Chapter 25
Water Hygiene

Dorothea Hansen

Key points

- Everyone should have access to water free from pathogenic microbial and chemical contaminants.
- Water sources should be protected. The quality of piped water should be regularly verified according to a risk assessment and national regulations by water suppliers or public authorities. Analyses at point of use should be regularly performed (e. g., plate counts of *E. coli* or coliforms, *Pseudomonas aeruginosa*, *Legionella* species).
- 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).
- Efforts are necessary to prevent infectious risks from bacterial contamination and formation of biofilms.

Background[1]

Water is essential for human life; 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 drinking water. Outbreaks of waterborne diseases may involve large numbers of individuals. Poor water quality may cause the spread of cholera, typhoid, dysentery, hepatitis, giardiasis, guinea worm, and schistosomiasis. 1.8 million people die every year from diarrhoeal diseases, most of them due to unsafe water. Waterborne outbreaks also occur in industrialised countries; for example, an outbreak of cryptosporidiosis in Milwaukee (US) affected 400,000 people.[2]

Chemical contamination of drinking water may also pose health risks. Chemical contamination tends to cause chronic long-term effects whereas microbiological contamination causes acute diseases and outbreaks.

Illness Related to Water

Domestic

Water-related infectious diseases are classified on the basis of transmission.

Water-borne

Diseases are due to microorganisms in water. Transmission can be caused by ingestion of contaminated water (e.g., diarrhoeal diseases, cholera, typhoid, hepatitis A, giardiasis, amoebiasis), inhalation of contaminated droplets or aerosols (e.g., legionellosis), or contact with contaminated water (e.g., skin diseases, otitis externa). Many pathogens are transmitted through contaminated drinking water, depending on their infectivity and their capability to persist in the environment or proliferate in water [See Table 25.1]. Microorganisms may be introduced into water by faecal contamination. Other pathogens may be naturally present in the environment or in source water.

Water-washed

Diseases caused by the lack of water and which are often associated with poor hygiene. Examples are diarrhoeal diseases, trachoma, conjunctivitis, and skin infection.

Water-based
Diseases which are caused by parasites that need an intermediate aquatic host for their life cycle. An example is schistosomiasis (bilharzia).

Water-related vector
Diseases which are transmitted by water-related insect vectors. Examples are malaria, dengue, and yellow fever.

Table 25.1. Microorganisms found in water

Microorganisms which may multiply in water supplies	Microorganisms which may persist in water supplies between 1 week and 1 month	Microorganism which may persist in water supplies for more than 1 month
Bacteria		
Legionella spp.	*Campylobacter jejuni*, *Campylobacter coli*	*Yersinia enterocolitica*
Non tuberculous mycobacteria	Pathogenic *E. coli*, enterohaemorrhagic *E. coli*	
Pseudomonas aeruginosa	*Salmonella typhi*	
Viruses		
		Adenoviruses
		Enteroviruses
		Hepatitis A virus
		Noroviruses
		Rotaviruses
Protozoa		
Acanthamoeba spp.	*Entamoeba histolytica*	*Cryptosporidium parvum*
Naegleria fowleri	*Giardia intestinalis*	*Cyclospora cayetanensis*
		Toxoplasma gondii

Health Care[3-6]

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 increases with the age of the water distribution system. Biofilm particles can then become dislodged and aerosolised. The numbers of microbes are highest in the initial sample after opening the faucet. Inhalation of particles containing *Legionella* spp. can cause Legionnaire's disease even in the immunocompetent. Moulds can be resistant to the standard concentrations of free chlorine found in water.

Drains always harbour microorganisms, particularly *Pseudomonas aeruginosa*. If the water-jet from a sink impinges directly into the outlet, bacteria containing droplets can be aerosolised and pose infectious risks to the immunocompromised and patients with cystic fibrosis.

Uses of Water

Domestic

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[6-7] 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)

Health care

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.

Ambient-temperature water treatment systems are susceptible to microbiological contamination, particularly when there are periods of no or low demand for water. Stagnation promotes formation of biofilm and growth of water-borne microorganisms, e.g., *Pseudomonas aeruginosa*, *Aeromonas hydrophila*, non-tuberculosis mycobacteria and *Legionella* spp. Biofilms hinder disinfection.

Basic Principles[8-9]

Making water safe – boiling, chemicals, ozone, filtration

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 applicable in both domestic and health care settings.

Domestic water

Domestic water can be made safe by boiling, chlorination, or filtration.

Boiling

The recommended procedure is to raise the temperature so that a "rolling boil" (large bubbles continuously coming to the surface of the water) is achieved. "Rolling boil" must be maintained for 1 minute before removing the water from the heat source and allowing it to cool naturally in the same container. Water boils at lower temperatures as altitude increases. One minute of extra boiling time should be added for every 1000 m above sea level.

Water should be protected from post-treatment contamination during storage. Boiling inactivates vegetative cells of bacteria, viruses, and protozoa. Because spores are more resistant to thermal inactivation, treatment to reduce spores by boiling must ensure sufficient temperature and time.

Chlorination

Chlorination can be achieved by adding 2 drops of unscented liquid household chlorine (5-6%) bleach for each litre of clear water and 4 drops for each litre of cloudy water respectively. The mixture has to be stirred well and should stand at least 30 minutes before use. Because bleach solutions are unstable in sunlight and at warm temperatures, they should be stored in brown or green glass bottles or opaque plastic bottles in a cool, dark place.

Filtration

There are different types of simple household filters available, i.e., candle and stone filters. In a candle filter, water is allowed to filter slowly through a porous ceramic material. Large parasites (ova, cysts) and most bacteria are retained by the outer layer of the filter material. The filter can be periodically cleaned by gently scrubbing it under clean, running water. Viruses are not removed by candle filters.

Stone filters are carved from porous local stone. Their disadvantage is that they are difficult to clean.

Construction of the collecting vessel should prevent recontamination of filtered water.

Health care issues

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. 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.

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.

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 25.2)

Storage tanks

Storage tanks should be contaminant free and watertight. Storage tanks should be 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 frequency depends on the quality of water. 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.

Table 25.2. 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

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 bacteria are not removed or destroyed by the deionisation unit, a submicron or endotoxin/ultrafilter will be needed downstream of the deionisation unit. If a storage tank is used in the water treatment system, bacterial levels should be evaluated directly from this tank.

Engineering

Domestic and health care

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

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 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 gray cast iron, lead, bitumen coated steel, copper, galvanized 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 of 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.

Establish a surveillance method for detecting healthcare-associated Legionnaires´ disease. One way to do it is to perform appropriate laboratory tests for all healthcare-associated 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.

- High-temperature decontamination: flush each outlet for ≥ 5 minutes with water at 71°C – 77°C.
- 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 detected. Maintain the elevated chlorine concentration in the system for ≥ 2 but ≤ 24 hours.

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 July 26, 2011]
- Guidelines for safe recreational (bathing) waters, 2003. http://www.who.int/water_sanitation_health/bathing/en/ [Accessed July 26, 2011]

In countries of the EU 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 July 26, 2011]

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)[9] can be applied.

Low Resource Issues

Basic principles to follow are:

- 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 pretreatment 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 have been 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

This chapter is an update of the earlier one by Dr. Shaheen Mehtar.

References

1. WHO. *Guidelines for drinking-water quality*. Volume 1 Recommendations. Third edition. Geneva, 2008. http://www.who.int/water_sanitation_health/dwq/guidelines/en/ [Accessed July 26, 2011]
2. Mackenzie WR, et al. Massive outbreak of water-borne Cryptosporidium infection in Milwaukee, Wisconsin: recurrence of illness and risk of secondary transmission. *Clin Inf Dis* 1995; 21:57-62.
3. Anaissie EJ, Penzak R, Dignani C. The hospital water supply as a source of nosocomial infections. *Arch Intern Med* 2002, 162: 1483-1492.
4. Squier C, Yu VL, Stout JE. Waterborne nosocomial infections. *Curr Infect Dis Rep* 2000; 2 (6): 490-496.
5. Anaissie EJ, Stratton SL, Dignani MC, et al. Pathogenic molds (including Aspergillus species) in hospital water distribution systems: a 3-year prospective study and clinical implications for patients with hematologic malignancies. *Blood* 2003; 101(7):2542-2546.
6. Tumwine JK, Thompson J, Katua-Katua M, Mujwajuzi M, Johnstone N, Porras I. Diarrhoea and effects of different water sources, sanitation hygiene behaviour in East Africa. *Trop Med Int Health* 2002; 7 (9): 750-756.
7. White GF, et al. Drawers of water: domestic water use in East Africa. 1972. *Bull World Health Organ* 2002; 80 (1): 63-69.
8. WHO. *Practical guidelines for infection control in health care facilities.* 2004. http://www.who.int/water_sanitation_health/emergencies/infcontrol/en/index.html [Accessed July 26, 2011]
9. Centers for Disease Control and Prevention. Healthcare Infection Control Practices Advisory Committee (HICPAC). *Guidelines for Environmental Infection Control in Health-Care Facilities*. Atlanta 2003. http://www.cdc.gov/hicpac/pdf/guidelines/eic_in_HCF_03.pdf [Accessed July 26, 2011]

Web Sites

US Centers for Disease Control and Prevention: Healthy water. www.cdc.gov/healthywater/ [Accessed July 26, 2011]

WHO health topic: Water. www.who.int/topics/water/en [Accessed July 26, 2011]