Chapter 26
Water Hygiene
Nagwa Khamis and Samia A Girgis

Key Points

- Everyone should have access to water free from pathogenic microbial and chemical contaminants.

- Hospitals often have complex plumbing and ambient-temperature water treatment systems. Both can be colonised by microorganisms. Efforts are necessary to prevent infectious risks from bacterial contamination and formation of biofilms.

- In health care settings a continuous supply of a great quantity of safe water is essential.

- Potable water can be rendered microbiologically safe by boiling, filtering, or chlorination.

- In health care settings, additional water treatment may be necessary (e.g., deionisation).

- The infection prevention and control team should monitor and assess the risks for contamination of water in their facilities.

- Hospital water supplies from specific areas should be tested regularly to confirm freedom from contamination.

Background[1]

Water is essential for human life, for hydration, food and hygiene; the minimum daily requirement is 7.5 litres per person per day. Diseases may be caused by ingestion, inhalation of droplets from, or contact with water.

Domestic water

The World Health Organization (WHO) defines domestic water as being "water used for all usual domestic purposes, including consumption, bathing, and food preparation." When considering quantities required for domestic supply, subdividing uses of domestic water is proposed. In the "Drawers of Water" study[2-3] four types of use were outlined:

- Consumption (drinking and cooking)

- Hygiene (personal and domestic cleanliness)

- Amenity use (car washing, lawn watering)

- Productive use (commercial activities)

A well-trained team should be responsible for maintaining the water supply within both community and health care facilities. The quality of source water and possible sources of contamination should be known. Water sources should be protected and treatment processes controlled. Water and sewerage pipes should be well separated. Measures should be taken to prevent backflow. Pipes for hot water should be well insulated.

Health care water[1]

In health care facilities, water is additionally used:

- to maintain autoclaves for sterilisation;

- during disinfection of medical devices, e.g., endoscopes;

- in dialysis units;

- in dental units; and

- in pharmacy.

Water as potential source of infection[2-4]

Hospitals often have complex plumbing and ambient-temperature water treatment systems. Both can be colonised by microorganisms (e.g., non-pathogenic amoeba, *Pseudomonas* spp., *Legionella* spp. ubiquitous *Mycobacteria,* moulds) which may combine to form biofilms. Bacterial growth is promoted by stagnation of water. Because of their optimal growth temperature, *Legionella* spp. mainly colonise warm water distribution systems.

Biofilm formation containing Legionella bacteria can increase with the age of the water distribution system. Once formed, biofilm particles can then become dislodged and aerosolised. The numbers of microbes are highest in the initial sample after opening the faucet.

Drains always harbour microorganisms, particularly *Pseudomonas and Stenotrophomonas.* If the water-jet from a sink spout impinges directly into the drain, bacteria-containing droplets can be liberated and pose infectious risks to the immunocompromised.

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.[5]

Modes of transmission for waterborne infections
    a.   Direct contact [e.g., hydrotherapy]
    b.   Ingestion of water [e.g., contaminated ice]
    c.   Indirect-contact transmission [e.g., improperly reprocessed medical device]
    d.   Inhalation of aerosols dispersed from water sources

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.[6-7] *Legionella* spp. are commonly found in various natural and man-made aquatic environments and can enter health-care facility water systems in low or undetectable numbers.[8-9] See table 26.1.

Table 26.1. Clinical and epidemiologic characteristics of legionellosis/Legionnaires disease[10] (modified)

Causative agent	***Legionella pneumophila*** (causes 90% of infections); *L. micdadei, L. bozemanii, L. dumoffii, L. longbeachii,* (14 additional species can cause infection in humans)
Mode of transmission	Aspiration of water, direct inhalation of fine water droplets
Source of exposure	Exposure to environmental sources of *Legionella* spp. (i.e., water or water aerosols)

Clinical syndromes and diseases	Two distinct illnesses:
	    a) Pontiac fever [a milder, influenza-like illness]; and
	    b) progressive pneumonia that may be accompanied by cardiac, renal, or gastrointestinal involvement

Populations at greatest risk	Immunosuppressed patients (e.g., transplant patients, cancer patients, and patients receiving corticosteroid therapy) Immunocompromised patients (e.g., surgical patients, patients with underlying chronic lung disease, and dialysis patients) Elderly persons Patients who smoke
Occurrence	Proportion of community-acquired pneumonia caused by *Legionella* spp. ranges from 1%–5%; estimated annual incidence among the general population is 8,000–18,000 cases in the United States; the incidence of health-care– associated pneumonia (0%–14%) may be underestimated if appropriate laboratory diagnostic methods are unavailable.
Mortality rate	Mortality declined markedly during 1980–1998, from 34% to 12% for all cases; the mortality rate is higher among persons with health-care–associated pneumonia compared with the rate among community-acquired pneumonia patients (14% for health-care–associated pneumonia versus 10% for community-acquired pneumonia [1998 data]).

Other Gram-negative bacteria present in potable water can also cause health-care–associated infections. Clinically important, opportunistic microorganisms in tap water include *Pseudomonas aeruginosa,* other *Pseudomonas* spp., *Burkholderia cepacia, Ralstonia pickettii, Stenotrophomonas maltophilia*, and *Sphingomonas* spp. Immunocompromised patients are at greatest risk of developing infection.[11]

Medical conditions associated with these bacteria range from colonisation of the respiratory and urinary tracts to deep, disseminated infections that can result in pneumonia and bloodstream infection.[12] Colonisation by any of these microorganisms 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 (e.g. humidifier reservoirs), and during the final stages of instrument disinfection) therefore presents a potential risk for exposure. Colonised patients 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 other *Pseudomonas* spp. are among the most clinically relevant, Gram-negative, health-care–associated pathogens associated with water. These and other Gram-negative, non-fermentative bacteria have minimal nutritional requirements (i.e., these bacteria can grow in distilled water) and can tolerate a variety of physical conditions. Measures to prevent the spread of these and other waterborne, Gram-negative bacteria include hand hygiene, glove use, barrier precautions, and eliminating potentially contaminated environmental reservoirs.[13-14] See Tables 26.2 and 26.3.

Table 26.2. *Pseudomonas aeruginosa* infections in health-care facilities[10] (modified)

Clinical syndromes and diseases	Septicaemia, pneumonia (particularly ventilator-associated), chronic respiratory infections among cystic fibrosis patients, urinary tract infections, skin and soft-tissue infections (e.g., tissue necrosis and haemorrhage), burn-wound infections, folliculitis, endocarditis, central nervous system infections (e.g., meningitis and abscess), eye infections, and bone and joint infections
Modes of transmission	Direct contact with water, aerosols Aspiration of water or inhalation of water aerosols Indirect transfer from moist environmental surfaces via hands of health-care workers
Environmental sources of pseudomonads in healthcare settings	Potable water, distilled water, antiseptic solutions contaminated with tap water, sinks, hydrotherapy pools, whirlpools and whirlpool spas, water baths, lithotripsy therapy tanks, dialysis water, eyewash stations, flower vases, and endoscopes with residual moisture in the channels
Environmental sources of pseudomonads in the community	Fomites (e.g., drug injection equipment stored in contaminated water)
Populations at greatest risk	Intensive care unit (ICU) patients (including neonatal ICU), vented patients, transplant patients (organ and hematopoietic stem cell), neutropenic patients, burn therapy and hydrotherapy patients, patients with malignancies, cystic fibrosis patients, patients with underlying medical conditions, and dialysis patients

Two additional Gram-negative bacterial pathogens that can proliferate in moist environments are *Acinetobacter* spp. and *Enterobacter* spp. Members of both genera are responsible for healthcare–associated episodes of colonisation, bloodstream infections, pneumonia, and urinary tract infections among medically compromised patients, especially those in ICUs and burn therapy units.[15-17]

Basic principles of safe water[10,18]

Water from non-piped supplies, such as roof catchments, surface water, water collected from wells or springs, or water from microbiologically unsafe piped water supplies, requires point-of-use treatment and protected storage. Technologies to improve the microbial quality of household water include a number of physical and chemical treatment methods. However, not all methods are equally effective in reducing pathogens or are applicable in both domestic and health care settings.

In health care settings, a continuous supply of a great quantity of safe water is essential. Depending on the kind of water supply, different approaches for safe water may be appropriate.

If there is a piped water supply, chlorination may be sufficient to make water safe, if there is no particulate matter in the water. In addition to sodium hypochlorite, liquid bleach, or sodium calcium hypochlorite, chlorination can be achieved by chlorine gas, liquefied under a pressure of 505 kPa. Chlorine gas is highly toxic and should be handled carefully by well-trained technical personnel.

Table 26.3. Other Gram-negative bacteria associated with water and moist environments[10] (modified)

Bacteria	Implicated contaminated environmental vehicle
Burkholderia cepacia	Distilled water Contaminated solutions and disinfectants Dialysis machines Nebulizers Water baths Intrinsically-contaminated mouthwash Ventilator temperature probes
Stenotrophomonas maltophilia, *Sphingomonas* spp.	Distilled water Contaminated solutions and disinfectants Dialysis machines Nebulizers Water Ventilator temperature probes Sink Drains
Serratia marcescens	Potable water Contaminated antiseptics (i.e., benzalkonium chloride and chlorhexidine) Contaminated disinfectants (i.e., quaternary ammonium compounds and glutaraldehyde)
Acinetobacter spp.	Medical equipment that collects moisture (e.g., mechanical ventilators, cool mist humidifiers, vaporizers, and mist tents) Room humidifiers Environmental surfaces
Enterobacter spp.	Humidifier water Intravenous fluids Unsterilised cotton swabs Ventilators Rubber piping on a suction machine Blood gas analysers

Water from non-piped supplies may necessitate the use of drinking water treatment plants. Drinking water treatment plants combine coagulation and flocculation, filtration, and disinfection. They have to be regularly maintained according to manufacturer's instructions. Most technologies use free chlorine as a disinfectant. A minimum free chlorine residual of 0.5 mg/litre is recommended. The concentration of free chlorine should be monitored at least daily.

Ozone can be used for disinfection in water treatment. Because it is produced from oxygen in generators, a stable electricity supply is necessary. Ozone is toxic and has to be eliminated from water after treatment.

Ultraviolet (UV) light treatment of water is another technique to produce potable water, as long as the water has minimal particulate matter. A stable electricity supply is required with regular maintenance of the

bulbs. A prefilter may be required to remove particulates and allow the UV light to inactivate microbes.

An evaluation of the outcome of water treatment should be regularly performed by plate count cultures and tests for total coliform bacteria. There should be less than 500 CFU (colony forming units) per ml and no coliform bacteria in 100 ml. See Table 26.4.

Table 26.4. Requirements for water quality in healthcare

Plate counts at 22°C and 36°C	≤500 CFU/ ml
E. coli	0 in 100 ml
Coliform bacteria	0 in 100 ml
Pseudomonas aeruginosa	0 in 100 ml
Faecal streptococci	0 in 100 ml

CFU = colony forming units

Storage tanks

Storage tanks should be contaminant free and watertight; keep covered to prevent contamination. Tanks should be placed in shadow and be well insulated. Storage tanks for cold water should maintain temperatures at 20°C or lower. In storage tanks for hot water, the temperature should be maintained above 60° C. Construction of storage tanks should allow for adequate draining.

Because of the risk for formation of biofilms inside the tank, it should be inspected, emptied, cleaned, and disinfected at regular intervals. The hot and cold pipes should be tagged if these are close together to avoid diffusion of heat and a possible increase in the cold water temperature.

Dialysis water – deionisation

Deionised water for dialysis is produced by reverse osmosis. Water entering the reverse osmosis machine must contain less than 0.5 ppm free chlorine or less than 0.1 ppm chloramines. If necessary, removal of chlorine or chloramines can be performed by filters containing granular activated carbon. Two carbon filters in series are recommended. Filters should be replaced rather than regenerated when exhausted. Whenever a carbon filter is replaced, the filter housing should be disinfected and rinsed before the new filter is installed.

Monthly bacteriologic assays of water should be performed immediately after the reverse osmosis process. If a storage tank is used in the water treatment system, bacterial levels should also be evaluated directly from this tank.

Engineering for safe water

Construction of the plumbing system should avoid stagnation of piped water. Terminal lines should be as short as possible. Water pipes which are not used should be removed. Aerators should be decalcified if necessary. The temperature of both hot and cold water should be monitored at the faucets.

All water treatment equipment and storage tanks should be regularly cleaned and disinfected. The frequency should be determined according to a risk assessment.

Newly constructed plumbing systems should be filled with water just immediately before bringing them into service in order to prevent biofilm formation. Newly constructed plumbing systems need to be disinfected (hyperchlorination) and rinsed prior to use.

To prevent formation of biofilm and microbial growth, a flow-through water treatment system should be maintained at all times. Water treatment components which can be thermally or chemically sanitised should be selected.

Role of the Infection Prevention and Control Team

The infection prevention and control team (ICT) should monitor patients for water-associated diseases, such as diarrhoeal illness or Legionnaire's disease. The ICT should assess the risks of the plumbing system of their health care facilities and of all equipment for water treatment. The ICT should know:

- Where drinking water comes from.

- How drinking water has been treated.

- Of which materials the plumbing system is constructed. Examples of plumbing materials are grey cast iron, lead, bitumen coated steel, copper, galvanised steel, polyethylene, or vinyl chloride.

- Chemicals that may contaminate the drinking water. There are chemicals which already contaminate ground water (e.g., arsenic, pesticides) and chemicals which can be released by plumbing material (e.g., copper, lead, cadmium, polycyclic aromatic hydrocarbons).

- The equipment for water treatment used in the facility.

- If there are persons at increased risk for Legionnaire's disease or if severely immunocompromised patients are present (e.g., transplant patients, patients with acquired immune deficiency syndrome)

According to the individual facility risk assessment and national regulations, the ICT should coordinate microbiological and chemical analyses of drinking water, deionised water, bathing water, etc. The frequency of analyses should be assessed according to the results.

In addition to the use of plate count cultures, tests for total coliform bacteria and nitrate should be analysed. Health care facilities which have patients at risk for Legionnaire's disease should regularly evaluate for *Legionella* spp. in the hot water system. If there is ambient water treatment or storage of water, *Pseudomonas aeruginosa* should be part of the evaluation. Routine water testing requirements vary by health jurisdiction.[19-20]

Establish a surveillance method for detecting healthcare-associated Legionnaires´ disease. One method is to perform appropriate laboratory tests for all healthcare-associated cases of pneumonia. If there is evidence of healthcare-associated Legionnaire's disease, conduct an environmental assessment to determine the source of *Legionella* spp.

If disinfection of the hot water distribution system is necessary, high-temperature decontamination or chlorination can be performed.

1. High-temperature decontamination: flush each outlet for ≥ 5 minutes with water at 71°C – 77° C.

2. Chlorination: Add enough chlorine (preferable sodium hypochlorite - bleach) to achieve a free chlorine residual of ≥ 2 mg/l (≥ 2ppm). Flush each outlet until a chlorine odour is not detected. Maintain the elevated chlorine concentration in the system for ≥ 2 and ≤ 24 hours.

Investigation of water supplies[21]

Water sampling in a health care facility is used to detect waterborne pathogens of clinical significance or to determine the quality of finished water in a facility distribution system. Hospital water supplies should be tested regularly to confirm their freedom from contamination; bacteriological assay of water and dialysis fluids is performed at least once a month and during outbreaks using standard quantitative methods. The standard of the Association for the Advancement of Medical Instrumentation (AAMI) is <200 CFU/ml. Also endotoxin testing is performed on a monthly basis with a maximum level of <2EU/ml.[21]

Sampling from a tap requires removal of any attachment then flushing the water line before collection. To ensure cleanliness of the tap, disinfection with 500-600 ppm sodium hypochlorite (1:100 v/v dilution of chlorine bleach) and flushing the tap should precede sampling. The minimum volume of water to be collect-

ed is 100 ml in a sterile container. Water samples should be sent to the laboratory cold (4°C) and testing should be performed preferably within 24 hours. For chlorinated water, a reducing agent (i.e., sodium thio-sulfate) needs to be added to the collected sample to neutralise the residual halogen.

Reduced nutrient media (e.g., diluted peptone and R2A) are preferable for recovery of the stressed bacteria in water. Use of aerobic, heterotrophic plate counts allows qualitative and quantitative measurement of water quality. If the expected bacterial count is high, as during a waterborne outbreak, assaying small amounts using pour or spread plates is appropriate.

Membrane filtration is used when low counts are expected; then larger samples are required (≥100 ml). A measured volume of the water sample is filtered through a 0.45 µm pore size membrane. The membrane is then placed on a selective media surface. See Figure 26.1.

1. Filtration apparatus: base supporting a porous disc under a graduated funnel. The base is connected to a vacuum source.	
2. Sterile 0.45 µm pore sized membrane filter is applied under funnel with grid side up over porous disc.	
3. Sterile funnel is placed securely over filter base. While vacuum is still turned off, requisite volume of water sample is poured into funnel. Then sample is filtered slowly through membrane by applying vacuum.	
4. When filtration is complete, funnel is removed and membrane is aseptically transferred, gridded side up, onto a plate of selective indicator agar medium.	
5. Plate holding membrane is incubated under appropriate conditions for 48 hrs, and then a colony count is performed for the characteristic bacterial growth.	

Figure 26.1. Procedure for Microfil system of water filtration

The colonies are recognised by their colour, morphology, and ability to grow on the selective media. Assay methods specific for clinically significant waterborne pathogens (e.g., *Legionella spp.*, *Aeromonas spp*, *Pseudomonas spp.*, and *Acinetobacter spp.*) are more complicated and costly compared with both methods

used to detect a total count of microorganisms and faecal coliforms and other standard indicators of water quality.

Applicable Guidelines

There are international guidelines on water published by the World Health Organization:

- WHO Guidelines for the safe use of waste-water, excreta and grey water, 2006. http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html [Accessed 10 November 2015]

- Guidelines for safe recreational (bathing) waters, 2003. http://www.who.int/water_sanitation_health/bathing/en/ [Accessed 10 November 2015]

In countries of the European Union or European Free Trade Association, the recommendations of the European Committee for Standardization should be applied. http://www.cen.eu/cen/pages/default.aspx. [Accessed 10 November 2015]

If there are no national guidelines, the "Guidelines for Environmental Infection Control in Health-Care Facilities" of the US Centers for Disease Control and Prevention's Healthcare Infection Control Practices Advisory Committee (HICPAC) can be applied.[10]

Low Resource Issues

Basic principles to follow:

- Use alcohol-based hand rub to prevent the hand transfer of waterborne pathogens.

- Eliminate contaminated water or fluid environmental reservoirs. Prevent stagnation of piped water.

- Storage tanks should be regularly drained and disinfected.

- Establish precautions for microbial growth within the distribution system, e.g., maintain cold water temperature below 20°C and hot water temperature above 51°C.

- After significant water disruption or an emergency, run faucets and drinking fountains at full flow for ≥ 5 minutes, or use high-temperature water flushing or chlorination. In dialysis units change the pre-treatment filter and disinfect the dialysis water system to prevent colonisation of the reverse osmosis membrane and downstream microbial contamination. If the facility has a water-holding reservoir or water-storage tank, verify if it has to be drained, disinfected, and refilled.

- Pharmaceuticals or medical solutions should not be stored on ice intended for consumption. Medical solutions should be kept cold only with sterile ice or with equipment specifically manufactured for this purpose.

- Ice storage chests should be regularly cleaned and disinfected according to manufacturer´s instructions.

- Water which is used for routine dental treatment should contain less than 500 CFU/ml on heterotrophic plate count.

- Water used for rinsing disinfected endoscopes and bronchoscopes should be boiled or filtered through 0.1-0.2 μm filters. Internal channels of the reprocessed endoscopes or bronchoscopes should be dried (e.g., using 70% alcohol followed by forced-air treatment).

Acknowledgement

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Additional Reading

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