SHEng
SMART HEALTHCARE ENGINEERING
2023-1-RO01-KA220-HED-000159985

Co-funded by
the European Union

LEGIONELLA PREVENTION AND CONTROL IN HEALTHCARE FACILITIES

Class content material

This document is part of a training materials collection developed within the Erasmus+ project “Smart healthcare engineering”, SHEng, project No. 2023-1-RO01-KA220-HED-000159985.

The collection is intended for engineering students and professionals working in the healthcare sector. It covers technical subjects relevant to hospital infrastructure, equipment, materials and support services, helping readers understand how engineering contributes to safe patient care and the reliable operation of healthcare facilities.

These materials support classroom teaching and independent study. They should be used alongside the project handbook and the presentations, courses and other learning resources available on the project website. Each document addresses a specific subject, while the collection provides a broader understanding of the responsibilities and practical challenges of healthcare engineering.

The content is educational. Its application in practice requires consideration of the conditions of each healthcare facility, the applicable standards and the instructions provided by equipment manufacturers.

Project website: www.smarthealtheng.com

SHEng
SMART HEALTHCARE ENGINEERING

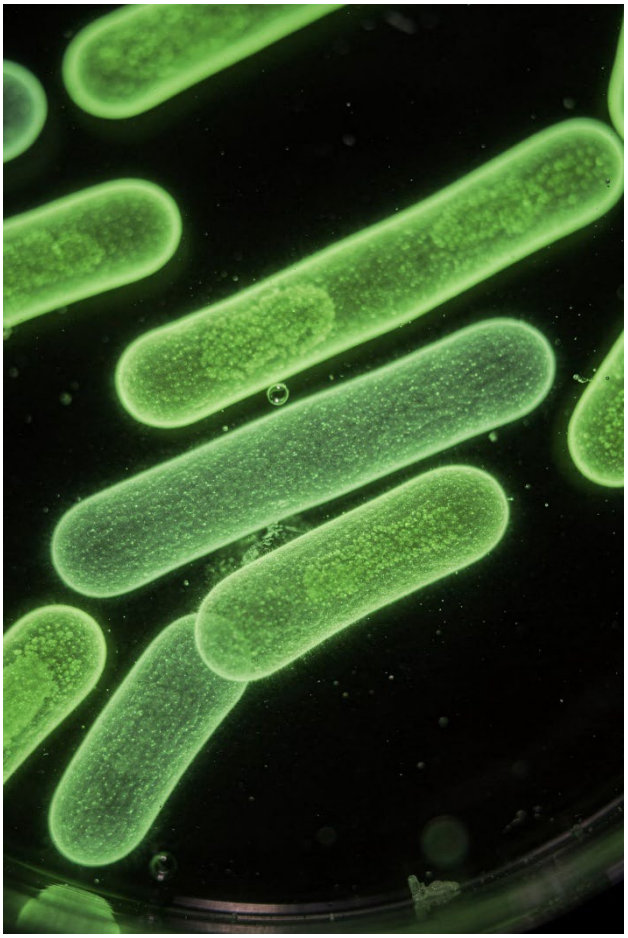
Transilvania University of Brasov
ULPGC Universidad de Las Palmas de Gran Canaria
MANISA CELAL BAYAR ÜNİVERSİTESİ
Servicio Canario de Salud
SPITALUL MUNICIPAL SĂCELE
Co-funded by the European Union

LEGIONELLA PREVENTION AND CONTROL IN HEALTHCARE FACILITIES

1. The bacterium and its transmission

Legionella is a genus of Gram-negative bacteria associated mainly with water environments, although some species have other important reservoirs. The organism became widely recognised after the 1976 pneumonia outbreak linked to an American Legion convention in Philadelphia, and its identification in 1977 established the cause of Legionnaires' disease. The historical review by Cunha and colleagues explains how environmental microbiology, clinical testing and outbreak investigation developed together (https://www.cdc.gov/legionella/hcp/clinical-overview/index.html).

From environmental presence to human exposure



The presence of bacteria in water does not by itself describe the risk to a patient, because multiplication, release from the system and a route into the respiratory tract are also involved. In hospital services, exposure commonly concerns small contaminated droplets produced by showers or other water devices, while aspiration can occur when contaminated water enters the airway rather than passing normally into the stomach. This distinction is important for patients with swallowing difficulties.

Legionella can survive within biofilms and multiply inside free-living protozoa, including amoebae, which provide nutrients and some protection from adverse conditions. Once inhaled into the lungs, the bacteria can multiply inside alveolar macrophages, the immune cells that would normally help remove them. This intracellular behaviour explains part of the difficulty of controlling the organism and treating the infection.

Table 1. Two different forms of illness

Feature	Legionnaires' disease	Pontiac fever
Main presentation	Pneumonia, sometimes with severe systemic illness	Flu-like illness without pneumonia
Onset after exposure	Usually within several days; exposure investigations commonly review 14 days	Usually within a few hours to 3 days
Clinical response	Prompt assessment and appropriate antibiotic treatment	Usually resolves without specific antibiotic treatment
Engineering implication	Investigate possible exposure and protect other patients	A cluster may also indicate a shared environmental exposure

Older adults, smokers and people with chronic lung disease or impaired immunity are more likely to develop serious illness, although risk differs between patients and exposure situations. Pontiac fever can also affect otherwise healthy people and usually lasts less than a week. A hospital assessment must therefore consider both the water system and the people who may use it.

Legionnaires' disease is generally not transmitted between people, so routine prevention focuses on contaminated environmental sources. Ordinary domestic air-conditioning units are different from cooling towers: units that do not use water to cool air do not create the same Legionella reservoir. Describing all air conditioning as a source can lead an investigation away from the relevant water equipment.

2. Where risk develops in a hospital.

Hospital water systems often include storage vessels, circulating hot water, long distribution branches and equipment with very different patterns of use. During normal operation, these features can create local conditions that differ considerably from those measured at the main plant, especially in older installations that have been extended several times. A good heater reading cannot demonstrate that every ward receives water under the same conditions.

Growth conditions and persistence

Warm water, prolonged residence time, deposits and loss of disinfectant residual can favour bacterial growth, with biofilm providing a protected habitat on wetted surfaces. Temperatures around 25-45°C are particularly favourable, but these boundaries should not be treated as an immediate switch between survival and elimination. The effect of heat

depends on temperature, exposure time and the conditions around the bacteria, including whether they are protected within a biofilm or host cell.

Stagnation commonly develops when a room is closed, a branch is oversized or an outlet is rarely used, and it may continue unnoticed when the rest of the building operates normally. Corrosion products, scale and sediment can add surface area and alter local water chemistry. For this reason, replacing a pipe material without correcting flow and temperature problems may leave the main causes of colonisation unchanged.

Location	Why it deserves attention	Useful engineering check
Hot water storage and returns	Uneven heating, poor circulation or sediment	Compare storage, supply and return conditions.
Distant or low-use outlets	Cooling, warming of cold water and long water age	Review actual use and temperature response.
Showers and mixing valves	Complex wetted parts and aerosol generation	Check maintenance, upstream supply and mixed-water sections.
Cooling towers	Recirculating water and aerosol drift	Review treatment, cleanliness and drift control.
Ice and respiratory equipment	Water may reach vulnerable patients	Confirm water specification and device maintenance.

Look beyond the main pipework

A short flexible hose, a sensor-operated tap or an incorrectly maintained mixing valve can create a local reservoir even when the main distribution system performs well. Inspection should therefore follow the water to the point of use, including connected devices and any filters, rather than stopping at the mechanical-room boundary.

Risk also changes during renovation and reduced occupancy, when temporary connections, interrupted circulation or low demand can alter a previously stable system. Before a ward reopens, the technical team should confirm that the relevant controls have been restored and documented, with infection prevention input where vulnerable patients will be admitted. The water may look clear and still require assessment.

3. Clinical recognition and diagnosis

Legionnaires' disease can present with fever, cough, shortness of breath and fatigue, sometimes accompanied by diarrhoea or confusion, but these findings cannot reliably distinguish it from pneumonia caused by other organisms. Clinicians therefore need both the clinical picture and a history of possible exposure, including recent hospital

stays or travel. For the engineering team, timely access to reliable locations and dates can help identify which systems should be reviewed.

Current CDC (Centers for Disease Control and Prevention) guidance recommends urinary antigen testing together with testing of a lower respiratory specimen by culture or a molecular method. The usual urinary antigen test mainly detects L. pneumophila serogroup 1, so a negative result does not exclude infection by other serogroups or species. Culture takes longer, but an isolate can be compared with environmental isolates during an investigation .

Method	Main value	Important limitation
Urinary antigen test	Rapid support for diagnosis of L. pneumophila serogroup 1	Usually misses other Legionella types.
Respiratory culture	Recovers an isolate for identification and comparison	Specialized media and time are needed; sensitivity varies.
Respiratory PCR or other molecular test	Rapid detection, potentially covering more types	Coverage depends on the assay; no isolate is recovered.
Paired serology	May help retrospective assessment	Results are too late for most immediate treatment decisions.

Direct fluorescent antibody methods are now a more limited, technically demanding option and should not be presented as the routine confirmatory step after every positive culture. Specimen selection and test interpretation belong to the clinical laboratory, which should be told when Legionella is suspected so that the appropriate methods are used. Environmental water testing cannot diagnose an individual patient.

Legionnaires' disease requires prompt medical treatment with antibiotics active against the organism, commonly a suitable macrolide or respiratory fluoroquinolone, while the choice, route and duration depend on severity, patient factors and current clinical guidance. Treatment should not be delayed while waiting for an environmental investigation or to complete specimen collection. Antibiotic doses are outside the purpose of this engineering material.

Standard precautions apply to Legionnaires' disease; additional isolation is not routinely required solely because this diagnosis has been established. A patient may still need other precautions for a separate suspected infection or another clinical reason. This distinction prevents confusion between isolating a patient and restricting use of a water source that could expose other patients.

Clinical and environmental work should proceed together, with clinicians managing the illness while infection prevention specialists, microbiologists and engineers assess whether the healthcare environment may have contributed to exposure.

4. Water safety planning and responsibilities

A water safety plan should explain how the hospital controls risk during ordinary operation and how staff respond when conditions fall outside the agreed limits. It needs to reflect the actual building, including changes made during maintenance and renovation, because an old drawing or an incomplete outlet list can hide parts of the system that no one is monitoring.

The first step is to bring together the people responsible for engineering, infection prevention, microbiology, clinical services and management, with specialist water-treatment support where needed. The team should map the supply, storage, distribution, returns and connected devices, then identify where bacterial growth and patient exposure could occur. Responsibilities should be assigned to named roles so that absence or staff turnover does not interrupt control.

The CDC water management approach links system description and hazard assessment with control measures, monitoring, corrective action, verification, validation and communication. In practice, each monitored item needs a defined location, an approved limit, a method and frequency of measurement, and a clear action when the result is unacceptable. The plan should also identify who has authority to restrict use or approve reopening.

Role	Typical contribution
Engineering and maintenance	Maintain the system map, measure operating conditions and correct physical defects.
Infection prevention and clinical teams	Identify patient vulnerability, review cases and define exposure precautions.
Microbiology laboratory	Advise on sampling, analysis, reporting and comparison of isolates.
Facility management	Provide resources, assign responsibility and ensure actions are completed.
Public health authority	Coordinate reporting and investigation where required by the jurisdiction.

Verification asks whether planned activities have been carried out, for example whether temperature checks were completed at the correct outlets and whether a failed pump was repaired. Validation asks whether the programme is effective in controlling the intended risk, using suitable evidence such as environmental results, operating trends and clinical surveillance. A signed maintenance sheet can demonstrate completion, but it cannot alone establish that the water system is under control.

5. Temperature and flow control

Temperature control is useful only when the required conditions are maintained through the relevant parts of the system, including return loops and distant branches. Increasing the heater setting may leave a poorly balanced branch lukewarm, while a cold pipe routed beside a hot service may warm during periods of low use. The investigation should therefore compare conditions across the network before deciding where to intervene.

As an example of a published healthcare framework [2], UK HSE guidance describes cold water below 20°C where possible, hot water storage at least at 60°C and hot water reaching 55°C within one minute in healthcare premises. These are reference values for that framework, not a universal legal specification for every country. In systems with mixing valves, the hot supply must be assessed at the appropriate upstream point; patients must not be exposed to these hot-water control temperatures.

Thermostatic mixing valves can reduce scald risk near the point of use, but they also create mixed-water sections that require maintenance and careful design. Locating the valve close to the fixture limits the volume of tempered water downstream. A satisfactory mixed outlet temperature should therefore be recorded separately from evidence that the hot circulation and cold supply meet their own requirements.

Reduce stagnation at its cause

Remove redundant branches where feasible, size storage for actual demand and check that circulation follows the intended route. A closed ward may need an interim flushing programme, but continued flushing should not become the permanent answer to unnecessary pipework. In frequently changing hospital layouts, the decision to retain an outlet should include its future use and maintenance burden.

Flushing should follow a documented procedure with a defined endpoint, suitable protection against aerosols and scalding, and recording of the relevant water conditions. Weekly flushing appears in published guidance for certain low-use sections, but frequency must also reflect the risk assessment and whether water quality remains controlled between visits. Running every tap briefly without measuring anything gives limited evidence of improvement.

Worked interpretation of temperature records

Consider a learning example in which storage is 62°C, the main return is 57°C and a distant hot branch reaches only 43°C after one minute. If the approved criterion for that measurement point is 55°C, the plant readings do not cancel the local failure; the team should check whether the measurement was taken before mixing, then investigate circulation, balancing, insulation and actual demand.

After corrective work, repeat the measurement under comparable conditions and check nearby points to establish whether the problem was local or part of a wider pattern. A single successful reading is useful, but a trend over normal operating conditions gives stronger evidence that the correction has lasted.

6. Disinfection and outlet protection

Chemical treatment can support Legionella control, but its performance depends on the water reaching the relevant parts of the installation with suitable conditions maintained throughout operation. Dose at the treatment unit and residual at a distant outlet are different measurements, particularly where temperature, deposits or long residence time increase disinfectant demand.

Choose a treatment for the system

Xi et al. [3] reviewed chlorine-based disinfection in building plumbing and found that effectiveness depends on multiple interacting factors, including temperature, stagnation, water chemistry, materials and biofilm. Their comparison favoured chloramine in many field studies, but a ranking across studies is not a universal instruction to replace an existing treatment. Compatibility, by-products, local approval and the ability to operate and monitor the system all need assessment.

Approach	Potential contribution	What must also be controlled
Free chlorine	Established disinfectant with measurable residual	Decay, pH, material compatibility and by-products
Monochloramine	Can maintain a more persistent residual	Formation and dose control, nitrification and water chemistry
Chlorine dioxide or other approved treatment	May suit a defined system and water quality	Process-specific residuals, by-products and operating limits
UV at a treatment point	Inactivates organisms passing through the unit	No lasting residual in downstream branches
Microbial outlet filter	Provides a barrier at the connected fixture	Correct specification, fitting, handling and replacement

The treatment specialist and water safety team should establish the operating limits and monitoring programme, including any effects on corrosion, seals and connected equipment. An unplanned interruption also requires a defined response, because an acceptable residual today gives little information about what happened during the preceding days.

Validated point of use microbial filters can provide an immediate barrier at selected taps or showers, but they protect only the connected fixture and do not remove colonisation from the distribution network. Selection should include microbial retention performance, permitted pressure and temperature, compatibility with treatment chemicals

and the manufacturer's replacement interval. A carbon cartridge intended to improve taste is not equivalent to a validated microbial barrier.

During an investigation, filters or restrictions may reduce exposure while the underlying system is assessed, provided that staff understand where protected water is available and how the devices should be handled. Outlet contamination, incorrect fitting or an overdue replacement can undermine the intended barrier.

Routine temperature management should also be distinguished from thermal shock. Current CDC potable-water guidance does not recommend thermal shock as a general remediation method because failure and rapid recolonisation are common. Any remedial treatment needs professional planning, exposure controls and follow-up evidence, together with correction of the conditions that allowed growth.

7. Sampling and interpreting results

Sampling should begin with a question, such as whether a positive result is limited to an outlet, whether a branch has become colonised or whether a corrective measure has remained effective. This question determines the locations and collection conditions, so a set of convenient samples taken without a plan may provide little help when the results arrive.

Use an agreed protocol and a competent laboratory, recording the outlet identifier, water system, date and time, recent use, temperature, disinfectant residual and whether the sample was collected before or after flushing. Collection containers, neutralisation where required, transport and holding conditions should follow the laboratory instructions. During an outbreak investigation, coordinate the plan with the responsible public health team.

A preflush sample may reflect water and contamination near the fixture, while a postflush sample can give information about water supplied from farther upstream. This distinction helps interpretation but does not prove the source on its own, because valve design, flow and sampling duration affect what reaches the bottle. Consistent collection conditions are essential when comparing results over time.

Culture measures organisms that grow under the method's conditions and usually reports colony-forming units per volume, while PCR detects a selected genetic target and can also detect DNA from organisms that are no longer viable. Genomic units and colony-forming units cannot be converted directly. A negative culture means that the organism was not recovered within that sample and method, rather than proving that the entire installation is free of Legionella.

Avoid a universal threshold

The response to a result depends on the applicable framework, the patient group, the type and distribution of Legionella, previous findings and whether disease has been

identified. A value used as an operational indicator in one programme should not be presented as a universal boundary between safe and unsafe water. Follow the approved response criteria and consider the result together with the condition of the system.

When a result changes unexpectedly, check sampling and laboratory information while also reviewing recent operating events. Repeat testing may be useful, but it should not delay precautions when the combined clinical and environmental evidence indicates an immediate concern.

8. Responding to cases and control failures

A suspected healthcare-associated case requires timely communication between the clinical team, infection prevention service, microbiology laboratory and those responsible for the water systems, following national reporting arrangements. The aim is to assess possible exposure and protect others while the clinical investigation continues, rather than waiting for every part of the source investigation to be complete.

Protect patients and preserve evidence

If a water source is suspected, the responsible team may restrict particular showers or devices, introduce suitable outlet barriers or arrange alternative water supplies according to the patient group and activity. CDC guidance provides examples of outbreak precautions, including sterile water for defined uses in transplant patients and limiting non-sterile ice for people at risk of aspiration. For respiratory equipment intended for nebulisation, sterile water requirements apply even without an outbreak; ordinary bottled, distilled non-sterile and filtered water are not automatically equivalent.

Record the affected locations and review where patients stayed or received care during the relevant exposure period, while the engineering team checks drawings, maintenance records, temperatures, treatment interruptions and recent construction. Collect environmental evidence in coordination with the investigation team before remediation where feasible, without delaying urgent measures needed to protect patients. A single positive outlet may be associated with a local fitting, but repeated findings across a branch or return loop raise different questions about circulation and treatment. Compare the environmental pattern with the hydraulic layout and the clinical exposure history. Similar clinical and environmental isolates can strengthen a source hypothesis, whereas failure to recover a match does not necessarily exclude a source that was intermittent or altered before sampling.

Water restrictions can themselves create stagnation, so the plan should address safe maintenance of unused sections while patient access is restricted. Staff also need clear instructions on permitted uses, alternative supplies and who can authorise a change, because informal workarounds can reintroduce exposure.

The response should identify both the immediate treatment and the longer-term correction, such as repairing circulation, removing redundant pipework or changing a maintenance practice. Before returning the affected service to normal use, verify that the

agreed engineering conditions have been restored and complete the microbiological and clinical review required by the responsible team.

Document the evidence supporting release, the person authorising it and the follow-up schedule. A negative sample immediately after treatment is not enough to demonstrate lasting control if the original defect remains. Further checks under ordinary operation help show whether the improvement has been maintained.

For training purposes, the sequence is recognition, communication, exposure reduction, investigation, correction and documented review. In a real incident, several of these activities proceed at the same time, guided by the urgency of the risk and the authority responsible for the investigation.

References

[1] Cunha, B. A.; Burillo, A.; Bouza, E. (2016). Legionnaires' disease. The Lancet, 387(10016), 376–385. https://doi.org/10.1016/S0140-6736(15)60078-2

[2] https://www.hse.gov.uk/legionnaires/hot-and-cold.htm

[3] Xi, H.; Ross, K. E.; Hinds, J.; Molino, P. J.; Whiley, H. (2024). Efficacy of chlorine-based disinfectants to control Legionella within premise plumbing systems. Water research, 259, 121794. https://doi.org/10.1016/j.watres.2024.121794

Further reading

CDC. Clinical overview of Legionnaires' disease. https://www.cdc.gov/legionella/hcp/clinical-overview/index.html

CDC. About Pontiac fever. https://www.cdc.gov/legionella/about/about-pontiac-fever.html

CDC. How Legionella spreads. https://www.cdc.gov/legionella/causes/index.html

DC. Clinical guidance for Legionella infections. https://www.cdc.gov/legionella/hcp/clinical-guidance/index.html

DC. Controlling Legionella in potable water systems. https://www.cdc.gov/control-legionella/php/toolkit/potable-water-systems-module.html

Acknowledgments

The content was supported by the project "Smart Healthcare Engineering (SHEng)", Grant Agreement No. 2023-1-RO01-KA220-HED-000159985, co-funded by the Erasmus+ programme of the European Union. Results, views and opinions expressed are however those of the project team and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor the granting authority can be held responsible for them.