Organism: NTM (*M. mucogenicum, M. chelonae, Mycobacterium* spp.)

Transmission mode: possibly patient washing using tap water, proposed entry via Hickman lines (CVCs).

Clinical setting: Haemato-oncology unit.

Source: water system.

Control measures: the cold water storage tanks supplying the transplant unit were cleaned and disinfected with chlorine dioxide. The ballcocks to the tanks and hot water pressure pumps were also removed and either cleaned or replaced. As stagnation of the tanks was thought to be a contributory factor, the tanks were rebalanced to allow the regular flow of water, and a system to maintain this was implemented. Subsequently, only one tank was available for use at a time and the other tank was emptied and shut down to ensure good flow of water. All showerheads and hoses were replaced, shower curtains were removed, and subsequently showers were treated as wet rooms. As biofilms re-accumulate with time, a package of preventive measures and maintenance was introduced, which included regular 12-weekly cleaning and chlorination of the hose, showerheads, washbasins and drain taps. Flushing of showers for 2 min before every use was also introduced. To prevent further cases, Hickman line Interlink connectors were replaced with Bionector connectors, which have fewer connections and a tighter seal. Prior to the cluster, Hickman line insertion sites and ports were covered with dressings, which were removed for showering. This practice was changed to the use of transparent semipermeable polyurethane dressings, which are maintained while showering. These ensure protection of the entry site of the Hickman line and easy visual inspection. Nursing staff and patients were re-educated in relation to these changes in practice, and the principles of good Hickman line care were reinforced.

Assessment of evidence
Limitations: Similar species matched between patient and water sources however not clear if matching of patient and environmental isolates attempted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M et al. Pseudo-outbreak of Mycobacterium chimaera through aerators of hand-washing machines at a hematopoietic stem cell transplantation center. Infection Control & Hospital Epidemiology (2019), 40, 1433–1435	Outbreak report	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared	Number of positive samples, sample type, typing results.

Assessment of evidence
This study reports a pseudo-outbreak of *Mycobacterium chimaera* due to biofilms in aerators on the faucets of handwashing machines (HWMs). Definition of pseudo-outbreak not defined. From context in paper it seems to refer to cases who do no experience clinical illness. Organism: *Mycobacterium chimaera*

Assessment of evidence
Transmission mode: Contaminated water system Clinical setting: 28 bed Hematopoietic stem cell transplantation (HSCT) Centre in Japan Source: Biofilm on the aerators of the handwashing machines in each patient's room Control measures: Replacement of aerators and related part every 6 months. Communication with facilities maintenance personnel including officers and mechanics, to incorporate this replacement into routine work.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wolf I, Bergervoet PW, Sebens FW, et al. The sink as a correctable source of extended-spectrum β-lactamase contamination for patients in the intensive care unit. Journal of Hospital Infection. 2014 Jun 1;87(2):126-30.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonization of extended-spectrum b-lactamase-positive bacteria (ESBLs) in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures (for example self-disinfecting siphons).	Molecular typing results between clinical strains and ESBLs isolated from environmental/water samples were compared to establish a link of colonization.	Number of positive samples, sample type and species, genotyping results (AFLP).

Assessment of evidence
Patients were not infected but colonized. ESBLs originating from sinks in patient's rooms were linked to patients who stayed in ICU. Organism: extended-spectrum b-lactamase-positive bacteria (ESBLs), Transmission mode: Assuming indirect contact; however this is not confirmed from the study. Clinical setting: ICU Source: sink (contaminated water systems). Control measures: All 13 siphons from sinks in the ICU patient rooms and five siphons from sinks at other locations where medical workers wash their hands frequently (two toilets, the medication room, the scullery room and the staff room) were replaced with taps that have permanent physical disinfection (heating and ultrasound) and electromagnetic cleaning and antibacterial coating. To monitor the effect of this intervention, all 18 sinks were sampled for the presence of ESBL 1,2,3,4,6,8 months after the intervention. During month 8, samples were cultured non-selectively to determine the whole microbial flora present in the sinks. Non-selective cultures eight months after the intervention showed no growth in 11 out of 18 sinks. Positive cultures contained small amounts of coagulase staphylococci and Bacillus spp. Limitation: positive clinical strains were only compared to isolates taken from sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (including finding	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were	Number of positive samples, sample type, typing results (PFGE)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.			the source) and to determine the impact of infection prevention and control measures.	compared to establish a link of infection.	

Assessment of evidence

The outbreak of this particular organism led to bloodstream infections. The outbreak was linked to several aspects of the pharmacy layout and the preparation and handling of medications that likely facilitated the exposure of locally compounded infusates and/or associated tubing to water or splash from the sink (including. presence of sink in cluttered pharmacy clean room, placement of infusate bags on counters adjacent to the sink, inadequate hand drying by staff.

Primary source associated with the pharmacy clean room sink not identified. *P. agglomerans* not identified in sink associated with pharmacy clean room

Organism: *Pantoea agglomerans*

Transmission mode: indirect/aerosolisation.

Clinical setting: oncology clinic.

Source: pharmacy sink, however primary source associated with this, not identified. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping. Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding.

Assessment of evidence
Reinforcing proper hand hygiene and medication preparation practices as well as implementing appropriate environmental controls in the pharmacy, including the removal of the clean room sink and the avoidance of any source of water near the hoods. Chemotherapy preparations were moved off-site and improved the building water system. Apart from 1 additional case of Pantoea BSI in a patient exposed before these interventions, no further cases were identified during the following year.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kotsanas D, Wijesooriya WR, Korman TM et al. "Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. Medical Journal of Australia. 2013 Mar;198(5):267-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant Enterobacteriaceae (CRE) cluster in the ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and CRE isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence
Molecular typing is performed. CRE is reported from an ICU and from identical organism isolated from patients and an environmental source (sink). However, other factors (due to lack of IPC measures) might have been facilitating transmission. Organism: Carbapenemresistant Enterobacteriaceae (CRE)

Assessment of evidence
Transmission mode: Indirect contact Clinical setting: ICU Source: uncertain, sinks drains found to be contaminated. It was reported that clinical waste and residual antibiotics were being disposed of in clinical hand wash sinks. A single brush was being used to clean down all the sink drains on the unit, without disinfection between sinks. Control measures: cleaning and decontamination the sinks using detergents and cleaning proved unsuccessful. First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard MM, et al. Investigation of an *Enterobacter hormaechei* OXA-436 carbapenemase outbreak: when everything goes down the drain.	Outbreak investigation	**Level 3**	The aim of the study was to investigate a *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene outbreak (including finding the source) and to determine the impact of infection	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Timeline of outbreak and overlap of patients, amount of positive environmental samples, whole genome sequencing results (MLST types).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infect Prev Pract. 2022;4(3):100228. Published 2022 Jun 30. doi:10.1016/j.infpip.2022.100228			prevention and control measures.		

Assessment of evidence

This study investigated an outbreak of *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene in the Cardiology department of a hospital in Denmark. Various environmental swab samples were taken (from shower drains, floor drains below sinks, sinks, bedpan boilers/instrument washers) and WGS results (MSLT types) revealed a link between patient strains and two environmental strains taken from the shower drains in the only two patient bathrooms in the unit. Staff reported that these drains had a tendency to become partly blocked resulting in regular overflow of water from the drains while patients were showering. Outbreak measures described below resolved the outbreak and no new cases nor new positive environmental samples were found after 3 years.

Organism: *Enterobacter hormaechei* OXA-436 carbapenemase

Transmission mode:

Clinical setting: Cardiology department.

Source: Shower drains (overflow of water from clogged drains while showering)

Control measures: Physical floor grate and traps were changed and fixed to the drain. The bathrooms were emptied and cleaned. The part of the floor drains, that wasn't possible to change were manually cleaned and afterward rinsed with vinegar. Finally the bathrooms were disinfected with vaporized hydrogen peroxide (RHEA Compact) following cleaning. The shower heads were relocated so that the water did not hit the drain directly (reducing splash risk). The waste pipes were cleaned and the function of the drains and sewer system re-established to prevent overflow. In addition to the regular cleaning of the two bathrooms, an extra daily cleaning with chlorine disinfection of all contact points was established.

Assessment of evidence
Limitations: Patient characteristics are not provided, only that the patients were admitted to the same department (different times 6/7).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Starlander G, Melhus Å. Minor outbreak of extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* in an intensive care unit due to a contaminated sink. Journal of hospital infection. 2012 Oct 1;82(2):122-4.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a extended-spectrum β-lactamase-producing *Klebsiella pneumoniae* outbreak in Sweden *(*including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumoniae* isolated from plughole samples were compared to establish link of infection.	Number of positive samples, sample type, genotyping results (PFGE).

Assessment of evidence
The cultures from the plughole showed growth of an ESBL-producing *K. pneumoniae*, exhibiting a DNA pattern identical to that of the patient isolates. Organism: *Klebsiella pneumoniae* Transmission mode: Unknown Clinical setting: Neurosurgical intensive care unit, Sweden

Assessment of evidence
Source: Contaminated sink Control measures: Sink and plumbing replaced. Waste was no longer disposed of into sinks. An active patient surveillance strategy was in place for one month (admission screening for outbreak strain before discharge from the source room). The plughole was cultured every 3 months for the duration of 1 year. Sink remained negative and no further cases. Limitation: only samples from the sink drain were collected.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lowe C, Willey B, O'Shaughnessy A et al. Outbreak of Extended-Spectrum β-Lactamase–producing *Klebsiella oxytoca* infections associated with contaminated handwashing sinks. Emerging infectious diseases 18.8 (2012): 1242.	Outbreak investigation	**Level 3**	This paper describes a retrospective review and investigation of a *K. oxytoca* outbreak in an ICU of an acute tertiary care hospital in Canada.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

Among 27 patients, 24 patients had 25 hospital-acquired infections (9 UTI, 4 of them bacteremic; 8 asymptomatic bacteriurias; 4 soft tissue infections, 1 of them bacteremic; 3 primary bacteraemia's; and 1 pneumonia with bacteraemia).

In 11 cases, clinical cultures were preceded by identified rectal colonisation; median time to first identification of a clinical isolate after recognition of colonisation was 10 days (mean 12.5 days, range 1–31 days). Isolates were considered hospital acquired if the first specimen (clinical culture or rectal swab) yielding resistant *K. oxytoca* was obtained >3 days after the admission date or if the specimen was obtained <3 days after admission in a patient who had been hospitalised at the outbreak hospital within the previous 3 months.

Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Organism: Extended-spectrum b-lactamase-producing *Klebsiella oxytoca.*

Clinical setting: ICU, Canada.

Transmission mode: unconfirmed.

Source: sink drains as reservoir.

Control measures: Although intended only for hand hygiene, foot-operated sinks were also used for disposal of fluids, including body fluids. When sinks were identified as a potential reservoir, use of the sinks for hand hygiene only was reinforced. Attempts were made to reduce or eradicate *K. oxytoca* contamination by cleaning sinks and leaving them unused for 48 hours with disinfectant standing in traps. When this process failed, routine daily sink disinfection was initiated; sink surfaces, including taps, rims of sinks, and basins, were cleaned with a 1:16 dilution of Virox and ≈250 mL of the diluted solution was poured down the drain. Neither this daily cleaning, nor month-long trials of cleaning with bleach and with a foaming hydrogen peroxide product, resulted in reduced sink colonization rates. Sink cleaning was increased to 2×/ day in late 2007 and 3×/day in August 2008 but compliance was poor. The average rate of sink contamination during the outbreak period was 16.4% (149/910). After implementation of 3×/day cleaning/disinfection of sinks (October–December 2008), the sink colonisation rate decreased to 3.9% (3/77) during the quarter; the rate increased to 16.7% (71/424) the following quarter (January–March, 2009), when adherence to routine sink cleaning was noted to have decreased. During February–June 2010, all drains were changed, eliminating the connection with the overflow drain; the overflow holes were decommissioned; the strainers in the sink basin were replaced

Assessment of evidence
by strainers containing a larger number of smaller holes to reduce backsplash; and sink traps were replaced. These modifications were temporally associated with persistent declines in the rate of clinical infections. Genetic relatedness: Cultures from handwashing sinks in the intensive care unit yielded *K. oxytoca* with identical PFGE patterns to cultures from the clinical cases.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bousquet A, Van der Mee-Marquet N, Dubost C et al. Outbreak of CTX-M-15–producing *Enterobacter cloacae* associated with therapeutic beds and syphons in an intensive care unit. American Journal of Infection Control 45 (2017) 1160-4.	Outbreak report	**Level 3**	This paper describes the investigation of a 4-month outbreak of extended-spectrum β-lactamase-producing *E. cloacae* between July and November 2013 in an ICU in military teaching hospital in France.	Molecular typing result (RAPD) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
Total of18 ICU patients affected (8 infected, 10 colonised). Sinks and drains tested positive.

Assessment of evidence
Single sink in patient room used for both handwashing and disposal of body fluids, and distance between sink and patient was <1 metre. Hand hygiene with water still being preferred over alcohol gel even when not indicated. Organism: ESBL-*Enterobacter cloacae* Clinical setting: ICU, France. Transmission mode: Unconfirmed Source: sink drains as reservoir (patients likely the original source). Control measures: Replacement of all sink taps in rooms, and of contaminated mattresses (patients decanted for this). Water system treated with chlorine. Disinfection by chlorine treatment of all taps once a week since the end of the outbreak Genetic relatedness: Molecular typing of the ESBL-ECL isolates using RAPD revealed that all clinical and environmental isolates except 1 had the same RAPD profile and therefore were considered likely clonally related.

Question 25: What flushing regimes are recommended for healthcare settings?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings:

“Regular flushing applies to all sporadically used outlets. If used less than once a week, showers should be removed. Safety showers should not be located at the end of lines.”

“During temporary closure of wards or departments, a procedure for flushing the hot and cold water service systems should be instituted. This should include opening all taps and showers for a period of three minutes and flushing WC cisterns etc on a twice-weekly cycle. Alternatively, when this is impracticable, the disinfection procedure recommended for new installations may be carried out immediately prior to occupation. This should be applied upstream of the closed area. Taps that include flow regulation may need to be flushed for

Assessment of evidence
longer than three minutes. In determining the flushing period, consideration should be given to the water pressure and length of dead-legs and spurs in the connecting pipework." "Where it is difficult to carry out flushing to the recommended frequency, stagnant and potentially contaminated water from within the shower and associated dead-leg should be purged to drain immediately before the appliance is used. This procedure must be carried out with minimum production of aerosols. It is important to note the distinction between self-purging and self draining showers. Self-purging showers can be an effective *Legionella* control procedure, while self-draining showers can support the proliferation of *Legionella*." "Risk assessment may indicate the need for more frequent flushing of outlets. It is preferable that this form part of the daily cleaning routine where appropriate. Alternatively, self-purging showers that discharge water to a drain prior to use and without the release of aerosols can be considered."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part C: *Pseudomonas aeruginosa* – advice for augmented care units. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document "identifies methodologies to control and minimise the risks of morbidity and mortality due to *P. aeruginosa* associated with water outlets. It provides guidance on considerations for water outlets and hot and cold water services in augmented care settings; protecting augmented care patients and ensuring a safe environment; and methods of cleaning wash-hand basins and other good hygiene practices to minimise the risk of *P. aeruginosa* contamination." The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings: "All taps that are used infrequently on augmented care units should be flushed regularly (at least daily in the morning for one minute). If the outlet is fitted with a POU filter, the filter should not be removed in order to flush the tap unless the manufacturer's instructions advise otherwise. A record should be kept of when they were flushed. Some taps can be programmed to flush automatically; such flushing may be recorded through the building management system (BMS)."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The Scottish Government CEL 08. Water sources and potential infection risk to patients in high risk units – revised guidance. 2013.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings:					

Assessment of evidence
"Boards must ensure that…all taps in all clinical areas in high risk units (manually or automatically) are flushed daily (and a record kept) to minimise the risk of pseudomonal contamination. Flushing should be for a period of one minute, first thing in the morning, at the maximum flow rate that does not give rise to any splashing beyond the basin."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. PD 855468:2015. Guide to the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages. BSI Standards Publication 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British document provides guidance "on the flushing and disinfection of services supplying water for domestic use within buildings and their curtilages." The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings: Hygiene Flushing – "The system should be flushed weekly (twice weekly in healthcare premises) to maintain a flow of water. The design of the flushing programme should be in accordance with the HSE's Approved Code of Practice L8, and HSG274 Part 2. NOTE This is not

Assessment of evidence
always possible unless the construction company obtains a derogation from the water undertaker, as it could breach legislation on wasting water.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from					

Assessment of evidence

water sources is suspected. The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings:

“Healthcare staff should be aware that under-utilised outlets may increase the risk of water stagnation and subsequent contamination. The EMC and the Unit/Ward clinical manager must ensure that all infrequently used outlets are flushed at least once per week in accordance with National Guidelines for the Control of Legionellosis in Ireland (2009). Outlets in augmented care units that are not in frequent daily use must be flushed on a daily basis.”

In Augmented care, “All water outlets in augmented care units should be in-use multiple times per day. Any water outlet that may not be in frequent daily use should be identified by the unit manager and those outlets must be flushed on a daily basis. Examples of infrequently used outlets may include single en-suite rooms and temporarily closed wards or departments. Outlets that require routine flushing must be documented. Records of flushing must be stored for at least 1 year.”

In Appendix 5: Water Outlet Flushing Protocol, the document states the following.

“Template Rationale: In order to ensure the quality and safety of the water supply it is essential that all infrequently used outlets must be flushed weekly in all areas other than augmented care units. In augmented care units if water outlets are not in frequent daily use, flushing on a daily basis is recommended. This may be determined by local risk assessment in the first instance and should include en-suite facilities in isolation rooms and in clinical areas when temporary service closures take place. To support healthcare facilities the following template is a minimum guide which should be considered further with local risk assessment as it is acknowledged there may be significant variances in each healthcare facility with types of taps and showers, water pressure and contamination levels.

Weekly

- Flushing of infrequently used water outlets
- Run cold for three minutes
- Run hot for three minutes once water is hot

Daily

- In augmented care settings flushing of infrequently used water outlets

Assessment of evidence

- Run cold for one minute
- Run hot for one minute once water is hot

Keep a central register of the flushing regimes for each department including frequencies and ensure signed record of the flushing procedure is available in each clinical area.

Please note: The door(s) to en-suite facilities and bathrooms should remain closed during the flushing period, and a notice should be affixed to the door indicating that cleaning is in progress and that the facility is out of use.

The following staff should be excluded from the flushing procedures:

- Staff with cancer, chronic lung or kidney disease, immunosuppression, especially those on long-term steroid therapy, and staff who have had an organ transplant.
- Staff who believe they are immunocompromised or belong to any of the above categories, should contact the Occupational Health Department in confidence."

On Commissioning and handover of buildings, the document states "Every effort should be made to ensure that new water systems and equipment are supplied free of biofilm. Water distribution systems should be cleaned and disinfected just prior to handover. Buildings should then be occupied and put into use immediately. Where buildings are not put into use immediately a flushing regime must be implemented. A disinfection regime may also be required."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2: Risk assessments	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.					
Assessment of evidence					
"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings: "If there is sufficient and regular movement of hot and cold-water to avoid stagnation and excessive heat gain where outlets might have little or no use, including in areas where there are patients. In augmented care areas flushing should be employed on a daily basis. NOTE 1 Incorporating flushing into the cleaning protocol together with the training of all relevant staff can be used to ensure this is carried out regularly"					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2:	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The control of *Legionella* bacteria in hot and cold water systems. 2014.					

Assessment of evidence

This British document provides “practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999.” The following section(s) are relevant for this research question on what flushing regimes are recommended for healthcare settings:

“The risk from *Legionella* growing in peripheral parts of the domestic water system, such as dead legs off the recirculating hot water system, may be minimised by regular use of these outlets. When outlets are not in regular use, weekly flushing of these devices for several minutes can significantly reduce the risk of *Legionella* proliferation in the system. Once started, this procedure has to be sustained and logged, as lapses can result in a critical increase in *Legionella* at the outlet. Where there are high-risk populations, eg healthcare and care homes, more frequent flushing may be required as indicated by the risk assessment.”

“Infrequently used equipment within a water system (ie not used for a period equal to or greater than seven days) should be included on the flushing regime. Flush the outlets until the temperature at the outlet stabilises and is comparable to supply water and purge to drain. Regularly use the outlets to minimise the risk from microbial growth in the peripheral parts of the water system, sustain and log this procedure once started. For high risk populations, eg healthcare and care homes, more frequent flushing may be required as indicated by the risk assessment”

Question 26: Who should be responsible for flushing?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on who should be responsible for flushing:

“NHS Boards may consider that there are advantages in having the Water Safety Group chaired by Designated Person with executive responsibilities and the ability to exchange information to and from Board level while ensuring that all disciplines (i.e. beyond estates functions) fulfil their particular responsibilities (such as flushing and cleaning procedures).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The Scottish Government CEL 08. Water sources and potential infection risk to patients in high risk units – revised guidance. 2013.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

The following section(s) are relevant for this research question on who should be responsible for flushing:

"Boards must ensure that… all taps in all clinical areas in high risk units (manually or automatically) are flushed daily (and a record kept) to minimise the risk of pseudomonal contamination. Flushing should be for a period of one minute, first thing in the morning, at the maximum flow rate that does not give rise to any splashing beyond the basin."

"It is the intention that the Board Water Safety Group will provide an assurance annually to the NHS Board on compliance with the requirement of this CEL through the Board's annual Controls Assurance process. Accordingly, NHS Boards should report annually confirming compliance or, where compliance has not been met, a plan and timescale for achieving compliance."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2:	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.					

Assessment of evidence

"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on who should be responsible for flushing:

"If there is sufficient and regular movement of hot and cold-water to avoid stagnation and excessive heat gain where outlets might have little or no use, including in areas where there are patients. In augmented care areas flushing should be employed on a daily basis. NOTE 1 Incorporating flushing into the cleaning protocol together with the training of all relevant staff can be used to ensure this is carried out regularly."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on who should be responsible for flushing: “Healthcare staff should be aware that under-utilised outlets may increase the risk of water stagnation and subsequent contamination. The EMC and the Unit/Ward clinical manager must ensure that all infrequently used outlets are flushed at least once per week in accordance with National Guidelines for the Control of Legionellosis in Ireland (2009).”					

Assessment of evidence
On flushing in augmented care, the document states “All water outlets in augmented care units should be in-use multiple times per day. Any water outlet that may not be in frequent daily use should be identified by the unit manager and those outlets must be flushed on a daily basis. Examples of infrequently used outlets may include single en-suite rooms and temporarily closed wards or departments. Outlets that require routine flushing must be documented. Records of flushing must be stored for at least 1 year…The EMC must ensure that regular audit of flushing is performed, documented and actioned.” “The environmental monitoring committee or equivalent committee must ensure a safe water system, appropriate materials, fixtures and fittings for all water outlets and documented flushing of infrequently used outlets.” “The following staff should be excluded from the flushing procedures: • Staff with cancer, chronic lung or kidney disease, immunosuppression, especially those on long-term steroid therapy, and staff who have had an organ transplant. • Staff who believe they are immunocompromised or belong to any of the above categories, should contact the Occupational Health Department in confidence.”

Question 27: What actions can be undertaken to reduce the risk of infection/colonisation associated with direct water usage?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jung J, Choi H-S, Lee J-Y et al. Outbreak of carbapenemase-producing Enterobacteriaceae associated with a contaminated water dispenser and sink drains in the cardiology units of a Korean hospital. Journal of Hospital Infection 104 (2020) 476-483	Outbreak investigation (with case – control study)	**Level 3**	The aim of this study was to investigate a carbapenemase-producing Enterobacteriaceae outbreak in Korea and to find the risk factors for acquiring CPE.	Epidemiologic links between patients and potential environmental sources.	Incidence rate, median days from admission to positive CPE test, proportion of samples with positive CPE results, typing (PFGE analysis)
Assessment of evidence					
Sinks in patient rooms and water dispenser acted as reservoirs (PFGE confirmed) The water dispenser for provision of water to patients was located near a handwashing sink; of note, used dialysing solution after haemodialysis was emptied into this handwashing sink.					

Assessment of evidence
Organism: KPC-producing *Escherichia coli*, NDM-1-producing *Citrobacter freundii*, NDM-1-producing *Enterobacter cloacae* Transmission mode: Contaminated water system Clinical setting: Cardiology and Cardiothoracic surgery intensive care units in a South Korean University Medical Centre Source: Water dispenser, sinks in the patient bathroom Control measures: Water dispenser was removed and bottled water was provided to patients. Sink drains were treated with bleach and afterward replaced. Active surveillance tests and pre-emptive isolation were also carried out alongside “thorough daily cleaning with monitoring and deep terminal cleaning using no-touch disinfection (hydrogen peroxide vapour and ultraviolet area decontaminator)”.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Nakamura S, Azuma M, Sato M et al. Pseudo-outbreak of Mycobacterium chimaera through aerators of hand-washing machines at a hematopoietic stem cell transplantation center. Infection Control & Hospital	Outbreak report	**Level 3**	The aim of this study was to investigate a Pseudo-outbreak of *Mycobacterium chimaera*	Molecular typing results between clinical strains and *Mycobacterium chimaera* isolated from environmental/water samples were compared	Number of positive samples, sample type, typing results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Epidemiology (2019), 40, 1433–1435					
Assessment of evidence					
This study reports a pseudo-outbreak of *Mycobacterium chimaera* due to biofilms in aerators on the faucets of handwashing machines (HWMs). Definition of pseudo-outbreak not defined. From context in paper it seems to refer to cases who do no experience clinical illness. Organism: *Mycobacterium chimaera* Transmission mode: Contaminated water system Clinical setting: 28 bed Hematopoietic stem cell transplantation (HSCT) Centre in Japan Source: Biofilm on the aerators of the handwashing machines in each patient's room Control measures: Replacement of aerators and related part every 6 months. Communication with facilities maintenance personnel including officers and mechanics, to incorporate this replacement into routine work.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Garvey MI, Wilkinson MAC, Holden KL et al. Tap out: reducing waterborne *Pseudomonas aeruginosa*	Before and after study	**Level 3**	Installation of new tap outlets (the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa).*	Contamination at the tap before/after installation of 'test taps' (i.e. engineering solution)	Total viable counts of test tap samples (cfu) *P. aeruginosa* cfu

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
transmission in an intensive care unit. Journal of Hospital Infection 102 (2019) 75-81					
Assessment of evidence					
This study investigated the impact of installation of new tap outlets on the number of outlets colonised with *P aeruginosa*. They also investigated wither *P. aeruginosa* could be removed from contaminated tap and how often water sampling needed to be done in a setting where contamination of tap outlets with *P. aeruginosa* is high. Organism: *Pseudomonas aeruginosa* Transmission mode: Contaminated water system Clinical setting: ICUs in a tertiary referral NHS teaching hospital in England Source: Colonised tap outlet Control measures: Holistic measures – revised tap-cleaning method, disposal of patient waste water into a sluice or marcerator after addition of absorbent gel sheets. Limitations: The other IPC measures ('holistic masures') were implemented at the same time as the installation of the new taps which makes it difficult to ascertain whether the decrease in *P. aeruginosa* was due to the installation of the new taps.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following sections are relevant for this research question on actions that can be undertaken to reduce the risk of infection/colonisation associated with direct water usage. The document provides the following water system components that may mitigate contamination risks:					

Assessment of evidence
“Central absolute bacteria filters – These filters are installed as close to the heat source/calorifier outlet as possible. The filters range in size from 0.2 to 0.65 micron. They operate by continuously cleaning the system and assist in preventing the build-up of deposits at final outlets. They are generally protected upstream by either a 1 or 5 micron particulate filter and in some circumstances by a strainer upstream of that. The pressure drop and/or flow-rate through the filter should be monitored via the Building Management System (BMS). Provided they are installed as close to the heat source/ calorifier outlet as possible and in accordance with supplier/manufacturer specifications and UK HTM 04-01, they may be a cost effective method to reduce system particulate and sediment levels. Intelligent water management systems (IWMS) – Intelligent water management systems should be encouraged particularly in new build projects. A life cycle costing appraisal will determine their value for money (VFM) at the design stage. Retrofitting may not be economically viable. Alternately, elements of an IWMS can be installed and linked to the existing BMS on site. Such elements include water meters, temperature sensors, tank level water sensors, control valves, balancing valves, biocide level sensors and pressure drop sensors. A number of companies provide packaged solutions which address these aspects. Some of these packaged intelligent systems provide preventive measures that assist in avoiding stagnation in the water system. They can also reduce personnel and operating costs, for example, through controlled flushing measures carried out in an efficient manner. Overall these systems provide for better water quality management, enabling better control, monitoring, recording and communication, all of which are essential elements of a water management system in a healthcare facility. However, the water distribution system’s pipework must be configured appropriately to work with IWMS Other components – The risk assessment may indicate a need to employ a variety of other engineering controls to reduce the risk of contamination, for example: - Backflow prevention devices - Venturi-type valves to induce circulation - Purge valves to dump stagnant water - Balancing valves on the flow and return system - Shunt pumps to reduce stratification in cylinders

Assessment of evidence

- Pressure control and non-return valves to equalise pressures in the hot and cold water supplies to combination taps”

“Clinical areas where patients may be at increased risk of waterborne infection must be identified within each healthcare facility by the environmental monitoring committee or equivalent”

“The healthcare facility manager must ensure that clinical hand wash sinks should be dedicated for the purposes of hand washing only and that alternative sinks and sluices are available for other purposes.”

“Household/cleaning staff must clean clinical hand wash sinks in a manner that minimises the risk of contamination of the tap from organisms in the basin trap.”

“When ice is required, use an automatic dispenser and avoid open chest storage compartment.”

“Sterile water must be used when water is required for administering any medication or treatment requiring water e.g. intravenous medications, nebulisers”

“Ice is not recommended for use in augmented care units and for patients who are at high risk of water-borne infections. Use of ice has been associated with rare but important infections, outbreaks and pseudo-outbreaks”

The document also provides some guidance specific to neonatal units:

- “Infants born at extreme prematurity (less than 28 weeks gestation) may have fragile skin which may breakdown easily during the early days of life; these infants are usually placed in a humidified incubator. Sterile water or saline must be used for washing non-intact skin, including during nappy change.”
- “The neonatal unit manager must ensure that when an incubator is being humidified, a sterile water reservoir and sterile water must be used. The reservoir and water must be changed daily. A re-usable reservoir must be cleaned and sterilised between uses in a central decontamination unit.”
- “Tap water may be used for bathing high risk infants with intact skin, who are not placed in humidified incubators, such as infants <1500g birth weight with central vascular catheters, endotracheal intubation or the presence of other invasive devices, provided there are no current clinical incidents suggesting water system contamination. However, if surveillance of infection identifies an

Assessment of evidence

outbreak or increased incidence of infection with water-borne organisms, sterile water should be used for bathing high risk infants until an infection control investigation and water testing concludes that tap water is safe for bathing."

- "Washing with tap water is indicated for neonates with normal healthy skin without invasive devices."
- "Humidified incubators may be provided for infants less than 28 weeks gestation or birth weight less than one kilogram in order to maintain their body temperature and to reduce fluid loss. These incubators present a potential risk to the occupant for water-associated infection, especially *Pseudomonas aeruginosa*. The neonatal unit manager must ensure that when an incubator is being humidified, a sterile water reservoir and sterile water is used. The reservoir and water must be changed daily. A re-usable reservoir must be cleaned and sterilised between uses in a central decontamination unit."
- "Non-humidified incubators present a lower risk to the occupant from water-associated infection. All incubators should be regularly cleaned and decontaminated by trained competent personnel (once or twice weekly depending on patient risk and between each patient use). The incubator must be completely dismantled, cleaned, decontaminated and dried before using again as per local agreed procedure. The serial number of the incubator must be recorded. There is no requirement to use sterile water to clean incubators. Tap water and detergent may be used. The critical factor is thorough drying of all parts of the incubator and mattress before use."
- "A closed system must be used for infants that require cooling. Sterile water must be used in the system. There should be no direct contact between the infant and the water. Ice or ice packs must not be used for passive or therapeutic cooling."
- "Frozen breast milk may be defrosted safely using one of the following methods:

Defrost using a warming/thawing device designed to ensure no direct contact with the syringe/bottle and non-sterile water

Defrost in a designated milk fridge

Defrost at room temperature and discard any unused milk"

"Frozen breast milk must never be defrosted by placing the container in tap water, unless the tap water has been boiled first."

"Breast or formula milk must never be warmed by placing the container in tap water, unless the tap water has been boiled first."

Assessment of evidence
On use of water for patient care activities in augmented care, the guidance states the following: “Tap water may be used for washing adult or paediatric patients in augmented care units, provided there are no current clinical incidents suggesting water system contamination. Care must be taken during bathing to prevent contamination of invasive devices, as outbreaks of bacteraemia have been described in critical care units following exposure of central vascular catheters to hospital water supply during bathing. For neonates in augmented care units see specific guidance in this Chapter under 4.9 Neonatal Units. Potable mains water may be used for drinking, provided there are no current incidents suggesting water system contamination. Caution is advised when considering water coolers for patient use in high risk areas. Deterioration in water quality may occur due to stagnation or to biofilm formation in taps, filters and/or drip trays, especially if taps are manufactured from plastic.” “Ice is not recommended for use in augmented care units and for patients who are at high risk of water-borne infections. Use of ice has been associated with rare but important infections, outbreaks and pseudo-outbreaks. On occasion, ice may be used for high risk patients when the clinical benefit of using the ice outweighs the risk. In such circumstances, ice should only be used under senior medical instruction.” “With respect to the humidifiers in ventilator circuits and continuous positive airway pressure (CPAP) circuits, sterile water must be used.” “Water for Haemodialysis: Haemodialysis requires water of an appropriate quality in the preparation of dialysis fluid. This is to protect haemodialysis patients from adverse effects from chemical or microbiological contamination in the water or improperly prepared dialysis fluid. Water treatment facilities for haemodialysis in healthcare facilities need an associated quality system that accounts for governance, planning, commissioning, installation, operation, maintenance, and water monitoring.” Dental Chair Unit Water – “Dental chair units are equipped with intricate looms of narrow bore waterlines that are particularly prone to bacterial biofilm contamination. This water is aerosolised by high-speed dental instruments and ultrasonic scalers, thus exposing patients and dental healthcare staff to aerosolised microbial contaminants and bacterial endotoxins. There is no specific Irish or European legislation that regulates the quality of dental waterline output water. However dental waterlines should be disinfected regularly or continuously with a chemical disinfectant/agent that effectively eliminates waterline biofilm and provides good quality output water’”

Assessment of evidence
Therapeutic Pools e.g. Hydrotherapy and Birthing Pools: “Therapeutic pools used in healthcare facilities need to be formally managed to ensure that patients utilising these facilities are not exposed to potential pathogens and avoid acquiring a healthcare associated infection. This is achieved by regular maintenance, chemical disinfection and periodic water quality monitoring.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part C: *Pseudomonas aeruginosa* – advice for augmented care units. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British guidance document “identifies methodologies to control and minimise the risks of morbidity and mortality due to *P. aeruginosa* associated with water outlets. It provides guidance on considerations for water outlets and hot and cold water services in augmented care settings; protecting augmented care patients and ensuring a safe environment; and methods of cleaning wash-hand basins and other good hygiene practices to minimise the risk of *P. aeruginosa* contamination.” The following sections are relevant for this research question on actions that can be undertaken to reduce the risk of infection/colonisation associated with direct water usage.					

Assessment of evidence

- “In intensive care and other critical care areas, where patients are unlikely to be able to use the wash-hand basins, the installation of non-TMV mixing taps may be the preferred control option following a risk assessment.”
- “In new and existing premises, therefore, it is essential that the needs of individual patient washing and bathing requirements are carefully considered. In new premises, the provision, correct siting and installation of showers and wash-hand basins, particularly in accommodation where patients are unlikely to make use of them, requires assessment. For existing premises, and subject to a risk assessment, permanent removal of existing outlets and their associated pipework should be considered.”
- “Owing to their high surface-area-to-volume ratio and location at the tap outlet, certain designs of flow straightener may present a greater surface area for colonisation and support the growth of organisms. Therefore, when selecting new taps, where possible flow straighteners should be avoided/ not included. Health Building Note 00-09 also advises against using aerators in outlets.”
- “Rigorous reinforcement of standard infection control practices should be implemented. This includes regular refresher training for relevant staff.”
- “A TMV that is integral to the body of the tap/shower is preferred, as it is designed to always draw cold water through every time the outlet is used, thus helping to minimise the risk of stagnation”
- “For direct contact with augmented care patients, water of a known satisfactory quality should be used, that is, either:
  i. water where testing has shown absence of P. aeruginosa; or
  ii. water supplied through a POU filter; or
  iii. sterile water (for example, for skin contact for babies in neonatal intensive care units).”
- “Use of single-use cleaning wipes should be considered for patient hygiene.”
- “Clinical wash-hand basins are at particularly high-risk of contamination. It is therefore important to ensure the cleaning of these basins and the taps is undertaken in a way that does not allow cross-contamination from a bacterial source to the tap.”

Assessment of evidence

- "All other uses of water used in augmented care units should be considered and appropriate action/ changes to operational procedures taken. Uses of water to be considered include: i. drinking water fountains; ii. bottled water dispensers; iii. w et shaving of patients who have a central venous catheter inserted into the jugular vein; iv. washing patients with in-dwelling devices"

The document also provides the following notes for consideration in augmented care units:

1. "Tap water should not be used in neonatal units for the process of defrosting frozen breast milk.
2. Water features should not be installed in augmented care units.
3. Chilled water and ice-making machines should not be installed in augmented care units. Where ice is needed for treatment purposes, it should be made using water obtained through a microbiological POU filter or boiled water in sterile ice trays or ice bags"

On "Best practice advice relating to all clinical wash-hand basins in healthcare facilities", the guidance states the following:

"Clinical wash-hand basins should be used solely for hand-washing. In particular, the following dos and don'ts should be noted:

a. Do not dispose of body fluids at the clinical wash-hand basin. Use the slophopper or sluice in the dirty utility area to dispose of body fluids.
b. Do not wash any patient equipment in clinical wash-hand basins.
c. Do not use clinical wash-hand basins for storing used equipment awaiting decontamination.
d. Do not touch the spout outlet when washing hands.
e. Taps should be cleaned before the rest of the clinical wash-hand basin. Care should be taken to avoid transferring contamination from wash-hand basin to wash-hand basin.
f. Do not dispose of used environmental cleaning agents at clinical wash-hand basins.
g. Make sure that reusable containers containing environmental cleaning agents are used in a manner that will protect them from contamination with P. aeruginosa

Assessment of evidence
h. Use non-fillable single-use bottles for antimicrobial hand-rub and soap. i. Consider the appropriate positioning of soap and antimicrobial hand-rub dispensers. The compounds in the products can be a source of nutrients to some microorganisms. Therefore, it is advisable to prevent soiling of the tap by drips from the dispensers or during the movement of hands from the dispensers to the basin when beginning hand-washing. j. Identify and report any problems or concerns relating to safety, maintenance and cleanliness of wash-hand basins to the WSG. Escalate unresolved issues to higher management and/or the IPC as appropriate”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B et al. *Pseudomonas aeruginosa* Outbreak in a Neonatal Intensive Care Unit attributed to Hospital Tap Water. Infection control & hospital epidemiology. 2017 Jul;38(7):801-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the US (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence
PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient. Organism: *Pseudomonas aeruginosa* Transmission mode: Unclear, however it was noted that washing hands with infected water may have contributed. Clinical setting: Newly built community-based hospital, 28-bed neonatal intensive care unit in the United States of America. Source: Tap water Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model. They were reinstated after cases appeared again. Case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured. Limitations: Due to the size of the NICU, matching of cases and controls using a ratio greater than 1:1, matching by NICU admission date, or multivariable modelling could not be done.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wolf I, Bergervoet PWM, Sebens FW et al. The sink as a correctable source of	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonization of extended-spectrum b-lactamase-positive	Molecular typing results between clinical strains and ESBLs isolated from environmental/water	Number of positive samples, sample type and species, genotyping results (AFLP).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
extended-spectrum β-lactamase contamination for patients in the intensive care unit. Journal of Hospital Infection 87 (2014) 126-13			bacteria (ESBLs) in the Netherlands (including finding the source) and to determine the impact of infection prevention and control measures (for example self-disinfecting siphons).	samples were compared to establish a link of colonization.	

Assessment of evidence

This study aimed to "to investigate whether patients in the ICU could have been colonized with ESBLs originating from sinks in the patient rooms, and, if this was the case, whether self-disinfecting siphons could be an effective intervention to prevent future transmissions of ESBLs". Patients were not infected but colonised. ESBLs originating from sinks in patient's rooms were linked to patients who stayed in ICU.

Organism: Extended spectrum β-lactamase bacteria - Enterobacter cloacae was the dominant species. Other species found are *Citrobacter freundii, Citrobacter amalonaticus, Enterobacter aerogenes, Enterobacter amnigenus, Escherichia coli, Escherichia hermanii, Klebsiella oxytoca, Klebsiella ozaenae, Klebsiella pneumoniae, Kluyvera species, Raoultella planticola, Serratia marcescens*.

Transmission mode: Sink to patients, assuming indirect contact; however this is not confirmed from the study.

Clinical setting: ICU in a regional hospital in the Netherlands

Source: Sink

Control measures: All 13 siphons from sinks in the ICU patient rooms and five siphons from sinks at other locations where medical workers wash their hands frequently (two toilets, the medication room, the scullery room and the staff room) were replaced.

Assessment of evidence
To monitor the effect of this intervention, all 18 sinks were sampled for the presence of ESBL 1,2,3,4,6,8 months after the intervention. During month 8, samples were cultured non-selectively to determine the whole microbial flora present in the sinks. Limitation: positive clinical strains were only compared to isolates taken from sinks. Therefore it can be argued that the sink was the actual source, or whether it might have been the reservoir.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kline S, Cameron S, Streifel A, et al. An outbreak of bacteremias associated with *Mycobacterium mucogenicum* in a hospital water supply. Infection Control & Hospital Epidemiology. 2004 Dec;25(12):1042-9.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *M. mucogenicum* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *M. mucogenicum* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
Multilocus enzyme electrophoresis (MEE) and RAPD typing revealed that a blood isolate of M. mucogenicum matched an isolate from a shower in the same room used by the case-patient. Organism: *Mycobacterium mucogenicum*

Assessment of evidence
Transmission mode: Water contamination of central venous catheters (CVCs) during bathing Clinical setting: University – affiliated, tertiary-care medical center Source: Contaminated water system Control measures: The following control measures were recommended and implemented. • Showerheads and hoses on the Bone marrow transplant (BMT) units were replaced. • Shower hoses were allowed to hang straight with no dependent loops when not in use to reduce the risk of bacteria multiplying to higher levels in stagnant water. • Direct care providers, patients and family members were educated on the risks of water contamination of central venous catheters (CVC) during bathing and on prevention methods to minimize water contact during bathing. • IV catheters were disconnected before bathing when possible. • Catheter connections were covered with waterproof material if they could not be disconnected

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hopman J, Tostmann A, Wertheim H et al. Reduced rate of intensive care unit acquired gram-negative bacilli after removal of sinks and	Before and after study	**Level 3**	Removal of sinks from patient rooms and introduction of a method of 'water-free' patient care		Gram-negative bacilli (GNB) colonization rate, calculated as the number of primary positive microbiological results per 1000 ICU admission days, during the pre- and

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
introduction of 'water-free' patient care. Antimicrobial Resistance and Infection Control (2017) 6:59					post-intervention periods. The colonization rates of patients with yeasts were used as a 'negative control', as yeasts do not thrive in sinks and the ICU sinks at all times had been free of yeast colonization
Assessment of evidence					
This 2-year pre/post quasi-experimental study compared monthly gram-negative bacilli colonisation rates pre- and post-intervention using segmented regression analysis of interrupted time series data. Patients were included 12 months before and 12 months after the intervention). Sink removal from ICU patient rooms and swapping tap water to alternative hygiene options incl wipes, alcohol-based hand rub, bottled water and rinse-free shampoo cap. The study was prompted after an outbreak with extended-spectrum β-lactamase (ESBL)-producing Enterobacter cloacae the same ICU which was likely to be related to contaminated sinks. Organism: Gram-negative bacilli (GNB) Transmission mode: not studied Clinical setting: ICU in a tertiary medical center in the Netherlands Source: previous outbreak was linked to sinks Control measures: Removal of sinks from patient rooms and introduction of a method of 'water-free' patient care					

Assessment of evidence
A particular strength of this study is that no changes were made to hand hygiene protocols or transmission-based precautions or cleaning quality/routines or similar processes. Limitations: • Single center study • Sample size not large enough to have infection rate as the main outcome measure – colonisation used instead. • No specifications on organisms or testing methods (culture results collected from medical lab database, from routine SDD screenings) • Mobile hand washing sink needed as back-up in case of serious Clostridium infection outbreak

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kotsanas D, Wijesooriya WRPLI, Korman TM et al. "Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. MJA 2013; 198: 267–269	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant Enterobacteriaceae (CRE) cluster in the ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and CRE isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence
This study describes a Carbapenem-resistant Enterobacteriaceae (CRE) outbreak due to the presence of the metallo-β-lactamase gene bla_{IMP-4} in an intensive care unit (ICU) associated with contaminated sinks. This report highlights the key role of bacterial environmental contamination and sink design and usage in the propagation of CRE outbreaks. Molecular typing is performed. CRE is reported from an ICU and from identical organism isolated from patients and an environmental source (sink). However, other factors (due to lack of IPC measures) might have been facilitating transmission. Organism: CRE (*Klebsiella pneumoniae, Serratia marcescens, Enterobacter cloacae, Escherichia coli*) Transmission mode: Indirect contact Clinical setting: 14-bed ICU in a tertiary referral hospital in Australia Source: Sink drains were found to be contaminated and although PFGE confirms close relationship between clinical isolates of *S. marcescens* and isolates from sink, the authors maintain that they are unable to prove that the sinks were the source of patient infection. Control measures: cleaning and decontamination the sinks using detergents and cleaning proved unsuccessful. “First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Leitner E, Zarfel G, Luxner J, et al. Contaminated handwashing sinks	Outbreak investigation	**Level 3**	The aim of this study was to investigate a KPC-2-producing *Klebsiella oxytoca* clonal outbreak on a	Molecular typing results between patient strains and *P. aeruginosa* isolated from	Number of positive samples, sample type, genotyping results (MLST).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
as the source of a clonal outbreak of KPC-2-producing *Klebsiella oxytoca* on a hematology ward. Antimicrobial agents and chemotherapy. 2015 Jan 1;59(1):714-6			hematology ward in Austria and to determine the source.	environmental/water samples were compared to establish a link of infection.	

Assessment of evidence

The starting point of this Austrian outbreak study started with a colonized patient from the ICU who was later transferred to the hematology ward.

Organism: *Klebsiella oxytoca*

Transmission mode: Indirect/direct/patient-patient. Possible direct contact between the patients (who shared rooms) or through the hands of health care workers. Patients may have been colonised by contaminated aerosols when using sinks for personal hygiene.

Clinical setting: Hematology ward, in a tertiary care facility in Austria.

Source: Contaminated handwashing sink drains

Control measures: Replacement of sinks underway as at time of reporting however no detail was provided about the replacement. Other measures include isolation of colonized patients, enforcement of hand hygiene measures, cleaning ward especially sinks and equipment.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Landelle C, Legrand P, Lesprit P et al. Protracted Outbreak of Multidrug-Resistant *Acinetobacter baumannii* after Intercontinental Transfer of Colonized Patients. Infect Control Hosp Epidemiol 2013;34(2):119-124.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a hospital-wide outbreak of multidrug-resistant *Acinetobacter baumannii* (MDRAB) in France and to determine the source.	N/A	Number of patient cases, environmental sampling results including ward, phase, type of cleaning of positive sample as well as sample type (surfaces, equipment, water, sink or air), genotyping results (MLST).

Assessment of evidence

This French study describes “the protracted course and eventual control of a hospital-wide outbreak of MDRAB that occurred over an 18-month period”. The outbreak involved 86 patients (including the 2 index case patients), with case patients identified from 28 screening samples and 58 clinical specimens.

Organism: Multidrug-resistant *Acinetobacter baumannii*

Transmission mode: Unconfirmed however reservoirs identified in sink traps.

Clinical setting: Hospital wide – 860 bed University Hospital in France

Source: The outbreak MDRAB strain was recovered from 62% of surface samples, 11% of sink trap samples, and 12% of sink water splash samples.

Assessment of evidence
Control measures: Different measures were implemented at different phases of the outbreak. They include: Reinforcement of adherence to standard precautions and implementation of contact precautions for MDRAB carriers. Multiple active auditing of healthcare worker practices were also carried out, including adjustment and education, with special focus on hand disinfection and proper use of gloves. Strict environmental cleaning was enforced, rooms were cleaned two times a day with detergents and disinfectants and with hydrogen peroxide dry mist disinfection process on discharge of carriers from the ICU. Some devices (e.g. sphygmomanometers and stethoscopes) were dedicated for use with carriers when possible and left inside the room. New admissions were stopped on two occasions and patients were cohorted in another ICU. Other measures include hydrogen peroxide vapor disinfection of ICU A, weekly protocol of cleaning all sinks with sodium hypochlorite, revision of patient care and cleansing procedures, and initiation of chlorhexidine body washing for all patients. The disposal of water used for patient body washing in room sinks as well as the use of sink water for nasogastric tube rinsing or oral medicine administration was also forbidden. Limitations: There was no measure/analysis of effectiveness of interventions and the plurality of interventions makes identifying the effective intervention(s) difficult. Isolates were identified by pulsed-field gel electrophoresis and strains were seen as 'identical' by phenotypic analysis – genotypic analysis not shown if done.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. The NHSScotland National Cleaning Services Specification Healthcare	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Associated Infection Task Force. 2016.					
Assessment of evidence					
This Scottish guidance document aims to provide NHS Scotland staff with an overview of up-to-date guidance on “Standard Infection Prevention and Control Precautions (SIPCS), including cleaning and hand hygiene”, which must be embedded into everyday practice. This cleaning specification provides SOPs for specific cleaning tasks and risk assessments. On the method for cleaning sinks, wash hand basins and baths, the document states the following: • “Using a new disposable cloth and 1,000ppm available chlorine, clean tap(s) first. Start at the tap outlet end (do not put cloth inside the tap outlet), finish at the base and then clean tap handles • Using the same cloth clean the accessible part of the overflow or waste outlet to remove visible dirt, dispose of the cloth in the appropriate waste bag. • Using a new disposable cloth clean round the inside of the sink/basin from top rim of bowl”. The document also advises to “always work clean to dirty preventing cross contamination”.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Baker AW, Stout JE, Anderson DJ et al. Tap Water Avoidance Decreases Rates of	Before and after study	**Level 3**	Tap water avoidance (The intervention involved strict unit-wide tap water avoidance for all patients in 3 ICUs	Prevalence of tuberculous mycobacteria isolation pre and post intervention.	The outcome measure was an episode of respiratory non-tuberculous

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hospital-onset Pulmonary Nontuberculous Mycobacteria. Clinical Infectious Diseases 2021;73(3):524–7			and 1 intermediate unit where new lung transplant patients received post op care). The pre-intervention period was defined as August 2013 until May 2014. The intervention period was defined as June 2014 until December 2015.		mycobacteria isolation, defined as a positive culture from a respiratory specimen.

Assessment of evidence

This American study analysed the rates of hospital-onset episodes of pulmonary NTM in ICU and intermediate unit patients during a *Mycobacterium abcessus* complex (MABC) outbreak and in the post-outbreak period, following the introduction of sterile water use to evaluate the impact of tap water avoidance on incidence rate ratios of NTM isolation. They also evaluated if NTM species commonly obtained from patient specimens were also isolated from hospital water outlets." This study provides evidence that avoidance of tap water was associated with a significant decrease in respiratory acquisition of NTM in this ICU patient cohort. The prevalence of positive biofilm cultures for NTM was not significantly different over the study period. More research is required to determine if water free care has additional benefits beyond reduction of acquisition of NTM in respiratory samples.

Organism: Nontuberculous Mycobacteria (*Mycobacterium abcessus, M. chelonae, M. immunogenum, M. avium, M. gordonae)*

Transmission mode: Unclear

Clinical setting: ICU, in a tertiary care hospital in the United States of America

Assessment of evidence
Source: Water system Control measures: Strict unit-wide tap water avoidance for all patients in 3 ICUs and 1 intermediate unit where new lung transplant patients received post op care. “On these 4 units, sterile water that was commercially produced for irrigation replaced tap water for routine activities such as oral care, rinsing of suction catheters, and enteral tube irrigation. Patients were restricted from showering, and bathing was performed with waterless bath products or sterile water. Ice use was also avoided on these units and was not provided for consumption or patient care activities, such as speech therapy assessments.” Outcome: The incidence rate of NTM isolation decreased from 41.0 episodes per 10,000 patient-days during the 10-month outbreak period to 9.9 patients per 10,000 patient-days during the 19-month intervention period (IRR 0.24; 95% CI 0.17-0.34, P<0.001). This is a decrease in acquisition of 76%. The incidence rate of NTM isolation for lung transplant recipients decreased from 28.6 episodes per 10 000 patient-days during the outbreak period to 3.3 episodes per 10 000 patient-days during the intervention period (IRR, 0.12; 95% CI, .07–.20; P < .0001).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Tracy M, Ryan L, Samarasekara H. Removal of sinks and bathing changes to control multidrug-resistant Gram-negative bacteria in a neonatal intensive care unit: a	Outbreak investigation	**Level 3**	The aim of this study was to retrospectively investigate a multidrug-resistant Gram-negative bacteria outbreak in Australia. The intervention was the removal of 6 of 8 handwash sinks and	This study did not provide rates of infection pre and post intervention however detailed the overall numbers of infected/colonised neonates pre and post and provided a description of the	Number of positive patient cases per phase, time to colonisation, intervention measures (and their differences between phases).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
retrospective investigation. Journal of Hospital Infection 104 (2020) 508-510.			strict avoidance of tap water for patient care activities.	incidents in a 10 year follow up.	

Assessment of evidence

This Australian study describes “a historical outbreak of MRGNB in our NICU resistant to conventional infection control interventions and eventually controlled by modification of protocols for bathing infants and removal of sinks, practices beyond the normal strategies for infection control programmes at the time”.

The report divides the outbreak into three phases. In phase 1 of the outbreak, 52 neonates were positive for a multi-drug resistant Gram-negative bacteria (MRGNB). The average number of new cases ranged from 2-12 per week. Average time to colonisation was 10 days (range 0-66). In phase 2, a further 65 neonates were MRGNB positive and in phase 3 of the outbreak (following the water-free intervention which is described in Control measures below), 3 neonates were positive. Some of the environmental isolates were matched phenotypically to clinical colonisation specimens but not by WGS.

Organism: Multi-drug resistant Gram-negative bacteria (MRGNB)

Transmission mode: Presumed – droplets from clinical sinks

Clinical settings: Neonatal ICU in Australia

Source: Contaminated clinical sink drains

Control measures: Extensive cleaning of the ward and sinks. “Sink cleaning included prolonged inundation of the drain with concentrated chlorine solution, dismantling of the sink wastes with mechanical cleaning and replacement of the drainpipes.” MRGNB transmission continued despite these interventions and every sink in the unit was found to contain bla_{IMP4}-positive coliforms on initial screening and half the bays were found to have been recolonized. Following this, hand hygiene and antibiotic controls were intensified but sustained detection continued. A final string of interventions a) Prohibition of routine bathing of neonates in the NICU until NICU discharge, Bathing

Assessment of evidence
could be done in the bed space with bottled sterile water and wipes b) Decommissioning 6 out of 8 clinical sinks and the adoption of alcohol hand rubs as the alternative standard hand hygiene practice. Remaining sinks were used only when required for an aseptic surgical technique. Correspondence from the author: All cases were Enterobacteriaceae (including Carbapenem-resistant organisms like *Serratia*). This study provides evidence that in this ICU, the water-free care initiatives coincided with the reduction in cases of Gram-neg colonisation/infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR 2003; 52 (No. RR-10): 1–48	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on actions that can be undertaken to reduce the risk of infections associated with direct water use. The document provides the following recommendations for immunocompromised patients. ”If *Legionella spp*. are determined to be present in the water of a transplant unit, implement certain measures until *Legionella* spp. are no longer detected by culture. 1. Decontaminate the water supply as outlined previously (Water: IV). 2. Do not use water from the faucets in patient-care rooms to avoid creating infectious aerosols. 3. Restrict severely immunocompromised patients from taking showers. 4. Use water that is not contaminated with *Legionella* spp. for HSCT patients’ sponge baths. 5. Provide patients with sterile water for tooth brushing, drinking, and for flushing nasogastric tubing during legionellosis outbreaks.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Part B: Operational management. 2014.					
Assessment of evidence					
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infections associated with direct water use. "Regular flushing of showers reduces *Legionella*, but *Legionella* can significantly increase in number if regular flushing should cease. The most effective management of showers will be achieved by the removal of unnecessary ones and the regular use of others."					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises Part A: Design, installation and testing. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. This document covers a variety of actions that can be undertaken to reduce the risk of infections associated with direct water use including the fact that shower heads must not be capable of being accidentally immersed in water, come into contact with drains or other potential sources of contamination

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Jolivet S, Couturier J, Vuillemin X et al. Outbreak of OXA-48-producing Enterobacterales in a haematological ward associated with an uncommon environmental reservoir, France, 2016 to 2019. Euro Surveill. 2021;26(21):pii=2000118	Outbreak investigation (including case-control element)	**Level 3**	The study reports the epidemiological and microbiological investigations carried out to control a large and protracted outbreak caused by OXA-48 CPE, mostly *Citrobacter freundii.*	Phylogenetic properties of isolates and epidemiologic links between patients and environmental sources.	Number of clinical cases with OXA-48-producing Enterobacterales infection or colonisation in the haematological ward. Contamination/ growth of CPE in environmental samples. Antimicrobial resistance and typing.

Assessment of evidence
This outbreak highlights the possible role of toilets as a source of transmission of OXA-48 CPE. It was successfully controlled only after replacing all the toilets in the ward.

Assessment of evidence
Organism: A total of 78 OXA-48 CPE were detected including 22 *C. freundii*, 19 *E. coli*, 15 *K. pneumoniae*, seven *Klebsiella oxytoca*, six *Enterobacter cloacae*, two *Citrobacter koseri*, two *Enterobacter aerogenes*, one *Hafnia alvei*, one *Kluyvera cryocrescens*, one *Citrobacter amalonaticus*, one *Morganella morganii*, and one *Raoultella ornithinolytica* Transmission mode: Indirect contact (toilet splashback) Clinical setting: Haematological ward of a French hospital Source: Toilets rims Control measures: “Following the identification of the toilets as a potential source of the outbreak, intensive toilet cleaning with descaling and bleaching (initially daily, then weekly) was implemented. Afterwards, 23 environmental samples were taken (including 21 toilet rims and two drains), and only one toilet remained positive for OXA-48-producing *C. freundii*. This toilet was successfully re-decontaminated by performing a single additional cleaning and bleaching. In August 2018, all toilets bowls and tanks in two units with environmental CPE-positive samples were replaced by rimless toilets. Rimless toilets are easier to clean and reduce the risk of limescale deposits. After implementation of the environmental measures, the incidence of new CPE cases declined, and only two unrelated CPE cases”. Rimless toilets can reduce the risk of infections associated with indirect water use compared to toilet with rims as it is easier to clean and reduced water stagnation/build up of limescale that favours microbial growth.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Building Note 00-10 Part C: Sanitary assemblies. 2013.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British guidance document "outlines the policy and performance requirements for sanitary assemblies used in healthcare facilities. These requirements are a set of essential standards of quality and safety that sanitary assemblies must comply with". The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infections associated with direct water use. "Hospital pattern WCs should be rimless, washdown pans and be of the "back to wall" or wall-hung type with concealed cistern and services." "WC seats should not have a cover. If covers are to be considered, consultation should take place with the control of infection team at the planning stage, although it must be noted that they are not recommended for independent wheelchair and assisted toilets, as they prevent the use of the backrest." Limitations: No link to any evidence – considered best practice guidance.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 64. SHTM Building Component Series: Sanitary Assemblies. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish document provides “guidance to assist the design team in the selection, specification and application of sanitary assemblies in healthcare buildings”. The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infections associated with direct water use. “Hospital pattern WCs should be rimless, wash-down pans and be of the ‘backto-wall’ or ‘wall-hung’ type with concealed cistern and services.” Limitations: no link to any evidence – considered best practice guidance.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gravningen K, Kacelnik O, Lingaas E, et al. *Pseudomonas aeruginosa* countrywide outbreak in hospitals linked to pre-moistened non-sterile washcloths, Norway, October 2021 to April 2022. Euro Surveill. 2022;27(18):2200312. doi:10.2807/1560-	Outbreak investigation	**Level 3**	The aim of the study was to investigate a countrywide *Pseudomonas aeruginosa* (including finding the source) and to determine the impact of infection prevention and control measures. The intervention was discontinuing the use of pre-moistened disposable washcloths once the	Molecular genotyping results of clinical strains were compared to find the common outbreak strain (ST3875). Environmental samples were analysed to find this particular ST3875 to confirm link of infection from the tested product(s).	Timeline of outbreak and overlap of patients, case characteristics (including region, hospital ward, colonisation vs infection and contribution on the cause of death), amount of positive clinical samples and type of sample (blood, urine, airway, wound, other materials), genomic

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
7917.ES.2022.27.18.2200312			source was confirmed.		analyses results (WGS and AFLP).

Assessment of evidence

This outbreak study was prompted after three patients had died of *Pseudomonas aeruginosa* bloodstream infections at the University Hospital of North-Norway (Tromso) in November 2021. Whole genome sequencing revealed that it was caused by the same strain ST3875. Subsequently more cases were identified in several other hospitals within Norway, including Oslo University Hospital where they systematically tested several hundred different products to identify a link of infection (including soaps, creams, toothpaste, gels, washcloths). The same strain ST3875 was found in pre-moistened non-sterile washcloths from a specific manufacturer. By 25 April 2022 (6 months later), ST3875 had been detected by seven different hospital laboratories in 149 of the 577 washcloths tested from four lots produced on multiple dates.

Organism: *Pseudomonas aeruginosa*

Transmission mode: Direct

Clinical setting: Various

Source: pre-moistened non-sterile washcloths

Control measures: Discontinuation of the use of the product (pre-moistened non-sterile washcloths).

Limitations:

- Limited description of environmental sampling methods (how they were taken, how many, which sources etc)
- Possibility that the manufacturer had distributed the contaminated products internationally and therefore the extent of the outbreak could be underestimated. Delay in reporting is also a possibility.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Ambrogi V, Cavalie L, Mantion B, et al. Transmission of metallo-b-lactamase-producing *Pseudomonas aeruginosa* in a nephrology-transplant intensive care unit with potential link to the environment. Journal of Hospital Infection 92 (2016) 27-29	Outbreak report	**Level 3**	This study reports on a cluster of five cases of infection with metallo-beta-lactamase producing *P. aeruginosa* in a nephrology-transplant ICU in France.	Molecular typing results of patient vs environmental isolates.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

Genetic relatedness: All 5 clinical strains showed the same antibiotype (sensitive only to colistin), possessed bla_{vim-2} genes expressing VIM-2 carbapenemase and were genetically indistinguishable. From 37 water samples, 6 were positive and 1 of these matched the outbreak strain (tap in room vacated by infected patient). No water contamination in any other areas of hospital.

Organism: *Pseudomonas aeruginosa*

Clinical setting: Nephrology transplant ICU, France.

Transmission mode: Unknown (authors hypothesised that HCWs touching taps when washing hands may have cross-transferred from patients).

Assessment of evidence
Source: Sinks as reservoirs and potential source Control measures: Replacement of sinks/taps with ones that have a larger space between the tap and the basin. ABHR use reinforced and flushing of outlets instigated (presumably had not been happening before). Limitations: no details on how the water samples were taken or if this extended beyond just tap water samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Hong KB, Oh HS, Song JS et al. Investigation and Control of an Outbreak of Imipenem-resistant *Acinetobacter baumannii* Infection in a Pediatric Intensive Care Unit. Pediatr Infect Dis J 2012;31: 685–690.	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of imipenem-resistant *Acinetobacter baumanii* in a paediatric ICU in a Children hospital in Korea.	Molecular typing results (multilocus sequence typing) between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness
Assessment of evidence					
Environmental samples were obtained from mechanical ventilator devices, respiratory equipment, bed rails, side tables, blood pressure cuffs, door handles, intravenous stands, keyboards, water taps and sinks. Contaminated shallow sink with high water pressure created splashing onto surrounding areas; staff were using towels to soak this up.					

Assessment of evidence
Organism: *Acinetobacter baumannii* Setting: Paediatric ICU, Korea. Transmission route: Unknown Source: Sink drain a reservoir, cannot rule out patient-patient transmission (patient as a source) Control measures: Patient and nurse cohorting, active surveillance on admission, contaminated sink was replaced; following this the rate of colonisation decreased. Genetic relatedness: Multilocus sequence typing analysis linked environmental samples from sink drain and that sink tap water to patient cases.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Gebo KA, Srinivasan A, Perl TM et al. Pseudo-outbreak of *Mycobacterium fortuitum* on a Human Immunodeficiency Virus Ward: Transient Respiratory Tract Colonization from a Contaminated Ice Machine.	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *M. fortuitum* recovered from the respiratory tract of hospitalized patients on an HIV ward in a tertiary hospital in the United States.	Molecular typing results between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Clinical Infectious Diseases 2002; 35:32–8					

Assessment of evidence

40 patient's respiratory samples tested positive – no infection (a pseudo-outbreak).

Water and ice samples taken from 4 different floors in the hospital and from 6 other buildings (cold water supply on entry to ice machine, from the filter, reservoir etc), taps in sputum induction room and patient rooms, mains supply.

Water samples from ice machine tested positive. Mains water negative. Case-control added evidence to the ice machine being the likely source of colonisation for these patients.

Organism: *Mycobacterium fortuitum*

Clinical setting: HIV ward, United States of America

Transmission mode: Direct (ingestion of ice).

Source: Contaminated ice machine.

Outbreak report: Filters added to ice machines – no further cases detected following this.

Genetic relatedness: "Environmental investigation demonstrated that the *M. fortuitum* isolated from patients was identical to the ice machine isolates by pulsed-field gel electrophoresis."

Limitations: Although there are no details given regarding date of positivity since admission (to rule out acquisition outwith the care setting), the epidemiological evidence supports the ice machine as the likely source.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Engelhart S, Krizek L, Glasmacher A et al. *Pseudomonas aeruginosa* outbreak in a haematology-oncology unit associated with contaminated surface cleaning equipment. Journal of Hospital Infection (2002) 52: 93-98	Outbreak report	**Level 3**	This paper describes the investigation of an outbreak of *P. aeruginosa* associated with contamination of surface cleaning equipment in a hematology-oncology unit in a hospital in Germany.	Molecular typing (PFGE) result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

A total of 6 Cases identified as nosocomial infection as per CDC guidance. *P. aeruginosa* was isolated from six of 133 (4.5%) `sanitary equipment' samples (taps, 2; washbasin drains, 2; shower water, 1; tap water, 1), and from eight of 40 (20.0%) `surface cleaning equipment' samples (cleaning cloths, 4; mops, 2; cleaning solutions, 2) from both cleaning trolleys. None of 36 samples from dry environmental surfaces yielded *P. aeruginosa.* All water samples were pre-flush.

The environmental isolates (11) belonged to seven different PFGE types, two of which (i.e., PFGE types A and C) were identical with the PFGE types of the clinical isolates.

Organism: *Pseudomonas aeruginosa*

Clinical setting: Haemato-oncology unit, Germany.

Assessment of evidence
Transmission mode: unconfirmed (cleaning equipment may have been a vehicle for environmental transmission in the unit) Source: Sinks/taps/showers as reservoirs (and potential source) but cannot rule out patient as source for transmission Control measures: filters fitted to showers and taps, regular disinfection of sink drains using peroxide disinfectant, re-adoption of disinfectants rather than detergents for patients immediate environment. One further case in the following 6 month period. Genetic relatedness: “Genotypic analysis by pulsed-field gel electrophoresis showed different patterns for all (N = 6) of the patient isolates, however, two of the patient isolates were identical in comparison with environmental isolates from cleaning equipment (four samples) and sanitary equipment (one sample).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit. Antimicrobial Resistance and	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a teaching hospital in Belgium.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Infection Control (2017) 6:24					

Assessment of evidence

A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission).

Sink drain in this room was positive, as was every other isolation room on the unit.

Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc).

Organism: Enterobacteriaceae

Clinical setting: ICU, Belgium.

Transmission mode: Unconfirmed.

Source: Sink drain as reservoir (and likely source for some patients).

Control measures: daily disinfection of the sinks with a glucoprotamine product was implemented; sinks were dedicated to 'clean work' (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere.

Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kossow A, Kampmeier S, Willems S et al. Control of Multidrug-Resistant *Pseudomonas aeruginosa* in Allogeneic Hematopoietic Stem Cell Transplant Recipients by a Novel Bundle Including Remodeling of Sanitary and Water Supply Systems. Clinical Infectious Diseases, 65(6); 935-942, 2017	Prospective outbreak investigation	**Level 3**	This paper describes the study of microbiological surveillance data on *MDRPa* for 3 years during the reconstruction of a Bone marrow transplantation center in Germany.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

The number of nosocomially-infected patients decreased from 31 in 2012-13 (9.17%) to 3 (1.68%) in 2014 ($p<0.001$).

In 2012-13, 18.94% of toilet samples were positive, 8.11% of shower samples were positive. This decreased to 6.13% of toilets and 2.96% showers in 2014 (both statistically significant reductions). During follow up, 4% of toilets and 5.59% of showers were positive. Sinks tested positive in 0.93% samples in 2012-13 and in zero samples in 2014.

Assessment of evidence
Patients screened on admission and weekly thereafter. WGS indicated a close relationship between patient and environmental isolates however unable to determine exact transmission pathways. Organism: Multi-drug resistant *Pseudomonas aeruginosa* Clinical setting: Haematopoietic stem cell transplant unit, Germany Transmission mode: Unconfirmed. Source: Shower drains and toilets as potential reservoirs, unable to determine exact modes of transmission however this study provides evidence that patients acquired infection likely from an environmental source. Control measures: New shower drains installed (easy to clean/disinfect) with covers (disinfected weekly) to prevent removal by patients. Shower heads and taps fitted with point of use filters. Biorec disinfection units installed underneath all sinks (these use UV light, vibration (50-200 Hz), temperature (85'C) and have an antibacterial coating to prevent biofilm formation. Toilets replaced with rimless toilets and an automatic disinfectant flush (0.5% glucoprotamin). Limitations: some patients not screened weekly due to their clinical situation. Culture method may not have maximised growth of admission screening samples.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Walker J, Wilson B, Laing-Herridge K, et al. A default to standardised 100% single rooms in new hospital builds: a high cost strategy	Letter to editor	**Level 4**	The aim of the audit was to calculate the percentage of showers not used daily in Scottish hospitals.	N/A	Type of ward, sample date, number of patients showered, inpatient numbers, percentage of patients with no shower use.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
with the average non-use of showers in medical wards at 86% daily. J Hosp Infect 2023 2023/04/20. DOI: 10.1016/j.jhin.2023.04.002					
Assessment of evidence					
In this letter to the editor, concerns are raised regarding non-use of showers in Scottish hospitals. An audit of shower utilisation across 4 wards (general medical ward, mixed medical speciality ward, mixed general acute ward, rehab ward) within two Scottish hospitals demonstrated an average daily non-use of showers of 86%. The percentage of showers that were unused was not stated, but it does indicate that the requirement for showers is low in these ward types. The authors argue for a move away from ensuite provision in all rooms, to provision of pre-determined shower facilities per ward (located out with patient rooms) in a bid to reduce the risk of plumbing system contamination and its associated burdens.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Bringhurst J, Weber DJ, Miller MB, et al. A bronchoscopy-associated pseudo-outbreak of Mycobacterium	Outbreak study	**Level 3**	No intervention. Investigation of a pseudo-outbreak of *Mycobacterium mucogenicum* in 15 patients that underwent	N/A	Identification of *M. mucogenicum* in patient and environmental isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
mucogenicum traced to use of contaminated ice used for bronchoalveolar lavage. Infection Control and Hospital Epidemiology, 41 (1): 124-126, 2020.			bronchoscopic lavage.		

Assessment of evidence

19 respiratory samples from 15 patients tested positive for *M. mucogenicum*. Cases were not clinically infected (pseudo-outbreak). Bronchoscopes and automated endoscope reprocessors were negative.

The source was determined to be non-sterile ice from 2 ice machines which was mixed with sterile saline to form a slurry used for bronchoalveolar lavage to reduce the risk of bleeding. Cultures from both ice machines were positive and clonally matched patient isolates by PGFE.

Control measures included ceasing using ice from ice machines for bronchoalveolar lavage; sterile ice was used instead (however the method for producing this ice was not described).

Limitations: the report does not state whether other water sources were tested for the presence of *M. mucogenicum*.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Building Note 00-09 Infection Control in the Built Environment. 2013.	Expert opinion guidance	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This expert opinion guidance advises that ice for consumption by immunocompromised patients should be made with drinking water in single-use ice-making bags placed into conventional freezers. It advises that ice machines should be of a type that dispense ice using a non-touch nozzle. Limitations: no evidence is referenced, therefore this guidance is considered expert opinion.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schuetz AN, Hughes RL, Howard RM, et al. Pseudo-outbreak of Legionella pneumophila serogroup 8 infection associated with a contaminated ice	Outbreak report	**Level 4**	No intervention. Investigation of an - pseudo-outbreak of *Legionella pneumophila* in a bronchoscopy unit involving 13 immunosuppressed patients.	N/A	Analysis of environmental samples to determine a source, use of PFGE to compare with patient isolates.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
machine in a bronchoscopy suite. Infection Control and Hospital Epidemiology, 30(5):461-466, 2009.					
Assessment of evidence					
Cultures from bronchoscopes and water system were negative. Ice from ice machine and samples from the ice machine filters tested positive; one was indistinguishable from 11 isolates recovered from patients. Uncapped saline syringes were placed into ice water (from the ice machine) to use in bronchoscopes to reduce bleeding; this was determined to be the transmission mode to patients via bronchoscopy. Control measures: The practice of placing syringes in ice water was stopped. Ice machine was removed and disinfected and the filter replaced (filter had not been replaced for several year, and there was no maintenance schedule as the machine had been installed by an outside contractor). Ice machine cultures were negative when tested 5 months later.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Durojaiye OC, Carbarns N, Murray S et al. Outbreak of multidrug-resistant *Pseudomonas*	Outbreak report	**Level 3**	This paper reports a nosocomial outbreak of MDR strains of *P. aeruginosa* among 10 patients in a renovated adult ICU	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
aeruginosa in an intensive care unit. Journal of Hospital Infection 78 (2011) 152–159.			in a hospital in the United Kingdom.	compared to establish a link of infection.	

Assessment of evidence

All the 10 samples collected from the taps, water outlets and water supply to the sinks in the unit grew 300 cfu/100 mL of multidrug-resistant *P. aeruginosa*.

Organism: *Pseudomonas aeruginosa*

Clinical setting: ICU, Wales.

Transmission mode: Unknown. Possible patient-patient indirect transmission as well as environmental.

Source: Contaminated taps (newly installed sensor taps)

Control measures: All sinks in the unit decommissioned and portable sinks using bottled water were arranged. All sensor taps in the unit were replaced with conventional non-sensor mixer taps – repeated sampling showed no further contamination and no more cases. Monthly water sampling continued. ABHR used after hand washing.

Limitations: No details of time from admission to positive test.

Genetic relatedness: Isolates from the water samples showed three different strains of *P. aeruginosa*, two of which matched the strains isolated from patients (variable number tandem repeat).

Question 28: What actions can be undertaken to reduce the risk of infection/colonisation associated with indirect water usage?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and environmental microbiology 2019; 85.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing	Sample type, amount of positive samples, CFU counts, MIC, PFGE type
Assessment of evidence					
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca*					

Assessment of evidence
Transmission mode: contaminated water-based equipment Clinical setting: Perinatal setting/children's hospital in Germany Source: Isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Control measures: Environmental monitoring, admission screening, IPC training for HCWs, renovation/decontamination of ward rooms, removal of unused sinks, installation of new wall-mounted disinfection dispensers, feeding of new-borns with only precooked single-serving packages Use of sterile water for bathing of new-borns etc. All garments worn by new-borns and children were laundered by an external professional hospital laundry service. The washing machine was removed after which no further cases identified. The two colonized sinks were replaced by sinks with specialized thermosiphon systems. "Water-associated bacteria, such as *Pseudomonas aeruginosa, Serratia spp., Enterobacter spp., K. pneumoniae*, and *Stenotrophomonas maltophilia*, were detected in the siphons of hand wash basins. Identical clones of PFGE type 00531/ST201 *K. oxytoca* were isolated from the siphons of two sinks in the HCW staff room and in the room used for cleaning and disinfection." *K. oxytoca* isolates matched those found in the washing machine drawer and rubber seal, and on clothing. PFGE typed. "The use of professional washing machines and routine checking with a temperature logger are urgent requirements."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Campos-Gutierrez S, Ramos-Real MJ, Abreu R, et al. Pseudo-outbreak of *Mycobacterium fortuitum* in a	Outbreak investigation	**Level 3**	The aim of this study was to investigate a pseudo-outbreak of *Mycobacterium fortuitum* in Spain (including finding the source) and to determine the impact	Molecular typing results between patient strains and *M. fortuitum* isolated from a water sample (tap) were compared	Number of positive samples, sample type, typing results (by restriction fragment length polymorphism and by enterobacterial repetitive intergenic

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
hospital bronchoscopy unit. American Journal of Infection Control 2020; 48: 765-769.			of infection prevention and control measures.		consensus sequences)

Assessment of evidence

This paper describes a pseudo-outbreak of *M. fortuitum* amongst 9 patients who underwent bronchoscopy in the Pneumology bronchoscopy Unit of a University Hospital in Spain. The outbreak was described as a 'pseudo-outbreak' because it had no clinical impact on patients. Clinical samples and environmental isolates were typed by restriction fragment length polymorphism and by enterobacterial repetitive intergenic consensus sequences and found to be of the same strain.

Organism: *Mycobacterium fortuitum*

Transmission mode: Contaminated water-based equipment

Clinical setting: Pneumology bronchoscopy unit

Source: The hospital water used by the bronchoscope automatic washing machine (without antibacterial filter) – the machine lacked a terminal filter.

Control measures: Manually cleaning and disinfecting the washing machine with prefiltered water before each use.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use:

“Clinical areas where patients may be at increased risk of waterborne infection must be identified within each healthcare facility by the environmental monitoring committee or equivalent.”

“When ice is required, use an automatic dispenser and avoid open chest storage compartment.”

“Sterile water must be used when water is required for administering any medication or treatment requiring water e.g. intravenous medications, nebulisers.”

Assessment of evidence
On use of water for patient care activities in augmented care, the document notes the following: “Ice is not recommended for use in augmented care units and for patients who are at high risk of water-borne infections. Use of ice has been associated with rare but important infections, outbreaks and pseudo-outbreaks. On occasion, ice may be used for high risk patients when the clinical benefit of using the ice outweighs the risk. In such circumstances, ice should only be used under senior medical instruction” “With respect to the humidifiers in ventilator circuits and continuous positive airway pressure (CPAP) circuits, sterile water must be used.” “The augmented care unit manager must ensure that water outlets in augmented care units that are not used frequently each day are flushed on a daily basis.” Specific guidance is also provided for neonatal units: “Humidified incubators may be provided for infants less than 28 weeks gestation or birth weight less than one kilogram in order to maintain their body temperature and to reduce fluid loss. These incubators present a potential risk to the occupant for water-associated infection, especially *Pseudomonas aeruginosa*. The neonatal unit manager must ensure that when an incubator is being humidified, a sterile water reservoir and sterile water is used. The reservoir and water must be changed daily. A re-usable reservoir must be cleaned and sterilised between uses in a central decontamination unit.” “Non-humidified incubators present a lower risk to the occupant from water-associated infection. All incubators should be regularly cleaned and decontaminated by trained competent personnel (once or twice weekly depending on patient risk and between each patient use). The incubator must be completely dismantled, cleaned, decontaminated and dried before using again as per local agreed procedure. The serial number of the incubator must be recorded. There is no requirement to use sterile water to clean incubators. Tap water and detergent may be used. The critical factor is thorough drying of all parts of the incubator and mattress before use.“ “A closed system must be used for infants that require cooling. Sterile water must be used in the system. There should be no direct contact between the infant and the water. Ice or ice packs must not be used for passive or therapeutic cooling.” “Frozen breast milk may be defrosted safely using one of the following methods: a) Defrost using a warming/thawing device designed to ensure no direct contact with the syringe/bottle and non-sterile water b) Defrost in a designated milk fridge c) Defrost at room temperature

Assessment of evidence
and discard any unused milk. Frozen breast milk must never be defrosted by placing the container in tap water, unless the tap water has been boiled first” On equipment and environment, the guidance notes the following. Endoscopy Units and Endoscopy wash disinfectors - “Flexible endoscopes, due to their fragility, will not withstand standard thermal disinfection. Therefore chemical disinfection is utilised when reprocessing a flexible endoscope, most commonly in a washer disinfector. Cases of healthcare associated infection, outbreaks and pseudo-outbreaks have been reported following inadequate cleaning and disinfection of the endoscope, particularly relating to the air, water and biopsy channels. The final rinse water used to remove all traces of disinfectant from the endoscope following decontamination has also been associated with cases of healthcare associated infection, outbreaks and pseudo-outbreaks. The final rinse water utilised should comply with stringent microbiological controls. Periodic testing of the final rinse water is required and remedial actions should be triggered by non-conforming results.” “Water for Haemodialysis – Haemodialysis requires water of an appropriate quality in the preparation of dialysis fluid. This is to protect haemodialysis patients from adverse effects from chemical or microbiological contamination in the water or improperly prepared dialysis fluid. Water treatment facilities for haemodialysis in healthcare facilities need an associated quality system that accounts for governance, planning, commissioning, installation, operation, maintenance, and water monitoring.” “Dental Chair Unit Water Dental chair units are equipped with intricate looms of narrow bore waterlines that are particularly prone to bacterial biofilm contamination. This water is aerosolised by high-speed dental instruments and ultrasonic scalers, thus exposing patients and dental healthcare staff to aerosolised microbial contaminants and bacterial endotoxins. There is no specific Irish or European legislation that regulates the quality of dental waterline output water. However, dental waterlines should be disinfected regularly or continuously with a chemical disinfectant/agent that effectively eliminates waterline biofilm and provides good quality output water.” “Therapeutic Pools e.g. Hydrotherapy and Birthing Pools – Therapeutic pools used in healthcare facilities need to be formally managed to ensure that patients utilising these facilities are not exposed to potential pathogens and avoid acquiring a healthcare associated infection. This is achieved by regular maintenance, chemical disinfection and periodic water quality monitoring.”

Assessment of evidence
"Cleaning and Decontamination of Healthcare Equipment – Do not wash any patient equipment in clinical hand wash sinks. Healthcare equipment (non-invasive) should be cleaned, decontaminated, dried and stored in accordance with local policy and based on manufacturer's instructions." "Contamination of cleaning products, after they have been opened and are in use, has been linked to outbreaks; empty containers should be discarded after use and must never be topped-up."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part C: *Pseudomonas aeruginosa* – advice for augmented care units. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British guidance document "identifies methodologies to control and minimise the risks of morbidity and mortality due to *P. aeruginosa* associated with water outlets. It provides guidance on considerations for water outlets and hot and cold water services in augmented care settings; protecting augmented care patients and ensuring a safe environment; and methods of cleaning wash-hand basins and other					

Assessment of evidence

good hygiene practices to minimise the risk of *P. aeruginosa* contamination." The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use:

"The cleaning of patient contact equipment (for example, tap handles, incubators, humidifiers, nebulisers and respiratory equipment) should be reviewed. Options to minimise risk include the following measures:

i. Use of single-use equipment;

ii. If locally reprocessed – even if used on the same patient – clean equipment with water of a known satisfactory quality (see (a) above);

iii. Use of single-use detergent wipes for cleaning incubators. Manufacturers' instructions should be followed. If a disinfectant is used, it is important that it will not cause damage to the material of the incubator. Disinfectants should not be used to clean incubators while they are occupied."

"Tap water should not be used in neonatal units for the process of defrosting frozen breast milk."

"Chilled water and ice-making machines should not be installed in augmented care units. Where ice is needed for treatment purposes, it should be made using water obtained through a microbiological POU filter or boiled water in sterile ice trays or ice bags."

"All patient equipment should be stored clean, dry and away from potential splashing with water."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. Guidance for Decontamination and testing of Cardiac	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Heater Cooler Units (HCUs). 2019.					
Assessment of evidence					
This Scottish guidance "sets out the operational procedures covering decontamination of heater cooler units (HCU) used during cardiac surgeries, microbiological testing and associated actions based on water and air results." The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use: "Contaminated HCUs have been implicated in other post cardiac surgery infections with pathogens such as *Pseudomonas auriginosa*, *Legionella* species, other nontuberculous *Mycobacterium*, gram-negative bacteria and fungi. Therefore, whilst development of this guidance is in response to possible contamination of HCUs with *M. chimaera*, following this guidance and compliance with manufacturers' decontamination instructions will minimise the risk of HCUs with any pathogens." Cardiac Heater Cooler Units (HCUs) are a known potential reservoir of waterborne organisms that can indirectly infect patients undergoing cardiac surgery (see other RQs) and for this reason, specific guidance is developed for its decontamination and testing.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Infections Associated with Heater Cooler Units Used in Cardiopulmonary Bypass and ECMO Information for	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
healthcare providers in the UK. 2017.					

Assessment of evidence

This English guidance document "includes a revised risk assessment and a new instruction for patient notification to facilitate early diagnosis of *M. chimaera* infection". The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use:

The document recommends that "Providers who use heater cooler units (of any brand and model) should ensure that:

1. A full local risk assessment is conducted, at a minimum reviewed annually and acted upon, and a local quality assurance programme is put in place covering the use of the device
2. Devices are microbiologically monitored according to the manufacturer's instructions supplemented by the guidance presented here as required
3. Suitable cleaning and disinfection regimes are in use as directed by manufacturers or MHRA
4. Heater cooler units are positioned outside theatre where this is possible. If it is unavoidable that they are in the theatre, attention should be given to positioning as described below. Seek advice from the manufacturer in achieving this safely without affecting device performance
5. A *Legionella* risk assessment for the heater cooler units has been undertaken according to the information presented in this guidance. This should include the risks to potentially exposed healthcare staff
6. Impact on cardiothoracic surgical services is minimised. Decisions regarding delaying or continuing surgery must be made by the individual provider
7. Traceability of heater cooler units is ensured; the individual unit used for any surgery or ECMO should be recorded

Assessment of evidence

8. Notification of heater cooler unit related issues are made to MHRA, NHS England or PHE as appropriate. This should include problems encountered in cleaning and disinfection (MHRA), patient harm (MHRA/NHS England), and new cases of M. chimaera infection (PHE). Refer to the local guidance published alongside this document for reporting instructions for Wales, Scotland and Northern Ireland.
9. Patients are informed of the specific risk associated with these devices when they are consented for surgery.

"During 2014-15, PHE were made aware of cases of *Mycobacterium chimaera* endocarditis or deep infection following cardiac surgery in Switzerland, Germany and The Netherlands. *M. chimaera* is a recently described species within the *Mycobacterium avium* complex, a group of environmental organisms usually associated with lung infections, or systemic infections in the immunocompromised host. A Swiss investigation implicated the Sorin (now LivaNova) 3T heater cooler unit (HCU) of the cardiopulmonary bypass equipment, with the transmission of bacteria to the surgical site by aerosolisation of contaminated water from within the unit. The LivaNova device is widely used in the UK and internationally. Maquet, another manufacturer of devices used in the UK, has also indicated that *M. chimaera* has been identified in its HCU water tanks and issued advice to manage any associated risk."

Transmission mode: aerosolisation of *M. chimaera* from the contaminated water heater cooler unit.

Clinical settings: cardiac surgery

Source: contaminated water heater cooler units

Control measures: replacement of units

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Scotland. NHSScotland Guidance for the interpretation and	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
clinical management of endoscopy final rinse water. 2019.					
Assessment of evidence					
This Scottish guidance “aims to enhance patient safety and reduce risks of decontamination related Healthcare Associated Infection (HAI) by standardising the interpretation of and clinical management of endoscopy final rinse water results nationally, based on available scientific evidence, current practices and an estimation of infection risk within NHSScotland following endoscopic procedures.” The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use: The document made the following recommendations: • “Testing laboratories should use the methodology in BS EN ISO 15883 (2006) to assess the final rinse water TVC/*Pseudomonas aeruginosa* PA in the endoscope washer-disinfector. • Testing laboratories should be accredited for testing of endoscopy rinse water. • Staff responsible for undertaking testing of final rinse water should be trained in the aseptic process for collection and transportation of samples as described in SHTM 2030 and BS EN ISO 15883. • Weekly microbiological testing should be undertaken as described in SHTM 2030. • Where positive TVC counts of >10 cfu/100ml are identified on subsequent tests the testing laboratory should provide detail on the number and type of indicators of bacterial contamination found on the second result. • Where positive TVC counts of >100 cfu/100ml are identified the testing laboratory should provide detail on the number and type of indicators of bacterial contamination found.					

Assessment of evidence
• Health boards should monitor results and analyse trends. As a minimum, health boards should follow the guidance for clinical management of endoscopy final rinse water described in the algorithm below.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. 8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
“This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment.” The following section(s) are relevant for this research question on actions that can be undertaken to reduce the risk of infection associated with indirect water use:					

Assessment of evidence
The document recommends that "The relative location of water outlets to patients' beds, bedside cabinets, equipment trolleys, drug and food preparation areas are such that splash contamination cannot occur". "Poor design of wash hand basin in augmented care bathroom: where items of equipment, both of a personal and clinical nature can be stored within the splash zone. Stored items, a central drain point, small activity space and hand operated taps also increase the risk of waterborne infections as a result of cross-contamination to patients from items left in the splash zone."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Rogues AM, Boulestreau H, Lashéras A, et al. Contribution of tap water to patient colonisation with *Pseudomonas aeruginosa* in a medical intensive care unit. Journal of Hospital Infection. 2007 Sep 1;67(1):72-8.	Outbreak investigation	**Level 3**	The aim of this study was to investigate colonisation of *Pseudomonas aeruginosa* in a French ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and *P. aeruginosa* isolated from environmental/water samples were compared to establish a link of colonisation.	Number of positive samples, sample type, genotyping results (PFGE).
Assessment of evidence					
P. aeruginosa was found in tap water samples in patients rooms more than in other tap water in the unit. Also isolated from a bronchoscope which matched with 3 patients.					

Assessment of evidence
Half of the environmental isolates of *P. aeruginosa* derived from colonised patients and did not stem from a central source in the supply mains. Carriage happened by patients (source). Both water-related and non-water related strains appeared to have spread in half of the instanced. Organism: *Pseudomonas aeruginosa* Transmission mode: Carriage by patients Clinical setting: ICU in a large teaching hospital in France Source: Contaminated water systems Control measures: The following interventions were carried out: • Twice monthly chlorine disinfection (aqueous solution (4.5%) of sodium hypochlorite injected into taps with a 60mL syringe for 15 minutes. • Aerators were also removed every two weeks, immersed and brushed in a detergent-disinfectant solution. • Hand disinfection with alcohol – based solution between patient contacts • Exclusive use of bottled water for enteral nutrition and administration of drugs through gastric pipes. • Use of sterile water for mouth care. • Removal of defective flexible bronchoscope which was contaminated with an epidemic strain after manual reprocessing.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yetkin F, Ersoy Y, Kuzucu C et al.	Case control study	**Level 2+**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak	Case patients were compared to 56 randomly chosen patients who were	Odds ratio

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
An outbreak associated with multidrug-resistant *Pseudomonas aeruginosa* contamination of duodenoscopes and an automated endoscope reprocessor. Biomedical Research 2017; 28(13): 6064-6070			in a Turkish ECRP unit and to investigate the underlying risk factors.	hospitalized in the department during the same period but did not develop a *P. aeruginosa* infection. Each case patient was matched to 7 control patients.	

Assessment of evidence

This Turkish study aimed to "investigate an outbreak caused by *Pseudomonas aeruginosa* in a Gastroenterology department and Endoscopic retrograde cholangiopancreatography (ECRP) Unit in a University Hospital and it's underlying risk factors."

Organism: *Pseudomonas aeruginosa*

Transmission mode: Contaminated duodenoscopes

Clinical setting: Gastroenterology department and Endoscopic retrograde cholangiopancreatography (ECRP) Unit in a Tertiary teaching hospital in Turkey

Source: Automated endoscope reprocessor

Control measures: Withdrawal of contaminated duodenoscopes and automated endoscope reprocessor (AER) from service for cleaning using a disinfection and cleaning protocol that was drawn up for the ERCP unit. Reusable heat-stable accessories (e.g. biopsy forceps,

Assessment of evidence
guide wires) were cleaned with in an ultrasonic cleaner, and then steam sterilized. Catheters used for ERCP were recommended to be for single use only and all technical staff were trained on cleaning and disinfection procedures for the duodenoscopes and these processes were followed strictly. “Bacteriological reassessment was done afterwards, yielding *P. aeruginosa* in the rinsing water of the AER and these AER devices were cleaned again and remodelled by the manufacturers. The ERCPs were then allowed, and no further case of infection with this strain was detected.” The Case control study showed that all 8 case – patients had recently undergone ERCP compared with 14 of the56 control – patients (100% vs 24%; p=0.0001), hence no OR was calculated for this risk factor. Results of this study suggest that the outbreak in the gastroenterology unit resulted from failure of automated endoscope reprocessors (AER), and inadequate high level disinfection procedures.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aumeran C, Paillard C, Robin F et al. *Pseudomonas aeruginosa* and Pseudomonas putida outbreak associated with contaminated water outlets in an oncohaematology paediatric unit.	Outbreak investigation	**Level 3**	This paper reports an outbreak of catheter infections caused by *P. aeruginosa* and *P. putida* in the oncohaematology paediatric unit of a teaching hospital in Clermont-Ferrand, France	Molecular genotyping results between patient strains and *P. aeruginosa* and *P. putida* isolated from environmental/water samples were compared to establish link of infection.	Number of positive samples, sample type, antibiogram and genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Journal of Hospital Infection (2007) 65, 47-53					

Assessment of evidence

No further cases were identified after implementation of control measures.

Organism: *Pseudomonas aeruginosa* and *Pseudomonas putida*

Transmission mode: not confirmed

Clinical setting: haematology paediatric unit

Source: contaminated water outlets

Control measures: water network was chlorinated, and disposable seven-day filters were fitted on all taps and showers. Due to the deleterious effects of chlorination on the water network and the cost of the weekly filter change, a water loop producing microbiologically controlled water was installed. In addition, the concentration of the detergent disinfectant was increased and refillable sprayers were replaced with ready-to-use detergent disinfectant solution for high-risk areas.

Isolates from Patient 1 (CVC tip) and from Room 4 had the same antibiogram and the same molecular type (pattern 2). Isolates from Patient 3 (CVC blood culture) and Patient 1 (CVC tip) had different antibiograms but the same molecular types (pattern 2), as did Patient 5 (CVC exit site) and Room 2 (pattern 1).

Molecular typing revealed that some clinical strains were indistinguishable from environmental isolates (pattern 2 = Patient 1, Patient 3 and Room 4; pattern 1 = Patient 5 and Room 2).

Proliferation of the strain in the disinfectant was probably made possible by the development of a biofilm within the spray. Molecular typing of this strain and the strain isolated from Patient 8 revealed indistinguishable patterns.

The mean duration between the onset of symptoms and the first positive culture was 7.5 days (range 1-23 days).

Limitation: control measures were part of a bundled approach.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Cadot L., Bruguière H., Jumas-Bilak E., et al. Extended spectrum beta-lactamase-producing *Klebsiella pneumonia* outbreak reveals incubators as pathogen reservoir in neonatal care centre. European Journal of paediatrics, 178: 505-513, 2019.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a beta-lactamase-producing *Klebsiella pneumonia* outbreak (incl finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Klebsiella pneumonia* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence

The study investigated an outbreak of - *Klebsiella pneumonia* in a neonatal care center in France. They report that 90 neonates colonised over a 3-month period, 2 of whom developed infection. For every patient, the onset of digestive colonization was from 10 to 80 days. The strain of ESBL KP isolated from incubator displayed the same PFGE profiles as clinical strains demonstrating the persistence of the epidemic strain in one incubator despite the cleaning protocol. Provides evidence that mattresses and incubators can remain contaminated and may pose a reservoir for infection even after decontamination. Steam cleaning may not be suitable for mattresses as residual moisture can support grown of organisms.

Organism: *Klebsiella pneumonia*

Clinical setting: Neonatal Care Center in a French Hospital

Transmission mode: Not confirmed, however multiple environmental contamination identified and incubators and incubator mattresses found to be contaminated.

Assessment of evidence
Control measures: Incubators initially cleaned with disinfectant and then steam cleaned. Steam cleaning stopped after residual moisture noted, and contamination remained after cleaning. Switched to disinfection only. No further cases but low-level contamination persisted.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chroneou A, Zimmerman SK, Cook S et al. Molecular typing of *Mycobacterium chelonae* isolates from a pseudo-outbreak involving an automated bronchoscope washer. Infect Control Hosp Epidemiol 2008; 29:1088-90	Outbreak report	**Level 3**	This paper describes a pseudo-outbreak of *M. chelonae* in bronchoalveolar lavage fluid from 9 patients traced to a contaminated automated bronchoscope washer in a medical center in the United States of America.	Molecular typing result (REP-PCR) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 9 patients with positive bronchoalveolar lavage fluid specimens. None had symptoms or infection (Pseudo-outbreak). Incoming water supply and a bowl drain from the automated washer matched the 9 patient isolates (>90% similarity with REP-PCR). Organism: *Mycobacterium chelonae* Clinical setting: Bronchoscopy, United States of America

Assessment of evidence
Transmission mode: from water supply via contaminated automated washer Control measures: automated washer removed from service, and new one purchased. Responsibility for changing filters assigned to biomedical staff and changed every month rather than twice per year. Authors state this eliminated the strain but not clear how this was known. Genetic relatedness: “REP-PCR findings demonstrated a greater than 90% similarity among the isolates associated with the 9 patients…, the 2 environmental isolates recovered from the drain bowl…, and the isolate recovered from the incoming water supply/”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
UK Health Security Agency. Good IPC practice for the cleaning and handling of incubators and other equipment in neonatal units. 27 October 2022.	Expert opinion guidance	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This non-evidence based online guidance provides practical IPC advice for cleaning neonatal incubators; the methodology for production is not stated and it is assumed to be based on expert opinion. A terminal disinfection is advised when the incubator is vacated, or every 7 days if still occupied. Daily routine cleaning of frequently touched points is advised 3 times per day and the external surface daily.

Assessment of evidence
Manufacturers guidance is advised to be followed for the selection of cleaning and disinfectant products. Sterile water must be used for humidifiers, and the reservoir should be sterilised if supported by manufacturer instructions. Mattress integrity should be checked for breaches, and the internal mattress checked for stains and replaced if required.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Centers for Disease Control and Prevention. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC). MMWR 2003; 52 (No. RR-10): 1–48	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert					

Assessment of evidence
opinion guidance document. The recommendations are evidence-based whenever possible. The following sections are relevant for this research question on actions that can be undertaken to reduce the risk of infections associated with indirect water use: “Another reservoir for microorganisms in the cleaning process may be dilute solutions of the detergents or disinfectants, especially if the working solution is prepared in a dirty container, stored for long periods of time, or prepared incorrectly.” “Application of contaminated cleaning solutions, particularly from small-quantity aerosol spray bottles or with equipment that might generate aerosols during operation, should be avoided, especially in high-risk patient areas. Making sufficient fresh cleaning solution for daily cleaning, discarding any remaining solution, and drying out the container will help to minimize the degree of bacterial contamination. Containers that dispense liquid as opposed to spray-nozzle dispensers (e.g., quart-sized dishwashing liquid bottles) can be used to apply detergent/disinfectants to surfaces and then to cleaning cloths with minimal aerosol generation. A pre-mixed, “ready-to-use” detergent/disinfectant solution may be used if available.”

Question 29: What actions can be undertaken to facilitate the earliest possible detection and preparedness for clinical cases of water-associated colonisation or infection?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part C: TVC Testing protocol. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on actions that can be undertaken to facilitate the earliest possible detection and preparedness for clinical cases of water-associated colonisation or infection:

“Although TVCs are in themselves innocuous the testing procedures are intended to provide an early warning system whereby elevated TVCs should trigger some form of action to determine the identity of the organism and implement the appropriate treatment; this could inform adjustment of disinfection doses, cleaning and flushing procedures.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre (2015).	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on actions that can be undertaken to facilitate the earliest possible detection and preparedness for clinical cases of water-associated colonisation or infection: “Infection prevention and control teams must ensure that high-risk units have an ongoing surveillance system in place whereby unusual clusters of colonisation/infection due to *Pseudomonas aeruginosa* and other related gram-negative water-associated organisms (including					

Assessment of evidence
those due to potential environmental sources) are detected in a timely fashion. Clinical isolates of *Pseudomonas aeruginosa* from augmented care units and all clinical isolates of *Legionella* species should be monitored as alert organisms." "The Infection prevention and control team must have an active surveillance programme in place in each healthcare facility to detect alert organisms, clusters of infection, outbreaks, unexpected antimicrobial resistance mechanisms and unexpected infections."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This English guidance document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on actions that can be undertaken to facilitate the earliest possible detection and preparedness for clinical cases of water-associated colonisation or infection:

Assessment of evidence
"It is essential that microbiological results are monitored sequentially in order to identify normal variation and trends so that early action may be taken if problems arise."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. 8580-2:2022. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on how to carry out "risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on actions that can be undertaken to facilitate the earliest possible detection and preparedness for clinical cases of water-associated colonisation or infection:					

Assessment of evidence
"Microbiological surveillance is an essential element of the early identification of water outlet contamination to prevent hospital-acquired infections so the frequency of routine sampling for PA and other waterborne pathogens e.g. NTMs should be based on risk assessment and agreement with the WSG. The frequency of microbiological sampling, where there are high-risk patients, should be sufficient for trend analysis to establish evidence-based confidence that control measures remain effective. When establishing trends, sampling should be carried out frequently (for example, monthly). This frequency should be reviewed by the WSG based on sample findings. Where standard methods are not available e.g. for unusual waterborne opportunistic waterborne pathogens, input should be sought from expert microbiologists from national reference laboratories."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Davis RJ, Jensen SO, Van Hal S et al. Whole Genome Sequencing in Real-Time Investigation and Management of a *Pseudomonas aeruginosa* Outbreak on a Neonatal Intensive Care Unit. Infect. Control Hosp. Epidemiol. 2015;36(9):1058–1064	Outbreak report	**Level 3**	This paper describes the use of whole genome sequencing (WGS) to investigate the likely origin of an outbreak of *P. aeruginosa* in a neonatal unit in a hospital in Australia.	Molecular typing result (WGS) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
P. aeruginosa was isolated from 8 sinks, including 4 sink drains and 5 sink splashbacks; genetic match to 6 patients. There were 6 patient colonisations and 1 infection. Surveillance of clinical samples aided in early detection of colonisation/infection of water-associated organisms. The diversity in the environmental isolates indicated a large diverse bioburden with the NICU. As neonates do not bring in community acquisition, it is probable that environmental reservoirs were responsible for the colonisations (6 patients WGS was identical). Organism: *Pseudomonas aeruginosa* Clinical setting: NICU, Australia Transmission mode: Unconfirmed. Source: Sink drains as reservoir. Control measures: Sinks replaced along with splashbacks that were in one piece and easier to clean. In the following 6 months, only 2 infants were found to be colonised with *P. aeruginosa*, and one of these had an organism that differed phenotypically from the outbreak isolate. Prior to sink replacement, aerators were changed on all taps, sinks cleaned daily with bleach and weekly screening of all babies was initiated. Limitation: No mention of the water itself being tested at any point.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Zhou Z, Hu B, Gao X, et al. Sources of sporadic *Pseudomonas aeruginosa* colonizations/infections in surgical ICUs:	Surveillance investigation	**Level 3**	The aim of this study was to investigate *Pseudomonas aeruginosa* colonisations/ infections in surgical ICUs and to	Molecular typing results between patient strains and *P. aeruginosa* isolated from environmental/water samples (all pre-	Number of positive samples, sample type, genotyping results.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Association with contaminated sink trap. Journal of Infection and Chemotherapy. 2016 Jul 1;22(7):450-5.			determine the source(s). This study was a surveillance done in the absence of an outbreak.	flush cold tap water, tap inner surface, sink drain, counter surfaces, bed rail, bed control, equipment) were compared (PGFE) to establish a link of infection.	

Assessment of evidence

Genotyping was performed. The study included a total of 595 ICU patients of which 55 patients had positive active screening samples (58 samples) and 32 patients had positive diagnostic samples (35 samples). Environmental samples were also collected (n=456).

17.6% (6/34) of colonisations/infections with *P. aeruginosa* were most likely due to patient-to-patient transmission and 50% (17/34) from endogenous flora (diagnostic clinical sample identical to rectum and/or throat sample of the same patient). 64.7% (11/170) of exogenous sourced cases were associated with contaminated sink traps. Whereas no strains (genotypes) recovered from tap water were identical to that from patients – this suggests that the plumbing infrastructure rather than the water was the main environmental reservoir in this setting.

The percentage of carbapenem-resistant *P. aeruginosa* of diagnostic samples (45.7%, 16/35) was higher than that of screening samples (3.4%, 2/58) and environmental samples (15.1%, 8/53). Patient isolates associated with sink drains showed more resistance to antibiotics than patient-to-patient transmission strains (the percentage of carbapenem-resistant *P. aeruginosa*: 81.8% vs.16.7%).

Organism: *Pseudomonas aeruginosa*

Transmission mode: Water fitting

Clinical setting: ICU, China

Assessment of evidence
Source: Contaminated sink traps – contaminated sink drains linked to 11/34 (32.4%) patients; patient-patient transmission in 17.6% (6/34) patients; 50.0% (17/34) from endogenous flora (identical to rectum and/or throat sample of the same patient). Control measures: -

Question 30: How should water-associated incidents be assessed and reported locally and nationally?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Government. Management of Public Health Incidents: Guidance on the Roles and Responsibilities of NHS led Incident Management Teams. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This guidance document on the Roles and Responsibilities of NHS led Incident Management Teams was originally created by the Scottish Government in 2011 and has been updated in 2017 and again in July 2020 by Health Protection Scotland/Public Health Scotland. The purpose of this guidance document is to provide support to the NHS boards in preparing for or in response to public health incidents. It is intended to be strategic but not prescriptive and should allow for flexibility so that NHS boards can respond appropriately where necessary.

“An essential part of incident management is the recognition of a change in the distribution of illness or the occurrence of an illness of major public health significance. To this end surveillance, i.e. the timely collection and collation, analysis and dissemination of information for action, is a vital tool. Following the implementation of the Public Health (Scotland) Act 2008, all registered medical practitioners have a statutory responsibility to notify NHS board Health Protection Teams of any of the specified diseases or health risk states where there may

Assessment of evidence
be a significant risk to public health. These should be reported by telephone on the basis of reasonable clinical suspicion rather than awaiting laboratory confirmation. The telephone call should be followed up by written notification using the electronic system, Scottish Care Information (SCI) Gateway, within three working days or by written notification. (Schedule 1 of Public Health (Scotland) Act 2008"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
The Regulation and Quality Improvement Authority. Independent review of incidents of Pseudomonas aeruginosa infection in neonatal units in Northern Ireland. Final Report. 31 May 2012.	Report	**Level 4**	N/A	N/A	N/A

Assessment of evidence
The Regulation and Quality Improvement Authority (RQIA) is the independent body responsible for regulating and inspecting the quality and availability of health and social care services in Northern Ireland. Four of the five major neonatal units in Northern Ireland had outbreaks or incidents of *Pseudomonas aeruginosa* between November 2011 and January 2012. At the time of the investigation it was not a requirement or routine practice across the UK to carry out an investigation of possible causes when a single sporadic case of Pseudomonas aeruginosa was detected. It was recommended that Pseudomonas aeruginosa is identified

Assessment of evidence
as an alert organism for neonatal intensive care and high dependency units. When identified from a sample from a baby, taps and sinks should be tested in rooms that had been occupied by that baby since birth. The report advised that a pseudomonas surveillance system would enable early sharing of information between trusts.

Question 31: What are the water testing requirements during a water-associated incident/outbreak?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on the water testing requirements during a water-associated incident/outbreak:					

Assessment of evidence
On water testing, the documents states “Monitoring of water supplying an augmented care unit for *Pseudomonas aeruginosa* may be required, based on risk assessment. Water testing is recommended during an outbreak or if surveillance identifies an increased incidence of infection. Water testing may also be indicated following a single invasive *Pseudomonas aeruginosa* infection, if the organism is an unusual pathogen in the augmented care unit. Furthermore, evidence suggests that there is a greater risk of the internal surfaces and components of non-touch or sensor taps becoming contaminated with microorganisms and biofilm in comparison to manually operated taps. Therefore, water testing may be considered by the environmental monitoring committee for augmented care units with sensor taps.” “Pre-flush and post-flush water samples may be indicated depending on the nature of the outbreak and/or the purpose of the sampling. If contamination is detected, compare the pre- and post-flush bacterial counts. A substantially higher bacterial count in the pre-flush sample, compared with the post-flush, should direct remedial measures towards the tap and associated pipework and fittings near to that outlet. A higher bacterial count in the post-flush sample than in the pre-flush sample suggests stagnation in the water system and inadequate flushing. A similar bacterial count in preflush and post-flush samples indicates that attention should focus on the whole water supply, storage and distribution system.” “Although water sampling is the principal means of sampling, there may be occasions when water samples cannot be obtained immediately for analysis. In the event of a suspected outbreak, swabbing water outlets (as per section 5.4 of the Microbiology of Drinking Water (2010) – Part 2.26 Practices and Procedures for sampling) to obtain strains for typing may provide a means of assessing a water outlet, but this does not replace water sampling.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Water safety for healthcare premises. Part B: Operational management. 2014.					

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on the water testing requirements during a water-associated incident/outbreak:

“The infection prevention and control team, however, will need to consider the level of risk before deciding that *Legionella* testing is indicated. For example, testing may be required:

- when storage and distribution temperatures do not achieve those recommended under the temperature control regime and systems are treated with a biocide regime, a monthly frequency of testing for *Legionella* is recommended. This may be reduced as confidence in the efficacy of the treatment regime is established;
- in systems where the control regimes are not consistently achieved, for example temperature or biocide levels (weekly checks are recommended until the system is brought under control);
- when an outbreak is suspected or has been identified”

“Testing of water for *Pseudomonas aeruginosa* is only required if a very specific reason has been identified such as suspected or confirmed outbreak or a series of sequential cases, as guided by the Responsible Person (*Pseudomonas*).”

“As part of the outbreak investigation and control, the enforcing authority may make the following requests and recommendations:… to take water samples from the system before any emergency disinfection is undertaken. This will help the investigation of the cause of illness. The investigating officers from the local authority/authorities may take samples, or require them to be taken;”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on the water testing requirements during a water-associated incident/outbreak:

On sampling for clusters and outbreak investigations, the document states as follows: “In the event of a cluster or outbreak, the epidemiological information available at the time should be used to determine the locations where samples are to be collected. As an outbreak proceeds and the investigation progresses, the collated epidemiological and environmental information should be continually reassessed and updated by the outbreak investigation team, and the emphasis of the environmental investigation should reflect this. NOTE 1 Depending on the nature and size of the outbreak, the investigation might centre around or involve a single property or might involve a number of properties within a certain area. Thus, the number of samples to collect is difficult to assess in advance, especially in the early stages of the investigation. NOTE 2 The police might be involved in the investigation if there is a death and require particular samples to be taken and transported under forensic conditions. The primary consideration of any large outbreak investigation should be the containment of the outbreak and the prevention of further infection. An overall investigation plan should be drawn up by the outbreak investigation team to identify and prioritize potential sources. At individual premises, all potential sources of contamination should be identified on each site, switched off if appropriate and, if possible, investigated, sampled and then rendered safe, and the corresponding

Assessment of evidence
risk assessments reviewed as soon as possible. Appropriate liaison should be initiated with all those involved in dealing with the incident. Sample results from potential sources of infection from *Legionella*e should be analysed by an outbreak investigation team to verify that they have identified the source." "Where there are large numbers of potential sources of infection, the sampling of potential sources should be prioritized by the outbreak investigation team, based on the likelihood of one or more of these being a major source and taking account of the geographical distribution of the infected cases. If cases are clustered, for example, in one part of a site or limited area, initial efforts should be concentrated on potential sources within that part of the site or area. Where several infected people have visited one particular location, this area should be the focus of initial investigations. However, other nearby potential sources should not be discounted or overlooked."

Question 32: What are the environmental testing requirements when investigating healthcare water system-associated incidents/outbreaks?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This English guidance document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak:

"… qualitative sampling (to determine the presence or absence of a pathogen) is usually appropriate when investigating the source of an outbreak or a cross-contamination incident. In this case, the larger the area sampled, the better the chance of detecting the pathogen of interest."

Assessment of evidence
"For large areas, sponges are often found to be most convenient, while cotton-tipped swabs are often more convenient for complex surfaces or areas which are less accessible. However, it should be noted that sponges generally achieve a more efficient recovery of micro-organisms than cotton-tipped swabs, whilst contact plates give a lower recovery than either swabs or sponges. In this case, the larger the area sampled, the better the chance of detecting the pathogen of interest." "Swabbing for norovirus or other viruses is not usually indicated. However, in some situations (for example, verification of cleaning procedures during norovirus outbreaks) it may be useful to carry out surface swabbing. Appropriate procedures, equipment and sample numbers should be discussed with the local PHE Food Water and Environmental Microbiology Laboratory and/or Virus Reference Laboratory before undertaking any sampling."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Sehulster LM,Chinn RYW, Arduino MJ et al. Guidelines for environmental infection control in health-care facilities. Recommendations from CDC and the Healthcare Infection Control Practices Advisory Committee (HICPAC).	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
American Society for Healthcare Engineering/American Hospital Association; 2004.					

Assessment of evidence

These international guidelines reviewed and reaffirmed strategies for the prevention of environmentally mediated infections, particularly among health-care workers and immunocompromised patients. Due to the lack of a systematic evidence search, it is labelled as an expert opinion guidance document. The recommendations are evidence-based whenever possible. The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak:

The document provides the following recommendations on environmental sampling:

A. “Do not conduct random, undirected microbiologic sampling of air, water, and environmental surfaces in health-care facilities.

B. When indicated, conduct microbiologic sampling as part of an epidemiologic investigation or during assessment of hazardous environmental conditions to detect contamination and verify abatement of a hazard.

C. Limit microbiologic sampling for quality assurance purposes to

- biological monitoring of sterilization processes;
- monthly cultures of water and dialysate in hemodialysis units; and
- short-term evaluation of the impact of infection-control measures or changes in infection control protocol”

On “Air, water, and environmental – surface sampling”, the document states:

A. “When conducting any form of environmental sampling, identify existing comparative standards and fully document departures from standard methods.

Assessment of evidence
B. Select a high-volume air sampling device if anticipated levels of microbial airborne contamination are expected to be low. C. Do not use settle plates to quantify the concentration of airborne fungal spores. D. When sampling water, choose growth media and incubation conditions that will facilitate the recovery of waterborne organisms. E. When using a sample/rinse method for sampling an environmental surface, develop and document a procedure for manipulating the swab, gauze, or sponge in a reproducible manner so that results are comparable. F. When environmental samples and patient specimens are available for comparison, perform the laboratory analysis on the recovered microorganisms down to the species level at a minimum and beyond the species level if possible.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS 7592:2022. Sampling for *Legionella* bacteria in water systems – Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on the sampling of water and related materials for determination of the presence of organisms of the genus *Legionella*. The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak.					

Assessment of evidence
On sampling for cluster and outbreak investigation, the document states the following: “In the event of a cluster or outbreak, the epidemiological information available at the time should be used to determine the locations where samples are to be collected. As an outbreak proceeds and the investigation progresses, the collated epidemiological and environmental information should be continually reassessed and updated by the outbreak investigation team, and the emphasis of the environmental investigation should reflect this. NOTE 1 Depending on the nature and size of the outbreak, the investigation might centre around or involve a single property or might involve a number of properties within a certain area. Thus, the number of samples to collect is difficult to assess in advance, especially in the early stages of the investigation” “Running taps, showers, fountains, humidifiers, spa pools, whirlpool baths and evaporative cooling towers and certain industrial processes can generate aerosols. Infection is also thought to have resulted from aspiration in certain nosocomial cases, either from drinking contaminated water, or ingesting liquid feeds or ice made with contaminated water, or using contaminated water for purposes such as irrigation or washing wounds.” “Water closet cisterns should not be overlooked as potential sources of infection, particularly if used in warm environments. Those cisterns most likely to have been used by infected people should be sampled in accordance with 7.7.2 and 7.7.5.” “For most routine purposes, water is the most convenient and readily reproducible type of sample; biofilm samples collected with swabs or by scraping should not be collected for routine sampling, but might be necessary for some other sampling purposes, such as monitoring biofilm formation. NOTE The recovery of *Legionella*e from swabs is not as consistent as that from water and so it is more difficult to interpret the result.” “Samples from showers used by people infected with Legionnaires’ disease or in proximity to these areas should be collected. Most bacterial colonizations within showers occur in the region of the outlet, including mixer valves, shower heads and any flexible hoses.” “Wherever possible, samples that are representative of the water (where aerosols are capable of being produced) should be collected, as should biofilm samples from the surfaces of cisterns or other containers.” “The primary consideration of any large outbreak investigation should be the containment of the outbreak and the prevention of further infection. An overall investigation plan should be drawn up by the outbreak investigation team to identify and prioritize potential sources. At

Assessment of evidence
individual premises, all potential sources of contamination should be identified on each site, switched off if appropriate and, if possible, investigated, sampled and then rendered safe, and the corresponding risk assessments reviewed as soon as possible." "Where there are large numbers of potential sources of infection, the sampling of potential sources should be prioritized by the outbreak investigation team, based on the likelihood of one or more of these being a major source and taking account of the geographical distribution of the infected cases. If cases are clustered, for example, in one part of a site or limited area, initial efforts should be concentrated on potential sources within that part of the site or area. Where several infected people have visited one particular location, this area should be the focus of initial investigations. However, other nearby potential sources should not be discounted or overlooked."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Network. Guideline on the management of Legionella cases, incidents, outbreaks and clusters in the community. Health Protection Network Scottish Guidance 2 (2014 Edition). Health Protection Scotland, Glasgow, 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document "aims to provide a user-friendly, evidence-informed guideline for Scotland that offers best practice advice/guidance for investigation and management of incidents, clusters and outbreaks of *Legionella* in the community". The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak: On cases acquired in hospital, the document states amongst other things to • "Conduct environmental sampling, • Institute remedial control measures" "In order to identify the source of the *Legionella*, samples of water, biofilm or compost can be collected where accessible. The samples are normally examined for *Legionella* bacteria using conventional culture methods based on BS 6069- 4.12:1998 and BS ISO 11731-2:2014. The examination of the sample involves the concentration of bacteria from the sample matrix, followed by inoculation onto a culture medium that is selective for *Legionella* bacteria. The inoculated selective medium is then incubated at 36°C in a moist environment for a period of up to 10 days. Suspect *Legionella* colonies that develop during the incubation period are then confirmed as *Legionella* bacteria and broadly grouped using serological based reagents into one of three groupings: *L. pneumophila* serogroup 1, *L. pneumophila* serogroup 2-15 or *Legionella* species. The confirmed *Legionella* colonies are then sent to SHLMPRL for further characterisation and to enable the matching of the environmental isolates with isolates from human cases."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre (2015).					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak:

“Due to the nature of medical equipment (e.g. ventilators) and the moisture associated with this equipment in intensive care areas, patients and healthcare workers contribute significantly to the environmental contamination of surfaces and equipment with *Acinetobacter* spp. In addition, hand carriage and hand transfer are also associated with healthcare–associated transmission of *Acinetobacter* spp.”

“Measures to prevent spread include consistent application of appropriate standard and transmission based precautions including hand hygiene and appropriate use of PPE, as well as elimination of potentially contaminated environmental reservoirs.”

Assessment of evidence
Thus, to eliminate potentially contaminated environmental reservoirs, the source needs to be confirmed with environmental testing. Most important in outbreak when the source is unclear. However, the tables show the frequency of testing for environmental water sources that is not in the hot and cold system (endoscopy, renal dialysis, hydrotherapy etc).”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on “how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment.” The following section(s) are relevant for this research question on the environmental testing requirements during a water-associated incident/outbreak:					

Assessment of evidence
"…clinically relevant fungi have been implicated in locations such as bone marrow transplant units, causing infections associated with both water and moist environments after a flooding or other water ingress event affecting wall surfaces, and also from cleaning and touching equipment including mops, foam floats, pool surrounds and changing areas." "NOTE 1 Clinical surveillance for infections is vital to detect transmission and prevent outbreaks. Typing of detected organisms is crucial to understand if transmission has occurred and to support interventions to prevent further transmission. The interpretation of typing results requires input from expert microbiologists. Where typing results from patient and environmental isolates do not match, it does not exclude the water system as a source of infection. NOTE 2 Whilst person to person outbreaks usually originate from a single clone, environmental source outbreaks can be polyclonal requiring a different approach to analysis and interpretation. NOTE 3 National reference laboratories are usually able to advise on the most appropriate expert for advice on specific pathogens. Investigation of environmental source cases and outbreaks therefore should involve: a) identification and sampling of all potential environmental reservoirs to which the patients may have been exposed; NOTE 4 This may require checking patient notes to determine if they might have been exposed to water sources in areas outside their ward/unit. b) the use of a sensitive methodology; NOTE 5 Molecular techniques, especially metagenomics, have been shown to have a higher sensitivity for detecting environmental sources than routine swabbing. c) picking and typing of several isolates from cultures to increase the likelihood of detecting the relevant hazard, identify polymicrobial and polyclonal infections and identify relatedness; and d) understanding that several strains might simultaneously be involved in an outbreak Collection, validation, analysis and interpretation of data requires the IPCT to have a list of alert organisms which could be associated with exposure to water. This list should be utilized to verify that infection control software is set up to aid the recognition and trends of these organisms automatically to identify potential waterborne transmission events. As environmental outbreaks can occur

Assessment of evidence
intermittently over a protracted period of time and across a hospital site (i.e. not restricted to a single ward), analysis should take this into account."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schmithausen RM, Sib E, Exner M, et al. The Washing Machine as a Reservoir for Transmission of Extended-Spectrum-Beta-Lactamase (CTX-M-15)-Producing *Klebsiella oxytoca* ST201 to Newborns. Applied and Environmental Microbiology 2019 *85*(22), e01435-19	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella oxytoca* outbreak in Germany (including finding the source) and to determine the impact of infection prevention and control measures.	The PFGE type of isolated environmental/water *K. oxytoca* strains were compared with those for the human strains and the isolates detected on clothing.	Sample type, amount of positive samples, CFU counts, MIC, PFGE type.

Assessment of evidence
Washing machine was identified as the source, however it remained unclear how the washing machine became contaminated. Organism: *Klebsiella oxytoca*

Assessment of evidence
Transmission mode: contaminated water-based equipment Clinical setting: Perinatal setting/children's hospital in Germany Source: Isolates detected in high concentrations from samples of residual water in the rubber seal and from a swab sample from the detergent compartment of a washing machines. Control measures: Environmental monitoring, admission screening, IPC training for HCWs, renovation/decontamination of ward rooms, removal of unused sinks, installation of new wall-mounted disinfection dispensers, Feeding of new-borns with only precooked single-serving packages Use of sterile water for bathing of new-borns etc. All garments worn by new-borns and children were laundered by an external professional hospital laundry service. The washing machine was removed after which no further cases identified. The two colonized sinks were replaced by sinks with specialized thermosiphon systems. "Water-associated bacteria, such as *Pseudomonas aeruginosa, Serratia spp., Enterobacter spp., K. pneumoniae*, and *Stenotrophomonas maltophilia*, were detected in the siphons of hand wash basins. Identical clones of PFGE type 00531/ST201 *K. oxytoca* were isolated from the siphons of two sinks in the HCW staff room and in the room used for cleaning and disinfection." *K. oxytoca* isolates matched those found in the washing machine drawer and rubber seal, and on clothing. PFGE typed. "The use of professional washing machines and routine checking with a temperature logger are urgent requirements."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Lv Y, Xiang Q, Jin YZ, et al. Faucet aerators as a reservoir for Carbapenem-resistant *Acinetobacter*	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Acinetobacter baumannii* (including finding the source) and to determine the	Molecular typing results between patient strains and *Acinetobacter baumannii* isolated from environmental/water	Number of positive samples, sample type, typing results

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
baumannii: A healthcare-associated infection outbreak in a neurosurgical intensive care unit. Antimicrobial Resistance and Infection Control 2019; 8 (1) (no pagination).			impact of infection prevention and control measures.	samples were compared	

Assessment of evidence

Typing results found that the outbreak strain was only found in the faucet aerator of the dining room, used by HCWs. The faucet aerator may have acted as a reservoir for bacteria in the outbreak, and contamination of the faucet aerator might have occurred from splashes originating from handwashing by the healthcare workers (HCWs).

Organism: Carbapenem-resistant *Acinetobacter baumannii* (CRAB)

Transmission mode: Possible transmission from the contaminated tap to the patient via contaminated HCW hands – not confirmed.

Clinical setting: Neurosurgical intensive care unit (NSICU) in a tertiary hospital in China.

Source: Unknown (could have been municipal water, pipeline, or hands of medical staff). Faucet aerator was a likely reservoir – see limitations.

Control measures: Intensive infection control measures (strengthening hand hygiene measures, isolation, fluorescent labelling to control cleaning, aerosolized hydrogen peroxide to carry out terminal disinfection, contact precautions, cessation of unnecessary transfer of patients, retraining of staff on emergency response to HAI) and environmental microbial sampling were implemented immediately, but their

Assessment of evidence
effects were poor. Use of all faucet aerators in the NSICU was then stopped. Following the emergency response process, an outbreak control team was established including an infection control officer, bacteriologists, cleaning staff, NSICU doctors, and nurses. Limitations: the sampling was carried out AFTER control measures were implemented, therefore may not have represented what was present at the time of infection/colonisation. Hands of HCWs were not sampled after washing under the contaminated faucet, therefore there is a lack of direct evidence to support the stated mode of transmission.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Decraene V, Phan HTT, George R, et al. A large, refractory nosocomial outbreak of *klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* demonstrates carbapenemase gene outbreaks involving sink sites require novel approaches to infection control.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Klebsiella pneumoniae* carbapenemase-producing *Escherichia coli* outbreak (incl finding the source) and to determine the impact of infection prevention and control measures.	23 CRE-colonised heart patients, 2 infections (UTI, SSI).	Positive samples: 850 total samples taken from sink/drain/shower/bath sites, 18 from toilets, hoppers or sluices, 33 from high-touch sites (keyboards, door handles, sponges). 85 samples positive, including shower drains, sink taps, sink drain tailpieces, sink drain strainers, sink trap water, toilet bowls.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Antimicrobial Agents and Chemotherapy 2018; 62 (12).					

Assessment of evidence

This English study "investigated a large *Klebsiella pneumoniae* carbapenemase (KPC)-producing *Escherichia coli* outbreak and wider CRE incidence trends in the Central Manchester University Hospital NHS Foundation Trust (CMFT) (United Kingdom) over 8 years, to determine the impact of infection prevention and control measures". Molecular typing confirmed link between patient cases and environment. Source not identified but sink drains identified as reservoirs, likely biofilm formation.

Organism: *Klebsiella pneumoniae* Carbapenemase-Producing *Escherichia coli, (Carbapenem-resistant Enterobacteriaceae (CRE)*

Transmission mode: contaminated water systems

Clinical setting: Manchester Heart Centre

Source: not confirmed; sink drain identified as reservoirs, likely biofilm formation.

Control measures: Sink trap replacement for colonised sinks, horizontal pipework cleaning with a brush to remove biofilm. Replacement of the plumbing infrastructure back to the central drainage stacks. Replaceable sink plughole devices designed to prevent water aerosolization in the sink U-bend and to limit biofilm formation (HygieneSiphon; Aquafree) were installed.

Outcome: Following patient relocation to another ward and after plumbing refurb, cases significantly decreased, suggesting the environment was responsible. However, ward utility room sinks drains were positive after plumbing refurb and prior to patient readmissions suggesting residual contamination or reintroduction.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B et al. *Pseudomonas aeruginosa* Outbreak in a Neonatal Intensive Care Unit attributed to Hospital Tap Water. Infection control & hospital epidemiology July 2017, vol. 38, no. 7.	Outbreak investigation (with Case control study)	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak in the US (incl finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results between patient strains and *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	Clinical and patients' characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Assessment of evidence

Environmental sampling was performed in areas with the strongest epidemiologic links to cases (i.e. rooms with multiple cases or a recent case). Samples were taken from sinks – the POU filters on taps were removed and 1litre samples collected, POUs were replaced after sampling. Swab samples were also collected from taps and drains, and sponge-stick samples from sink basins. Sponge-stick and swab samples were taken from ventilator equipment, breast pumps, an incubator humidity outlet, and shelves adjacent to the patient room sinks. Water samples were also collected from pipes delivering hot and cold water to the NICU. Samples were tested on MacConkey selective agar using an automated biochemical identification system and were positive for *P. aeruginosa*. To determine relatedness, PFGE was performed on 21 *PA* environmental samples and 10 case isolates (5 surveillance and 5 clinical).

Organism: *Pseudomonas aeruginosa*

Transmission mode: Unclear, however it was noted that washing hands with infected water may have contributed.

Clinical setting: Newly built community-based hospital, 28-bed neonatal intensive care unit in the United States of America.

Assessment of evidence
Source: Tap water Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model. They were reinstated after cases appeared again. Case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured. "PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient." The paper concluded as follows: "Our findings are consistent with the statement made by Williams et al that waterborne healthcare-associated infections occur "at the 3-way intersection of nonsterile potable water, susceptible individuals, and a lapse in infection control practices." All 3 factors likely contributed to this outbreak. Although interruption of the outbreak with POU filters provided a short-term solution, eradication of *P. aeruginosa* in the hospital water, faucets, and sinks was necessary to protect patients. This outbreak highlights the importance of addressing and understanding the inherent risks (e.g., biofilm formation) in healthcare facilities where water has been stagnant for extended periods." Limitations: Due to the size of the NICU, matching of cases and controls using a ratio greater than 1:1, matching by NICU admission date, or multivariable modelling could not be done.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Yablon BR, Dantes R, Tsai V, et al. Outbreak of *Pantoea agglomerans* Bloodstream Infections at an Oncology Clinic—Illinois, 2012-2013. Infection control and hospital epidemiology. 2017 Mar;38(3):314.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pantoea agglomerans* outbreak at an oncology clinic in the US (incl finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *P. agglomerans* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)

Assessment of evidence

This American outbreak study aimed to "determine the source of a healthcare-associated outbreak of *Pantoea agglomerans* bloodstream infections".

P. agglomerans was isolated from composite samples of sinks in several rooms, including the infusion room (4 of 5 sinks), the pharmacy clean room, the staff bathroom, and a patient examination room. *P. agglomerans* was also isolated from a composite sample of the ice machine in the staff break room. No *Pantoea* were isolated from handwipe specimens, from surface samples, or directly from water samples. Water samples from all 8 sinks exceeded the US guideline ceiling of 500 CFU/ml.

Organism: *Pantoea agglomerans*

Transmission mode: Indirect/aerosolization.

Clinical setting: oncology clinic.

Source: Possibly contaminated pharmacy sink, however primary source associated with this, not identified.

Assessment of evidence
Control measures: immediate terminal cleaning, focusing on sink areas in all rooms, and consultation with state and local experts to improve the facility's water system, including rectifying the inadequate residual chlorine and dead-end piping. Staff were advised to refrain from placing any infusion products in or adjacent to sinks and to ensure strict adherence to national standards for safe compounding. Outcome: "Improvements in parenteral medication preparation, including moving chemotherapy preparation offsite, along with terminal sink cleaning and water system remediation ended the outbreak" Genetic relatedness: "Of the 9 case patients from whom *P. agglomerans* isolates were available, 7 had a pulsedfield gel electrophoresis pattern indistinguishable from the isolate recovered from the sink composite sample in the pharmacy clean room." Limitations: • "Patient data were collected through retrospective medical chart reviews instead of patient interviews, and incomplete documentation in charts might have limited our ability to identify all potential exposures"; • Investigation was conducted several months after the onset of the outbreak which means some practices and conditions at the time of the outbreak might have changed. • The primary source of *P. agglomerans* associated with the pharmacy clean room sink could not be determined. Water samples from all 8 sinks exceeded the US Environmental Protection Agency's ceiling heterotrophic plate count of 500 colony-forming units/mL, with counts ranging from 550 to more than 3,000 colony-forming units/mL from infusion room sinks and from 1,070 to more than 3,000 colony-forming units/mL from pharmacy sinks.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Schneider H, Geginat G, Hogardt M, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak	Molecular typing results between clinical strains and *P. aeruginosa* isolated	Number of positive samples, sample type, genotyping results (RAPD-PCR

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa outbreak in a pediatric oncology care unit caused by an errant water jet into contaminated siphons. The Pediatric infectious disease journal. 2012 Jun 1;31(6):648-50.			(incl finding the source) and to determine the impact of infection prevention and control measures.	from environmental/water samples were compared to establish a link of infection.	and single-nucleotide polymorphism–type *P. aeruginosa* microarray).
Assessment of evidence					
This German study was conducted "to assess the effectiveness of the outbreak management, the incidence of infections with *P. aeruginosa* in patients of the POCU." Contaminated aerosols may have emerged from the siphon at every water use. Patients could have acquired infection with the outbreak clone due to inhalation of contaminated aerosols (patients B and C), via smear infection with water drops directly from the water tap (patients B and C) or through horizontal transmission from contaminated persons such as staff or family members (patient A). Organism: *Pseudomonas aeruginosa* Transmission mode: Aerosolisation, indirect contact Clinical setting: Pediatric oncology care unit (POCU) Source: Contaminated siphons.					

Assessment of evidence
Control measures: New water taps were installed throughout entire POCU to avoid direct water flow into the sink. Siphons in the anterooms in isolation rooms 2 and 3 were additionally replaced. Patients and staff were obliged to rinse the water taps with running hot water preceding every water use.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pena C, Dominguez MA, Pujol M, et al. An outbreak of carbapenem-resistant *Pseudomonas aeruginosa* in a urology ward. Clinical microbiology and infection. 2003 Sep;9(9):938-43.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant *Pseudomonas aeruginosa* outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between clinical strains and Carbapenem-resistant *Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, genotyping results.

Assessment of evidence
This Spanish study reports the investigation of a Carbapenem-resistant *Pseudomonas aeruginosa* outbreak in a urology operating theatre in a hospital in Spain involving 59 patients, 32 of whom were colonized while 27 were infected. Organism: Carbapenem-resistant *Pseudomonas aeruginosa*. Transmission mode: Indirect contact

Assessment of evidence
Clinical setting: Urology Operating theatre cystoscopy room in a Spanish Hospital. Source: Unsealed drain Control measures: Environmental surveillance, Strict adherence to disinfection protocol, examination and repairs of cystoscopy room, restricting surgical drape to single use only. Although these measures resulted in a prompt decrease in the number of CRPA clinical samples, the outbreak was not totally ended until the open drainage was closed. Genetic relatedness: “A single clone was found in 20 CRPA clinical samples and two CRPA environmental samples.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Novosad SA, Lake J, Nguyen D, et al. Multicenter outbreak of Gram-negative bloodstream infections in hemodialysis patients. American Journal of Kidney Diseases. 2019 Nov 1;74(5):610-9.	Outbreak investigation	**Level 3**	Two case-control investigations were performed to examine risk factors for becoming a case. The first investigation focused on patient-specific risk factors (for example age and comorbid conditions). The second investigation looked at factors specific to a patient	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection. Risk factors for becoming a case are investigated using case-control study designs (2x).	Clinical and patients’ characteristics of cases. Growth/ contamination of environmental/water samples, genotype results (PFGE).

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
			during a particular treatment.		
Assessment of evidence					
In this American study an outbreak was investigated where wall boxes seemed to have been contaminated with Gram-negative organism (*S. marcescens*) and contributed to an outbreak of BSIs. Organism: *S. marcescens, Pseudomonas aeruginosa, Enterobacter cloacae* Transmission mode: Indirect contact (opportunities for health care workers' hands to contaminate CVCs with contaminated fluid from the wall boxes). Clinical setting: Outpatient haemodialysis facilities Source: Dialysis station wall boxes (contaminated water-based equipment) Control measures: Implementation of wall box drain care protocol, educated staff on the importance of performing hand hygiene after touching wall boxes, and had increased their frequency of hand hygiene audits. Staff at all facilities were re-educated and received training regarding the importance of hand hygiene, aseptic technique during CVC care, and station disinfection. 3 more cases were identified after implementation of these measures.					

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Constantinides B, Chau KK, Phuong Quan T, et al. Genomic surveillance of *Escherichia coli* and	Surveillance study	**Level 3**	The aim of this study was to investigate the prevalence of contamination of healthcare sinks by	Phylogenies of sink drain aspirates sampled over 12 weeks across three wards and patient samples.	Number of positive samples, sample type, whole-genome sequence analysis (including

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Klebsiella spp. in hospital sink drains and patients. Microbial Genomics 2020; 6: 4-16.			strains of *E. coli* and *Klebsiella* spp.		metagenomic sequencing)

Assessment of evidence

In this study isolates were identified from sinks from different hospital wards and were linked retrospectively to isolate results from patients staying in the same units during the same time period. Genomic overlap with sink isolates was only identified in 1/46 of all sequenced isolates causing clinical urine-infection over the same timeframe, associated with acquisition from a sink source.

Organism: *Enterobacterales* species (*E. coli* and *Klebsiella* spp)

Transmission mode: Not confirmed.

Clinical setting: General medicine ward in hospital UK

Source: Possibly a sink

Control measures: Not documented

Even though isolates from the sinks were compared to isolates from patients' samples there was no epidemiological data used to investigate whether this correlation is actual true. Both microbiological and epi data is needed to link strains to infection. This study provides evidence that sinks can be colonised with a wide abundance of microorganisms that are associated with healthcare-associated infections, indicating a possible reservoir and risk of infection. This study provides evidence for the source of infection.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Raun-Petersen C, Toft A, Nordestgaard MM, et al. Investigation of an *Enterobacter hormaechei* OXA-436 carbapenemase outbreak: when everything goes down the drain. Infect Prev Pract. 2022;4(3):100228. Published 2022 Jun 30. doi:10.1016/j.infpip.2022.100228	Outbreak investigation	**Level 3**	The aim of the study was to investigate a *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene outbreak (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular genotyping results of clinical strains and environmental strains were compared to establish link of infection.	Timeline of outbreak and overlap of patients, amount of positive environmental samples, whole genome sequencing results (MLST types).

Assessment of evidence

This study investigated an outbreak of *Enterobacter hormaechei* harboring OXA-436 carbapenemase gene in the Cardiology department of a hospital in Denmark. Various environmental swab samples were taken (from shower drains, floor drains below sinks, sinks, bedpan boilers/instrument washers) and WGS results (MSLT types) revealed a link between patient strains and two environmental strains taken from the shower drains in the only two patient bathrooms in the unit. Staff reported that these drains had a tendency to become partly blocked resulting in regular overflow of water from the drains while patients were showering. Outbreak measures described below resolved the outbreak and no new cases nor new positive environmental samples were found after 3 years.

Organism: *Enterobacter hormaechei* OXA-436 carbapenemase

Assessment of evidence
Clinical setting: Cardiology department. Source: Shower drains (overflow of water from clogged drains while showering) Control measures: Physical floor grate and traps were changed and fixed to the drain. The bathrooms were emptied and cleaned. The part of the floor drains, that wasn't possible to change were manually cleaned and afterward rinsed with vinegar. Finally the bathrooms were disinfected with vaporized hydrogen peroxide (RHEA Compact) following cleaning. The shower heads were relocated so that the water did not hit the drain directly (reducing splash risk). The waste pipes were cleaned and the function of the drains and sewer system re-established to prevent overflow. In addition to the regular cleaning of the two bathrooms, an extra daily cleaning with chlorine disinfection of all contact points was established. Limitations: • Patient characteristics are not provided, only that the patients were admitted to the same department (different times 6/7)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
De Geyter D, Blommaert L, Verbraeken N et al. The sink as a potential source of transmission of carbapenemase-producing Enterobacteriaceae in the intensive care unit.	Outbreak report	**Level 3**	This paper describes an outbreak of CPE in the ICUs of a teaching hospital in Belgium.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Antimicrobial Resistance and Infection Control (2017) 6:24					

Assessment of evidence

A total of 3 patient cases (2 infections) all with different species and antibiograms, all housed in the same room but not at the same time (all negative on admission).

Sink drain in this room was positive, as was every other isolation room on the unit.

Sinks were being used for hand hygiene, rinsing medical equipment before disinfection, flushing patient fluids (e.g. dialysis containing antibiotics etc).

Organism: Enterobacteriaceae

Clinical setting: ICU, Belgium.

Transmission mode: Unconfirmed.

Source: Sink drain as reservoir (and likely source for some patients).

Control measures: daily disinfection of the sinks with a glucoprotamine product was implemented; sinks were dedicated to ‘clean work’ (undefined, although it is stated that dialysis fluids were disposed of separately). These measures were unsuccessful; the whole sinks were then replaced with ones that have an open inlet to allow better cleaning. Following this, 1 further case however admission screening was not undertaken so unable to rule out acquisition elsewhere.

Genetic relatedness: PGFE showed that patient strains and those from the sink drain were highly related.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Wong V, Levi K, Baddal B, et al. Spread of *Pseudomonas fluorescens* Due to Contaminated Drinking Water in a Bone Marrow Transplant Unit. Journal of Clinical Microbiology 2011, 49(6), 2093-2096.	Outbreak study	**Level 3**	This study reports the findings of the epidemiological and microbiological investigation of a *Pseudomonas fluorescens* outbreak.	Molecular typing result (PFGE) between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence

Nine patient cases, 6 of this developed febrile neutropenia. All had positive pharyngeal samples. Water sample from a water dispenser in the unit tested positive and genetically matched the patient isolates. All other environmental samples were negative.

Organism: *Pseudomonas fluorescens*

Clinical setting: Bone marrow transplant unit, England UK.

Transmission mode: Direct (ingestion).

Source: Chilled water dispenser as reservoir, unclear how it became contaminated (authors theorised that the nozzle may have been touched by contaminated hands).

Control measures: Removal of the contaminated chilled water dispenser (the remaining one was kept). The long-term plan for the unit is to install filtered plumbed-in main water dispensers and to implement regular qualitative and quantitative water assessments.

Assessment of evidence
Genetic relatedness: All nine patient isolates and the one environmental isolate were identified as being *Pseudomonas fluorescens*. "The isolate from the water dispenser was found to be genotypically identical to the patients' isolates: all isolates of *P. fluorescens* produced identical RAPD patterns (type b pattern), and typing by PFGE revealed that all isolates recovered were indistinguishable, with a designated profile of NOTT PF1." Limitations: Water was sampled via the nozzle of the chiller unit and not directly from the bottle before or after installation, so unclear where the contamination originated from.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Seara N, Oteo J, Carrillo R et al. Interhospital spread of NDM-7-producing Klebsiella pneumoniae belonging to ST437 in Spain. International Journal of Antimicrobial Agents 46 (2015) 169–173	Outbreak report	**Level 3**	This paper describes an interhospital spread of carbapenem-resistant Klebsiella pneumoniae (CRKP) producing NDM-7 carbapenemase across three hospitals in Spain.	Molecular typing result between patient strains and environmental strains isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Assessment of evidence
A total of 7 cases across 3 different hospitals (4 infected, 3 colonised) were categorised as HAI according to CDC definition (supported by admission screening). The median duration from admission to detection of CRKP in these 7 patients was 32 days (range, 21–44 days). Presence of NDM-7 producing *K. pneumoniae* in the traps of the shower and sink. Organism: *Klebsiella pneumoniae* Setting: 3 different hospitals (An acute tertiary hospital, an acute rehabilitation care hospital and a secondary center that provides medical and surgery support to all other hospitals in the Madrid hospital network), Spain. Transmission: Unconfirmed. Source: Sink/shower drain as reservoir for some cases Control measures: Active surveillance at admission following first case. cleaning of the sink and shower with sodium hypochlorite, vaporisation of the inner trap with a steam cleaner for 1 min, and pouring 0.1% sodium hypochlorite, 0.1% sodium hydroxide and 0.1% C12–C16 alkyl dimethyl amine oxide down the drain. 2 months later NDM-producing *K. pneumoniae* was still present in the sink trap and consequently the trap was replaced. Genetic relatedness: PFGE indicated that all CRKP isolates were closely related; MLST showed that all of the isolates belonged to ST437, a single-locus variant of ST11. 5 patients had no overlap of stay but had stayed in same room – this room had colonised sink and shower traps.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Chapuis A, Amoureux L, Bador J et al. Outbreak of Extended-Spectrum Beta-Lactamase	Outbreak report	**Level 3**	This paper describes an investigation of an outbreak of extended-spectrum beta-lactamase (ESBL) producing	Molecular typing result between patient strains and environmental strain isolated from environmental/water	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Producing *Enterobacter cloacae* with High MICs of Quaternary Ammonium Compounds in a Hematology Ward Associated with Contaminated Sinks. Front. Microbiol. 7:1070, 2016.			Enterobacter cloacae in the hematology ward of a University Hospital in France.	samples were compared to establish a link of infection.	

Assessment of evidence

A total of 43 patients (10 infected (urine, wound, blood) and 33 colonised).

Positive samples in patient shower drains, sink drains; 6 were identical to patient isolates. Biofilm was visible in drains and there were no positive water samples.

Organism: *Enterobacter cloacae*

Clinical setting: Haematology unit, France.

Transmission mode: Unconfirmed, possible direct contact with water from drain/spray/splash as correlation between contaminated sink and subsequent acquisition in same room

Source: Sink/shower drains as reservoir, however patient seeding environment not considered

Control measures: Prior to outbreak, QAC-based disinfectant poured daily into all sinks. Following environmental investigation, a bleach-based disinfection programme was implemented. Biofilm was removed on one occasion from all drains (sinks, showers) but no details

Assessment of evidence
given as to method (sinks had to be completely dismantled) – this did not completely eradicate the biofilm as more grew. Possible that below-concentration disinfection (as no contact time with sides of pipes) influenced the decreased susceptibility to QAC disinfectant. Genetic relatedness: "Among the 17 environmental ESBL-producing *E. cloacae* there were 9 distinct pulsotypes and 7 STs. Among the 9 pulsotypes, 6 were identical to those of patients isolates."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kotsanas D, Wijesooriya WRPLI, Korman TM et al. "Down the drain": carbapenem-resistant bacteria in intensive care unit patients and handwashing sinks. MJA 2013; 198: 267–269	Outbreak investigation	**Level 3**	The aim of this study was to investigate a Carbapenem-resistant Enterobacteriaceae (CRE) cluster in the ICU (including finding the source) and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and CRE isolated from environmental/water samples were compared to establish a link of infection.	Number of positive samples, sample type, typing results (PFGE)
Assessment of evidence					
This study describes a Carbapenem-resistant Enterobacteriaceae (CRE) outbreak due to the presence of the metallo-β-lactamase gene bla_{IMP-4} in an intensive care unit (ICU) associated with contaminated sinks. This report highlights the key role of bacterial environmental contamination and sink design and usage in the propagation of CRE outbreaks. Molecular typing is performed. CRE is reported from an ICU and from identical organism isolated from patients and an environmental source (sink). However, other factors (due to lack of IPC measures) might have been facilitating transmission.					

Assessment of evidence
Organism: CRE (*Klebsiella pneumoniae, Serratia marcescens, Enterobacter cloacae, Escherichia coli*)
Transmission mode: Indirect contact
Clinical setting: 14-bed ICU in a tertiary referral hospital in Australia
Source: Sink drains were found to be contaminated and although PFGE confirms close relationship between clinical isolates of *S. marcescens* and isolates from sink, the authors maintain that they are unable to prove that the sinks were the source of patient infection.
Control measures: cleaning and decontamination the sinks using detergents and cleaning proved unsuccessful.
“First, cleaning of grates and drains using single-use, soft brushes was attempted, but repeat screening revealed continued CRE growth. Next, in addition to the brushes, hypochlorite deep cleaning was used after the scrub; however, heavy CRE growth was again evident 1 week later. Finally, an attempt using pressurised steam decontamination (Jetsteam Maxi with plunger tool attachment, Duplex) for 1 minute at 170°C on grates and drains appeared to eradicate almost all CRE at Day 1 (one sink remained colonised); however, repeat testing 3 days after steam treatment showed re-emergence of CRE in all previously affected sinks.”

Question 33: How and by whom should water-associated incidents be investigated?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Protection Surveillance Centre. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

"If an outbreak is suspected, an outbreak control team (OCT) with multi-disciplinary representation should be established by the healthcare facility manager." [HPSC 2015]

"The OCT must investigate the potential outbreak by careful assessment of all the epidemiological, microbiological and environmental information available. "[HPSC 2015] (Evidence from: Healthcare outbreak checklist – For patient, healthcare worker and visitor (PHV) safety. Version 2 ed2013. Health Protection Scotland).

"If surveillance of infection indicates a possible outbreak, this should be thoroughly investigated by an outbreak control team including obtaining water samples for testing. Appropriate corrective actions and preventive actions should be agreed" [HPSC 2015]

"Outbreak Control Team (OCT) Membership: Senior clinical staff from affected area(s); Hospital management Nursing/Midwifery management; Infection prevention and control; Engineering/facilities/estates; Clinical microbiology consultant / Infectious diseases consultant; Specialist in Public Health Medicine; Household / hygiene manager; Risk Manager; Principal; Environmental Health Officer (as required); Health and Safety Manager (as required); Press Officer (as required)." [HPSC 2015]

Assessment of evidence
"Follow-Up Investigation: • Investigate any change in practice, product or fixture that may have caused or be implicated in the outbreak. • Review potential risks associated with the water system in the affected area(s) • Review potential risks associated with the use of invasive devices in the affected area(s) • Review potential risks associated with the use of all water in the affected area(s) including humidified incubators, incubators, ventilators, nebulisers, medications, enteral feeds, ice, drinking water, bathing, hand hygiene etc. • Review occupancy levels and nurse to patient ratios. • Review space between beds/cots/incubators and investigate whether overcrowding may be associated with the outbreak • If a source has not been identified after the initial descriptive investigation, consider an analytical study such as a case-control study." [HPSC 2015]

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Scottish Government. Management of Public Health Incidents: Guidance on the Roles and Responsibilities of	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
NHS led Incident Management Teams. 2020.					

Assessment of evidence

This guidance document on the Roles and Responsibilities of NHS led Incident Management Teams was originally created by the Scottish Government in 2011 and has been updated in 2017 and again in July 2020 by Health Protection Scotland/Public Health Scotland. The purpose of this guidance document is to provide support to the NHS boards in preparing for or in response to public health incidents. It is intended to be strategic but not prescriptive and should allow for flexibility so that NHS boards can respond appropriately where necessary.

"It is the responsibility of the NHS board to call an IMT. In public health incidents, a Consultant in Public Health (CPH(M)) or Specialist in Public Health will lead the investigation and management of the incident on behalf of the NHS board, chair the IMT and co-ordinate the multi-agency IMT response. Usually this will be a CPH(M) with responsibility for Health Protection who will be acting with the delegated authority of the Director of Public Health. The CPH(M) will be responsible for initial action in response to the incident and convening an IMT. The size and nature of the incident will determine the exact arrangements and the IMT Chair can delegate some of the assigned tasks as necessary.

55. In a healthcare setting, the CPH(M) or the Infection Control Doctor (ICD) will chair the IMT depending on the circumstances and this should be agreed in advance and documented in the local plan. The ICD will usually chair the IMT, lead the investigation and management of incidents limited to the healthcare site, where no external agencies are involved and where there are no implications for the wider community. The CPH(M) would normally chair the IMT where there are implications for the wider community e.g. during TB or measles incidents. For rare events, or where there is doubt about who should lead the investigations, the CPH(M) and ICD should discuss and agree who should chair the IMT e.g. during CJD or hepatitis B/ HIV look backs. Where there is an actual or potential conflict of interest

Assessment of evidence

with the hospital service, it may be preferable for the CPH(M) to chair the IMT in discussion with DPH and HAI Executive lead (if necessary).

The IMT is an independent, multi-disciplinary, multi-agency group with responsibility for investigating and managing the incident. The IMT provides a framework, response and resources to enable the NHS board and other statutory agencies to fulfil their remits which are:

”7.4 Investigation

102. From the information gathered from the initial investigation, it may be possible to form a working hypothesis about the route of exposure to the infective agent or the environmental hazard involved, the source and level of that exposure, the nature and size of the population exposed or likely to be exposed, and the degree of risk to the public health. The IMT will then decide how to progress a fuller investigation to test the hypothesis. NHS Boards and HPS/PHS should have a clearly defined pathway to define costs for additional work required to access expertise and pay the associated costs.

103. The investigation should usually consist of three elements: an epidemiological investigation; an investigation into the nature and characteristics of the implicated hazard (in communicable disease incidents, this would be a microbiological investigation); and a specific investigation into how cases were exposed to the infective agent or other hazard (e.g. food supply and hygiene, hygiene in healthcare settings) to inform control measures.

Most incidents merit detailed description, and a descriptive epidemiological study of cases should be carried out. The IMT should agree a case definition for the purpose of the incident and regularly review and revise this definition, as appropriate, throughout the incident investigation. Standard surveillance forms should be available prior to the incident under investigation, and should be modified for the purposes of the incident. Information from individual cases should be collated preferably using an appropriate computer software package. Line listings and standard epidemiological output, e.g. epidemic curve, incidence rates and exposed populations, time line etc should be presented to the IMT. The working hypothesis may then need to be reviewed. Based on the outcome of the descriptive epidemiological investigation, the IMT may decide to carry out an analytical epidemiological study. HPS/PHS is a resource which can provide expertise and support. It is essential to involve scientific, especially diagnostic laboratories, as early as possible in the investigation of an incident. The scientific specialist on the IMT should advise on the taking of appropriate specimens and arrange for relevant investigations. This should include liaison with the relevant reference laboratory in Scotland, or other specialist laboratories in the UK if necessary. The public analyst should arrange for appropriate investigation of non-human samples e.g. food samples. It is essential that accurate results of tests

Assessment of evidence
are available as rapidly as possible to the IMT. The IMT should therefore consider carefully the best use of laboratory resources available, taking into consideration turn-around times for testing and reporting. The laboratory may need to prepare for a substantial increase in samples and plan for surge capacity. Guidance on the submission of clinical samples should be a high priority and should be communicated to all relevant clinicians. As part of the incident investigation, the specialist should advise on the information required by the laboratory to ensure prompt identification of such samples and to distinguish them from other samples. Specific investigations should be undertaken into the reasons for and circumstances in which cases were exposed to the hazardous agent implicated in the incident. This will often involve the taking of appropriate samples for microbiological or other laboratory testing. It also may involve tracing the likely passage of the agent causing illness from the most probable source of contamination or infection to the specific circumstances in which the case was exposed to it. NHS boards and HPS/PHS should liaise with LAs and other agencies in ensuring that relevant protocols for this type of investigation are in place. In the early stages of an investigation, the IMT members should consider whether a criminal investigation is likely to ensue. If so, the Crown Office should be consulted to provide appropriate guidance on evidential procedures required to enable progress but without jeopardising the investigation or control measures. “

Question 34: Should point-of-use (POU) filters be fitted in response to water-associated incidents/outbreaks?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kinsey CB, Koirala S, Solomon B et al. *Pseudomonas aeruginosa* Outbreak	Outbreak investigation (with Case control study)	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* outbreak	Molecular genotyping results between patient strains and	Clinical and patients’ characteristics of cases. Growth/ contamination of

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in a Neonatal Intensive Care Unit attributed to Hospital Tap Water. Infection control & hospital epidemiology July 2017, vol. 38, no. 7.			in the US (including finding the source) and to determine the impact of infection prevention and control measures.	*Pseudomonas aeruginosa* isolated from environmental/water samples were compared to establish link of infection.	environmental/water samples, genotype results (PFGE).
Assessment of evidence					
Environmental sampling was performed in areas with the strongest epidemiologic links to cases (i.e. rooms with multiple cases or a recent case). Samples were taken from sinks – the POU filters on taps were removed and 1litre samples collected, POUs were replaced after sampling. Swab samples were also collected from taps and drains, and sponge-stick samples from sink basins. Sponge-stick and swab samples were taken from ventilator equipment, breast pumps, an incubator humidity outlet, and shelves adjacent to the patient room sinks. Water samples were also collected from pipes delivering hot and cold water to the NICU. Samples were tested on MacConkey selective agar using an automated biochemical identification system and were positive for *P. aeruginosa*. To determine relatedness, PFGE was performed on 21 *PA* environmental samples and 10 case isolates (5 surveillance and 5 clinical). Organism: *Pseudomonas aeruginosa* Transmission mode: Unclear, however it was noted that washing hands with infected water may have contributed. Clinical setting: Newly built community-based hospital, 28-bed neonatal intensive care unit in the United States of America. Source: Tap water Control measures: The hospital removed aerators from faucets; cleaned, disinfected, and removed mineral deposits on faucets and sink fixtures; and performed multiple hyperchlorination flushes of the building's water system. The hospital also installed POU filters on all NICU faucets in December 2013. In May 2014, the hospital removed POU filters when NICU faucets were replaced with a different model.					

Assessment of evidence
They were reinstated after cases appeared again. Case patients had higher odds of having received care in a room with no POU filter installed on the sink faucet during the 7 days before positive culture (eOR, 37.55; 95% CI, 7.16–∞). All 31 case patients were in rooms without POU filters during the 7 days before positive culture, compared with 14 (45%) control patients. Implementation of policy of using ABHR after hand washing with soap and water, until water remediation efforts could be ensured. “PFGE analysis of CDC environmental samples and patient isolates sent to the CDC laboratory revealed 4 unrelated groups of environmental and patient isolates with indistinguishable PFGE patterns. Isolates from 2 case patients were indistinguishable by PFGE from environmental isolates collected in the rooms occupied by each case patient.” The paper concluded as follows: “Our findings are consistent with the statement made by Williams et al that waterborne healthcare-associated infections occur “at the 3-way intersection of nonsterile potable water, susceptible individuals, and a lapse in infection control practices.” All 3 factors likely contributed to this outbreak. Although interruption of the outbreak with POU filters provided a short-term solution, eradication of *P. aeruginosa* in the hospital water, faucets, and sinks was necessary to protect patients. This outbreak highlights the importance of addressing and understanding the inherent risks (e.g., biofilm formation) in healthcare facilities where water has been stagnant for extended periods.” Limitations: Due to the size of the NICU, matching of cases and controls using a ratio greater than 1:1, matching by NICU admission date, or multivariable modelling could not be done.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Watkins LK, Toews KA, Harris AM, et al. Lessons from an outbreak of Legionnaires’ disease on a	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of Legionnaires’ disease on a hematology-oncology unit (incl	Clinical and environmental isolates were compared by monoclonal antibody and sequence-based typing.	Number of positive samples, sample type, typing results (monoclonal antibody and sequence-based typing)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
hematology-oncology unit. Infection control & hospital epidemiology. 2017 Mar;38(3):306-13.			finding the source) and to determine the impact of infection prevention and control measures.		

Assessment of evidence

Investigation suggests that the potable water system was the likely source of infection. Lp1 strains isolated from water on the unit were indistinguishable from all 3 clinical specimens by SBT.

The median time between symptom onset and *Legionella* testing was 8.5 days (range, 0–65 days)

The authors suggest that a single case of LD that is definitely healthcare associated should prompt a full investigation. No further cases were identified after implementation of 0.2um point-of-use filters.

Lessons learned from this outbreak:

- Hospital had *Legionella* water management program, however providers were not routinely notified of positive environmental testing results. Clinicians may therefore have been less likely to include diagnostic testing for LD in their initial management of patients.
- Regular clinician education should be integral part of a hospitals *Legionella* water management program.
- Some cases were incorrectly misclassified as community acquired rather than HAI.

Organism: *Legionella*

Transmission mode: Indirect contact.

Clinical setting: hematology-oncology unit

Source: Contamination of the unit's potable water system (Contaminated water systems).

Assessment of evidence
Control measures: water restrictions (limiting contact with the affected building potable water to washing visibly soiled hands) were implements for all patients, visitors and staff. Bottled water was provided for drinking and hygiene activities, and alcohol-based hand sanitizer was provided for routine hand cleansing. Water restrictions were lifted once 0.2 um PoU filters were obtained for all sinks, shower heads, and ice machines. Remediation of the potable water system was initiated once environmental samples were obtained and consisted of superheating each of the 3 water-riser systems to 160°F, flushing, and hyperchlorination (a chlorine injection system was installed for emergency remediation). Ongoing monitoring of chlorine at points of use and follow-up sampling with subsequent remediation as needed were advised. Limitations: only confirmed cases were included in the study; potentially underestimating the actual extent of the outbreak. No control group was included. Unable to determine which of the measures was responsible for ending the outbreak as all measures were implemented simultaneously.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Litvinov N, da Silva MT, van der Heijden IM, et al. An outbreak of invasive fusariosis in a children's cancer hospital. Clinical Microbiology and Infection. 2015 Mar 1;21(3):268-e1	Outbreak investigation	**Level 3**	The aim of this study was to investigate an outbreak of invasive fusariosis in Brazil and to determine the impact of infection prevention and control measures.	Molecular typing results between patient strains and *Fusarium* spp. isolated from environmental/water samples were compared to establish a link of infection.	Positive patient samples, positive environmental samples, genotyping results.

Assessment of evidence
Outbreak was only controlled 1 year after the first case, when water filters filtering 0.2 um were installed at the exit of all faucets and showers in all patient rooms (PoU). Organism: *Fusarium* Transmission mode: - Clinical setting: Children's cancer hospital in Brazil Source: hospital water (contaminated water systems) Control measures: • Interruption of new admissions to the unit during 47 days • Transfer of the hospitalized patients to another unit in another building of the hospital • Renovation of rooms and bathrooms with closure of the communications between service floors and patient rooms; ceiling panels were replaced with plaster ceilings • Disconnection of central hot water reservoir and installation of electric instant heating devices • Cleaning of cold water reservoirs with chlorine and continuous chlorination of water in the reservoirs (1.5 ppm) controlled by a chlorination device • Filtration of water before entry into water reservoirs (10- µm filters)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Aumeran C, Paillard C, Robin F, et al.	Outbreak investigation	**Level 3**	The aim of this study was to investigate a *Pseudomonas aeruginosa* and	Molecular genotyping results between patient strains and *P.*	Number of positive samples, sample type, antibiogram

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Pseudomonas aeruginosa and *Pseudomonas putida* outbreak associated with contaminated water outlets in an oncohaematology paediatric unit. Journal of Hospital Infection. 2007 Jan 1;65(1):47-53.			*Pseudomonas putida* outbreak *(*incl finding the source) and to determine the impact of infection prevention and control measures.	*aeruginosa* and *P. putida* isolated from environmental/water samples were compared to establish link of infection.	and genotyping results.

Assessment of evidence

No further cases were identified after implementation of control measures.

Organism: *Pseudomonas aeruginosa* and *Pseudomonas putida*

Transmission mode: Not confirmed

Clinical setting: Haematology paediatric unit of a teaching hospital in France.

Source: Contaminated water outlets

Control measures: Water network was chlorinated, and disposable seven-day filters were fitted on all taps and showers. Due to the deleterious effects of chlorination on the water network and the cost of the weekly filter change, a water loop producing microbiologically controlled water was installed. In addition, the concentration of the detergent disinfectant was increased and refillable sprayers were replaced with ready-to-use detergent disinfectant solution for high-risk areas.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kessler M. A., Osman F., Marx J. J., et al. Hospital-acquired *Legionella pneumonia* outbreak at an academic medical center: Lessons learned. American Journal of Infection Control 49 (2021) 1014−1020	Outbreak investigation (incl case-control element)	**Level 3**	An epidemiological and laboratory investigation of a hospital-acquired *Legionella pneumonia* outbreak at of The University of Wisconsin Hospital. Case study: using outbreak data to identify potentially modifiable risk factors for *Legionella pneumonia*	Molecular genotyping results (WGS) between patient strains and *L. pneumonia* isolated from environmental/water samples were compared to establish link of colonisation/infection	Case-control study: ICU admission, 30-day mortality and 90-day mortality, Demographic data and patient factors, pertinent exposures Outbreak: number of clinical cases, environmental assessment of the hospital water treatment, contamination (/growth) of *Legionella* in environmental samples taken from patient rooms and clinical units, molecular type of isolates found.
Assessment of evidence					
This outbreak study with a case-control element showed that an outbreak occurred despite having silver-copper ionization system in place (which changed from high flow fixed dose to low flow, flow-based shortly before the outbreak occurred). The cause was thought to be the					

Assessment of evidence
implementation of changes to the water treatment strategy and it is recommended by the authors to assess levels of culturable *Legionella* in the months preceding and after implementing changes to the water system and/or its treatment strategy. The outbreak was under control after control strategies such as among others shower restriction, hyperchlorination and point-of-use filters. Organism: *Legionella pneumonia* Transmission mode: Direct (from water system) Clinical setting: 3 different inpatient floors (immunosuppressed patients: 3 bone marrow transplants, 2 solid organ transplants, 2 haematology and 2 oncology patients) 2 outpatients. The case-control study showed that being a current smoker, having showered during admission and being on prescribed steroids prior to admission were the strongest predictors for acquiring *Legionella* disease during the outbreak. Source: Hospital water circuit

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
BSI Standards Publication 2022.					

Assessment of evidence

"This British Standard gives recommendations and guidance on how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment." The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks.

On POU filters, the document states the following:

Where POU filters are fitted, assessors should verify they are suitable for the intended use (i.e. they are CE marked or the UK equivalent after 2022) and fitted correctly, and checked regularly for leaks around the fitting and there are predetermined criteria for removal. Due to the risk of contamination of POU filters and the surrounding area, the filters should not be re attached once removed. The assessment should also take into account whether:

a) the choice of filter is suitable for its intended purpose (0.2 µm sterilizing grade filters intended for use in healthcare settings to prevent dissemination of waterborne bacterial pathogens);

b) there are documented procedures agreed by the WSG for fitting, changing and cleaning filters;

c) there are suitable training and competence checks in place to verify filters are connected to the tap correctly and without any leakage around the fitting and filter;

d) where fitted as a short-term measure there are pre-determined criteria for when filters can be removed;

e) filters are fitted with an appropriate air gap;

NOTE 1 Attention is drawn to the Water Supply (Water Fittings) Regulations with regard to selection of the correct filters.

NOTE 2 In order to comply with the regulations, the filters can be WRAS approved.

Assessment of evidence
f) there is sufficient activity space to wash hands or fill drinking water receptacles without contact with the drain or any surfaces including of the filter housing; g) there is sufficient stock of POU filters and any necessary adapters to verify they are changed at the frequency recommended by the manufacturer with spares for when they need to be removed for sampling or blockages; and h) training of cleaners and ward staff is provided so they understand the risks of removal, crosscontamination and appropriate cleaning if any required" "The risks from all potential routes of transmission of waterborne pathogens should be assessed by the risk assessment team. Factors which increase the risk include…h) poor flow from filters increasing the likelihood of removal; i) poor fitting of POU filters allowing leakage of unfiltered water around the housing; j) refitting of POU filters resulting in cross-contamination"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
in Healthcare Facilities. Health Protection Surveillance Centre 2015.					

Assessment of evidence

This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks.

On disposable point of use filters, the document states, “Disposable point-of-use filters are attached to water outlets and act as a barrier to the passage of waterborne organisms at the point of water delivery. They do not eradicate waterborne organisms. To be effective, the filter membrane must have a nominal pore size no greater than 0.2µm. Where contamination of water or a water outlet has been identified they may allow for continuity of care in areas, especially areas where highly vulnerable patients are treated, e.g. burns units, transplant units, critical care units. They should only be used whilst the source of contamination is being identified and rectified through engineering controls. Installation should be subject to a risk assessment, taking note of the reduced flow that will arise from increased resistance and the cost of installing and maintaining them. A risk assessment is also required prior to discontinuation of use.(87) Disposable point-of-use filters are quick and easy to connect and exchange. However, when connected to water outlets they can obstruct access to handwash basins resulting in splashes. Filters become occluded over time and must be changed regularly. They may also cause retrograde contamination of the distribution system. Disposable point-of-use filters should be considered only as a temporary solution and complementary to a systemic disinfection modality. Continuous long-term use of point-of-use filters is not recommended, except where there is no effective alternative”.

“Central absolute bacteria filters - These filters are installed as close to the heat source/calorifier outlet as possible. The filters range in size from 0.2 to 0.65 micron. They operate by continuously cleaning the system and assist in preventing the build-up of deposits at final

Assessment of evidence
outlets. They are generally protected upstream by either a 1 or 5 micron particulate filter and in some circumstances by a strainer upstream of that. The pressure drop and/or flow-rate through the filter should be monitored via the Building Management System (BMS). Provided they are installed as close to the heat source/ calorifier outlet as possible and in accordance with supplier/manufacturer specifications and UK HTM 04-01, they may be a cost effective method to reduce system particulate and sediment levels."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Trautmann M, Halder S, Hoegel J, et al. Point-of-use water filtration reduces endemic *Pseudomonas aeruginosa* infections on a surgical intensive care unit. American journal of infection control 36.6 (2008): 421-429.	Before and after study	**Level 3**	Installation of Point-of-use water filters (0.2µ)	Comparison of a randomly sampled proportion of patients in the ICU who stayed more than 3 days before and after the installation of point-of-use water filters.	Proportion of sampled patients (and water) infected with *P. aeruginosa* before and after filter installation. Odds ratio Genetic relatedness

Assessment of evidence
This study shows that using disposable point-of-use water filters (0.2 µm) on outlets was associated with a significant reduction (56%, P<0.0003) of chronically endemic *P aeruginosa* infections on a surgical ICU of a German teaching hospital. They conclude from different viewpoints, that point-of-use water filtration was a simple, successful, and highly cost-effective strategy to lower the burden of chronically endemic *P aeruginosa* infections on a surgical ICU.

Assessment of evidence

Organism: *P. aeruginosa*

Transmission mode: Indirect/direct water usage (outlets)

Clinical setting: Surgical ICU in a teaching hospital in Germany

Source: Not certain. Likely to be in peripheral sites near the outlets e.g., rubber washers or mixing balls in the fittings.

Control measures: Point-of-use filters (Changing of aerators and cleaning of aerator threads, restriction of tap water for patient care and alcohol-based hand disinfection after hand washing had no apparent effect on water site colonization. This is thought to be possibly because tap water was still being used for lower body washes of patients which may increase the risk of recontamination of the bed environment and hands of nursing personnel).

Outcome: “After installation of the water filters, water sampling was continued at 1 to 3 monthly intervals. *P aeruginosa* was not detected in 52 water samples collected downstream of filters.” The risk of sampled patients belonging to the postfilter period was 74% lower compared to the prefilter period (P = 0.0022).

Genetic relatedness: “All water- and patient-associated isolates collected during this time period were genotyped by means of 2 sequentially performed random amplified polymorphic DNA polymerase chain reactions”. All the water isolates and 92.6% of patient isolates belonged to a single clone.

Limitations:

- Patients were only tested for *P. aeruginosa* when showing symptoms, thus reduction in colonisation cannot be accurately measured (missing ones that do not have symptoms but are colonised)
- Variables pre vs post filter periods include: Total cultures sent, consumption of antibiotics (total carbapenems and total DDDs)
- Significant differences only for *P. aeruginosa* and not for any pathogen (which was also calculated in table 5 including *S. aureus, E coli and C albicans*)

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Health Technical Memorandum 04-01: Water safety for healthcare premises Part A: Design, installation and testing. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish Health Technical Memorandum gives "comprehensive advice and guidance to healthcare management, design engineers, estate managers and operations managers on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises." The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks.

"Point-of-use filters have been found to provide protection from exposure to bacteria such as *Legionella* and *Pseudomonas* by preventing the dispersal of bacteria from showers and other water outlets. To be effective, the filter membrane needs to have a nominal pore size of no greater than 0.1µm. Before their use is contemplated, two factors should be considered:-

- the filters do not eradicate the organism, but prevent discharge to the environment from the filtered outlet only;
- by retaining the organism within the pipework, it may be possible for the organisms to multiply and regressively 'seed' other parts of the distribution system.

Assessment of evidence
Filters will also need to be changed routinely, depending on usage of the outlets. Their use, therefore, should be considered only as part of an overall regime of bacterial control to be used where the most vulnerable patients are to be treated. Installation of point-of-use filters should be subject to risk assessment and designers should be aware of the reduced flow that will arise from increased resistance. This could be an issue on upper floors of premises with a gravity-fed installation. Once a point-of-use filter has been installed it will require to be retained in use thereafter unless a risk assessment deems otherwise. In new or refurbished installations taps should be provided that can accommodate the later installation of point-of-use filters if the need arose.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks.

Assessment of evidence
“Point-of-use filters must be changed in accordance with the manufacturers’ recommendations, typically at least once a month. When changing filters, it is recommended that sampling of water quality takes place at outlets identified as sentinel points, before refitting a replacement filter. Except where taking samples as above, once point-of-use filtration has been introduced, taps or showers must not be used without a filter in place. Where point-of-use filters are no longer required, the outlet and associated pipework must be disinfected to remove any accumulated biofilm before the system is returned to service... Manufacturer’s instructions should be followed at all times.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part G: Operational procedures and Exemplar Written Scheme. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance “has drawn upon experience in producing the most comprehensive documentation to date in the form of operational procedures leading to the production of Written Schemes, a relevant extract from the HSE Approved Code of Practice L8 and

Assessment of evidence
a template or exemplar for NHS Boards to follow in the preparation of a Written Scheme". The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks. "Point-of-Use Filters (P.O.U) Filters will only be installed and used where this is practical and there has been a written policy decision by the Water Safety Group, along with a complimentary managed maintenance change-filter process. This will have to be put in place for life – or until a further policy decision is taken by the Water Safety Group confirming that they are satisfied that the affected outlet and pipework can be removed or disinfected without compromising the rest of the water system."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of *Legionella* bacteria in hot and cold water systems. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British document provides "practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999." The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks. Point of use (POU) filters are filters "with a maximal pore size of 0.2 µm applied at the outlet, which removes bacteria from the water flow."					

Assessment of evidence
"Dutyholders are required to prevent or control the risk from exposure to *Legionella*. Precautions include physical methods such as regular movement of hot and cold water in distribution pipework, regular flushing of outlets to ensure water cannot stagnate in the hot and cold water systems and POU filters. For control measures to be effective, it is essential to keep the whole system clean, as biofilms or inorganic matter such as scale can reduce the efficacy of any type of control measure significantly." "POU filters prevent the discharge of planktonic *Legionella* and other potentially pathogenic microorganisms (bacteria and parasites) from the tap and shower outlets. They should be used primarily as a temporary measure until a permanent safe engineering solution is developed, although long-term use of such filters may be needed in some healthcare situations. They may also be considered where high level of disinfection of water systems may dislodge biofilm. Where POU filters are fitted, they should be renewed and replaced according to the manufacturer's recommendations." "Where considered necessary for ongoing patient management, POU filters should be used primarily as a temporary control measure while a permanent safe engineering solution is developed, although long-term use of such filters may be required in some cases." In Table 2:1: Checklist for hot and cold water systems, the guidance recommends the following action to be taken according to manufacturer's guidelines for POU filters; "Record the service start date and lifespan or end date and replace filters as recommended by the manufacturer (0.2 µm membrane POU filters should be used primarily as a temporary control measure while a permanent safe engineering solution is developed, although long-term use of such filters may be needed in some healthcare situations"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Heath Technical Memorandum 04-01: Safe water in healthcare premises:	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Part B: Operational management. 2016.					
Assessment of evidence					
“This Health Technical Memorandum (HTM) gives comprehensive advice and guidance to healthcare management, design engineers, estate managers, operations managers, contractors and the supply chain on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises. It is equally applicable to both new and existing sites.” The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks. “Point-of-use (POU) filtration should be considered and agreed by the WSG only as an interim safeguard where control measures have been ineffective, prior to and during engineering remedial works, during periods of plumbing refurbishments and maintenance works, and where additional protection is required for vulnerable patients. Continuous long-term use of POU filters is not recommended, except where there is no effective alternative. The WSG should review their continued use and ensure an action plan is created and enacted to make certain they are changed at the intervals specified by the manufacturer.” “Where POU filters are installed as a temporary measure while appropriate remedial work is carried out, they should be changed in accordance with the manufacturers’ recommendations, typically at least once a month. Once removed for whatever reason, a replacement filter should be fitted. When changing filters, it is recommended that sampling of water quality takes place at outlets identified as sentinel points before refitting a replacement filter. It is essential to ensure that – where filters are to be used – they are constructed of the appropriate materials (see paragraph 3.1 in HTM 04-01 Part A)” “Where POU filters are to be used, the backflow protection requirements need to be maintained in accordance with the Water Supply (Water Fittings) Regulations 1999. This may require additional backflow protection or modification of the system. In addition, sufficient activity space should be maintained to enable the outlet to be used without contaminating the filter.”					

Assessment of evidence
”Where filters are in place, follow manufacturers’ instructions for cleaning, or they should be wiped clean as part of the basin/sink cleaning protocol as agreed by the WSG.”
”Where point-of-use filters are no longer required, the outlet connection should be flushed, cleaned and disinfected to remove any accumulated biofilm”
In Table 1: Checklist for hot and cold water systems (adapted from HSG274 Part 2), the document recommends the following action to be taken according to manufacturer’s guidelines for POU filters; “Record the service start date and lifespan or end date and replace filters as recommended by the manufacturer ((bacterial retention filters should be used primarily as a temporary control measure while a permanent solution is developed, although long-term use of such filters may be needed in some healthcare applications)”
“Ice machines should not be placed in augmented care units. Where ice is needed for treatment purposes, it should be made using water obtained through a microbiological POU filter or boiled water in sterile ice trays or ice bags.”
“POU filters, where they can be fitted, may be used to provide water free of *P. aeruginosa*. Where fitted, regard filters primarily as a temporary control measure until a permanent solution is developed, although long-term use of such filters may be required in some healthcare applications. Where POU filters are fitted to taps, follow the manufacturer’s recommendations for renewal and replacement and note that the outer casing of a POU filter and the inner surface can become contaminated. There should be sufficient activity space once a POU filter has been fitted.”
“When replacing taps, consider fitting… taps to which a filter can be attached to the spout outlet. Note: Such taps can be used for supplying water for cleaning incubators and other clinical equipment.”
The document also states that the following actions (amongst others) are required if *Legionella* bacteria (cfu/l) exceeds are within the following limits in pre-flush samples.
> 1000 – 10,000 cfu/l – “If a shower (spray outlet) cannot be taken out of use, consider installing point of use microbiological filters on all affected showers.”
> 10,000 cfu/l – “if outlet cannot be taken out of use, install a point of use microbiological filter on all affected outlets.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Health Technical Memorandum 04-01: Safe water in healthcare premises. Part C: *Pseudomonas aeruginosa* – advice for augmented care units. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This British document "identifies methodologies to control and minimise the risks of morbidity and mortality due to *P. aeruginosa* associated with water outlets. It provides guidance on considerations for water outlets and hot and cold water services in augmented care settings; protecting augmented care patients and ensuring a safe environment; and methods of cleaning wash-hand basins and other good hygiene practices to minimise the risk of *P. aeruginosa* contamination." The following section(s) are relevant for this research question on whether point-of-use (POU) filters should be fitted in response to water-associated incidents/outbreaks.

"Point-of-use filter: A filter with a maximal pore size of 0.2 µm applied at the outlet, which removes bacteria from the water flow"

"For direct contact with augmented care patients, water of a known satisfactory quality should be used, that is, either:

i. water where testing has shown absence of *P. aeruginosa*; or

ii. water supplied through a POU filter; or

Assessment of evidence
iii. sterile water (for example, for skin contact for babies in neonatal intensive care units)." "Chilled water and ice-making machines should not be installed in augmented care units. Where ice is needed for treatment purposes, it should be made using water obtained through a microbiological POU filter or boiled water in sterile ice trays or ice bags." "All taps that are used infrequently on augmented care units should be flushed regularly (at least daily in the morning for one minute). If the outlet is fitted with a POU filter, the filter should not be removed in order to flush the tap unless the manufacturer's instructions advise otherwise. A record should be kept of when they were flushed. Some taps can be programmed to flush automatically; such flushing may be recorded through the building management system (BMS)." "If POU filters are fitted to taps, the same cleaning regime applies to the wash-hand basin, but the filter itself should be cleaned according to the manufacturer's instructions. Care should be taken to avoid contaminating the external surface and outlet of the filter."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Kossow A, Kampmeier S, Willems S et al. Control of Multidrug-Resistant *Pseudomonas aeruginosa* in Allogeneic Hematopoietic Stem Cell Transplant Recipients by a Novel Bundle Including	Prospective outbreak investigation	**Level 3**	This paper describes the study of microbiological surveillance data on *MDRPa* for 3 years during the reconstruction of a Bone marrow transplantation center in Germany.	Molecular typing result between patient strains and environmental strain isolated from environmental/water samples were compared to establish a link of infection.	Number of positive environmental and clinical isolates. Genetic relatedness

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Remodeling of Sanitary and Water Supply Systems. Clinical Infectious Diseases, 65(6); 935-942, 2017					

Assessment of evidence

The number of nosocomially-infected patients decreased from 31 in 2012-13 (9.17%) to 3 (1.68%) in 2014 ($p<0.001$).

In 2012-13, 18.94% of toilet samples were positive, 8.11% of shower samples were positive. This decreased to 6.13% of toilets and 2.96% showers in 2014 (both statistically significant reductions). During follow up, 4% of toilets and 5.59% of showers were positive. Sinks tested positive in 0.93% samples in 2012-13 and in zero samples in 2014.

Patients screened on admission and weekly thereafter. WGS indicated a close relationship between patient and environmental isolates however unable to determine exact transmission pathways.

Organism: Multi-drug resistant *Pseudomonas aeruginosa*

Clinical setting: Haematopoietic stem cell transplant unit, Germany

Transmission mode: Unconfirmed.

Source: Shower drains and toilets as potential reservoirs, unable to determine exact modes of transmission however this study provides evidence that patients acquired infection likely from an environmental source.

Control measures: New shower drains installed (easy to clean/disinfect) with covers (disinfected weekly) to prevent removal by patients. Shower heads and taps fitted with point of use filters. Biorec disinfection units installed underneath all sinks (these use UV light, vibration (50-200 Hz), temperature (85'C) and have an antibacterial coating to prevent biofilm formation. Toilets replaced with rimless toilets and an automatic disinfectant flush (0.5% glucoprotamin).

Assessment of evidence
Limitations: some patients not screened weekly due to their clinical situation. Culture method may not have maximised growth of admission screening samples.

Question 35: When can POU filters be removed?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed:

“Point-of-use filters must be changed in accordance with the manufacturers’ recommendations, typically at least once a month. When changing filters, it is recommended that sampling of water quality takes place at outlets identified as sentinel points, before refitting a replacement filter. Except where taking samples as above, once point-of-use filtration has been introduced, taps or showers must not be used without a filter in place.”

“Where point-of-use filters are no longer required, the outlet and associated pipework must be disinfected to remove any accumulated biofilm before the system is returned to service (see also paragraph 5.16 in Part A). Manufacturer’s instructions should be followed at all times.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed: “Disposable point-of-use filters are quick and easy to connect and exchange. However when connected to water outlets they can obstruct access to handwash basins resulting in splashes. Filters become occluded over time and must be changed regularly.”					

Assessment of evidence
"Where contamination of water or a water outlet has been identified they may allow for continuity of care in areas, especially areas where highly vulnerable patients are treated, e.g. burns units, transplant units, critical care units. They should only be used whilst the source of contamination is being identified and rectified through engineering controls. Installation should be subject to a risk assessment, taking note of the reduced flow that will arise from increased resistance and the cost of installing and maintaining them. A risk assessment is also required prior to discontinuation of use."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This British Standard gives recommendations and guidance on "how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water					

Assessment of evidence

systems and the associated environment." The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed:

"NOTE 2 Studies have shown that installing sterilizing grade POU filters on outlets or removing all outlets from within areas where highly immunocompromised patients are treated significantly reduces the overall level of hospital acquired Gram-negative infections."

"Where POU filters are fitted, assessors should verify they are suitable for the intended use (i.e. they are CE marked or the UK equivalent after 2022) and fitted correctly, and checked regularly for leaks around the fitting and there are predetermined criteria for removal. Due to the risk of contamination of POU filters and the surrounding area, the filters should not be re attached once removed. The assessment should also take into account whether:

a) the choice of filter is suitable for its intended purpose (0.2 µm sterilizing grade filters intended for use in healthcare settings to prevent dissemination of waterborne bacterial pathogens);

b) there are documented procedures agreed by the WSG for fitting, changing and cleaning filters;

c) there are suitable training and competence checks in place to verify filters are connected to the tap correctly and without any leakage around the fitting and filter;

d) where fitted as a short-term measure there are pre-determined criteria for when filters can be removed;

e) filters are fitted with an appropriate air gap;

NOTE 1 Attention is drawn to the Water Supply (Water Fittings) Regulations with regard to selection of the correct filters.

NOTE 2 In order to comply with the regulations, the filters can be WRAS approved.

f) there is sufficient activity space to wash hands or fill drinking water receptacles without contact with the drain or any surfaces including of the filter housing;

g) there is sufficient stock of POU filters and any necessary adapters to verify they are changed at the frequency recommended by the manufacturer with spares for when they need to be removed for sampling or blockages; and

Assessment of evidence
h) training of cleaners and ward staff is provided so they understand the risks of removal, crosscontamination and appropriate cleaning if any required." "The risks from all potential routes of transmission of waterborne pathogens should be assessed by the risk assessment team. Factors which increase the risk include: … • poor flow from filters increasing the likelihood of removal; • poor fitting of POU filters allowing leakage of unfiltered water around the housing; • refitting of POU filters resulting in cross-contamination"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part G: Operational procedures and Exemplar Written Scheme. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance "has drawn upon experience in producing the most comprehensive documentation to date in the form of operational procedures leading to the production of Written Schemes, a relevant extract from the HSE Approved Code of Practice L8 and a template or exemplar for NHS Boards to follow in the preparation of a Written Scheme". The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed: "Point-of-Use Filters (P.O.U) Filters will only be installed and used where this is practical and there has been a written policy decision by the Water Safety Group, along with a complimentary managed maintenance change-filter process. This will have to be put in place for life – or until a further policy decision is taken by the Water Safety Group confirming that they are satisfied that the affected outlet and pipework can be removed or disinfected without compromising the rest of the water system."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Department of Health. Heath Technical Memorandum 04-01: Safe water in healthcare premises: Part B: Operational management. 2016.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Health Technical Memorandum (HTM) gives "comprehensive advice and guidance to healthcare management, design engineers, estate managers, operations managers, contractors and the supply chain on the legal requirements, design applications, maintenance and operation of hot and cold water supply, storage and distribution systems in all types of healthcare premises. It is equally applicable to both					

Assessment of evidence
new and existing sites." The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed. **"**Point-of-use (POU) filter: a filter with a maximal pore size of 0.2 µm applied at the outlet, which removes bacteria from the water flow." "Point-of-use (POU) filtration should be considered and agreed by the WSG only as an interim safeguard where control measures have been ineffective, prior to and during engineering remedial works, during periods of plumbing refurbishments and maintenance works, and where additional protection is required for vulnerable patients. Continuous long-term use of POU filters is not recommended, except where there is no effective alternative. The WSG should review their continued use and ensure an action plan is created and enacted to make certain they are changed at the intervals specified by the manufacturer." "Where POU filters are installed as a temporary measure while appropriate remedial work is carried out, they should be changed in accordance with the manufacturers' recommendations, typically at least once a month. Once removed for whatever reason, a replacement filter should be fitted. When changing filters, it is recommended that sampling of water quality takes place at outlets identified as sentinel points before refitting a replacement filter. It is essential to ensure that – where filters are to be used – they are constructed of the appropriate materials (see paragraph 3.1 in HTM 04-01 Part A)" "Where point-of-use filters are no longer required, the outlet connection should be flushed, cleaned and disinfected to remove any accumulated biofilm"

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health and Safety Executive. Legionnaires' disease – Part 2: The control of *Legionella* bacteria in	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
hot and cold water systems. 2014.					
Assessment of evidence					
This British guidance document provides “practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to *Legionella* and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999.” The following section(s) are relevant for this research question on when point-of-use (POU) filters can be removed: “Where considered necessary for ongoing patient management, POU filters should be used primarily as a temporary control measure while a permanent safe engineering solution is developed, although long-term use of such filters may be required in some cases.”					

Question 36: Whose responsibility is it to carry out any of the above actions?

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Prevention and Control of Infection from Water Systems in Healthcare Facilities Sub-Committee of the HPSC Scientific Advisory Committee. Guidelines for the Prevention and Control of Infection from Water Systems in Healthcare Facilities. Health Protection Surveillance Centre 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This Republic of Ireland guidance document provides advice on the environmental controls, risk assessment needs and routine sampling of water systems and sources in healthcare facilities as well as surveillance and actions required if healthcare-associated infection from water sources is suspected. The following section(s) are relevant for this research question on whose responsibility it is to carry out the actions described in this review:					

Assessment of evidence
"The healthcare facility manager must ensure that the recommendations in this guidance document are implemented in their institution." "If an outbreak is suspected, an outbreak control team (OCT) with multi-disciplinary representation should be established by the healthcare facility manager." "Sampling should be undertaken by staff trained in the appropriate technique for taking water samples including the use of aseptic technique to minimise extraneous contamination."

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Public Health England. Examining food, water and environmental samples from healthcare environments. Microbiological guidelines. 2020.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A
Assessment of evidence					
This English document "aims to summarise the available legislation and guidance for microbiologists and infection control nurses working within healthcare settings and to provide additional clarification and guidance on sampling and result interpretation where these are currently lacking." The following section(s) are relevant for this research question on whose responsibility it is to carry out the actions described in this review.					

Assessment of evidence
“Wherever possible, testing should be carried out by a laboratory that is UKAS-accredited to perform a specific test.”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part G: Operational procedures and Exemplar Written Scheme. 2015.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This Scottish guidance “has drawn upon experience in producing the most comprehensive documentation to date in the form of operational procedures leading to the production of Written Schemes, a relevant extract from the HSE Approved Code of Practice L8 and a template or exemplar for NHS Boards to follow in the preparation of a Written Scheme”. The following section(s) are relevant for this research question on whose responsibility it is to carry out the actions described in this revie: “Premises used by the NHS for the delivery of healthcare are dependent upon water to maintain hygiene through a safe and comfortable risk assessed environment for all who may use, interface and support the delivery of functional healthcare.”

Assessment of evidence
“NHS Board** has a Management and Control of Water Safety Policy, which requires all management and staff across the organisation to be aware of statutory regulations, NHS Scotland mandatory guidance documents and responsibilities with specific arrangements. ** The name of NHS Board would be inserted here.” This document provides a chart overview of the organisational structure of a NHS board for the management and control of risk from potential exposure to harmful bacteria. This can be included in the review as appendix. The responsible roles are: • General Manager – Facilities & Estates Designated Person (Water) • NHS Board Water Safety Group • Head of Maintenance • Deputy Head (maintenance) • Estates Officers • Competent Persons, Maintenance Technicians, Tradespersons, Installers, Contractors and Contract Supervising Officers “Note: The Head of Maintenance (or appointed deputy) is the “Responsible Person (Water)” managing day-to-day risks and will be the estates lead in the event of an operational incident”

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
Health Facilities Scotland. Scottish Heath Technical Memorandum 04-01. Water safety for healthcare premises. Part B: Operational management. 2014.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence

This Scottish guidance document provides information and recommendation on operational management for water safety for healthcare premises. The following section(s) are relevant for this research question on whose responsibility it is to carry out the actions described in this review.

“The Infection Control Manager, the Infection Prevention and Control Doctor (also known as the Infection Control Doctor) and the Consultant Microbiologist are nominated by management to advise on infection control policy and to have responsibility for the maintenance of water quality from the point it leaves the tap. “

“The policy should be acceptable to the Infection Prevention & Control Team and they should agree any amendment to that policy.“

“Water Safety Groups (WSG) within NHS Boards will be led and chaired, as a minimum, by the Responsible Person (Water) who will ensure that responsibility is taken for microbiological hazards and are identified by appropriate Group members They will assess risks, identify and monitor control measures and develop incident protocols. WSG should be a sub-group of and report to the Chair of the hospital Infection Control Committee and ensure a coordinated approach exists between Infection Prevention and Control Teams, clinical

Assessment of evidence
staff and Estates & Facilities on all water issues. There should be a clear line of responsibility to the Chief Executive through the Infection Control or other Committee." Water Safety Plan and Risk Assessment of Water Distribution Systems 5.28 A risk assessment of the water distribution system in a healthcare facility is a legislative requirement. A water safety plan (WSP) approach, incorporating a risk assessment, is outlined in the World Health Organisation (WHO) document Water Safety in Buildings, 2011. The latest HPS/HFS Guidance on *Pseudomonas aeruginosa* – advice for augmented care units, also recommends that a Water Safety Group (WSG) commissions and develops a WSP which includes a risk assessment. The key steps of a WSP, including a risk assessment, are outlined in this document.

Study	Study Type	Evidence Level	Intervention	Comparison	Outcome measure
British Standards Institution. BS8580-2:2022. Water quality Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice. BSI Standards Publication 2022.	Guidance (expert opinion)	**Level 4**	N/A	N/A	N/A

Assessment of evidence
This British Standard gives recommendations and guidance on “how to carry out risk assessments for *Pseudomonas aeruginosa* (PA) and other waterborne pathogens whose natural habitat is within constructed water systems and the aqueous environment (autochthonous) rather than those being present as a result of a contamination event. It includes those pathogens that can colonize and grow within water systems and the associated environment.” The following section(s) are relevant for this research question on whose responsibility it is to carry out the actions described in this review: “A multidisciplinary team needs to be appointed to carry out risk assessments and develop a WSP to manage the identified risks associated with water, as advocated by the World Health Organisation, national regulators (HSE ACOP L8 and associated Guidance HSG 274-2), national department of health regulations and guidance in England and where relevant, the devolved nations e.g. The Health and Social Care Act 2008 Code of Practice on the prevention and control of infections and related guidance. Relevant national health technical memoranda and building notes need to also be taken into account. This standard is intended to be used in conjunction with BS 8680 and BS 8580-1.” “In augmented care areas flushing should be employed on a daily basis. NOTE 1 Incorporating flushing into the cleaning protocol together with the training of all relevant staff can be used to ensure this is carried out regularly.”