These Guidelines provide a generally applicable approach to drinking-water safety. In chapters 2–5, approaches and, where appropriate, aspects of their application to drinking-water supply through piped distribution and through community supplies are described. In applying the Guidelines in specific circumstances, additional factors may be important. This chapter describes the application of the Guidelines in some commonly encountered specific circumstances and issues that should be taken into account in each.

6.1 Large buildings
Responsibility for many actions essential to the control of drinking-water quality in large buildings may be outside the responsibility of the drinking-water supplier. Significant contamination can occur because of factors within the built environment, and specific requirements in the large building environment (including hospitals and health care facilities) are distinct from those in the domestic environment.

General drinking-water safety is assured by maintenance protocols, regular cleaning, temperature management and maintenance of a disinfectant residual. For these reasons, authorities responsible for building safety should be responsible for developing and implementing WSPs. Regulatory or other appropriate authorities may provide guidance on the development and application of WSPs for large building drinking-water systems, which should be implemented by managers.

WSPs for large buildings may usefully address not only drinking-water systems but also other water systems, such as cooling towers and evaporative condensers of air conditioning devices.

The regulator can specify compliance requirements for buildings in general or for individual buildings. Compliance may require that maintenance and monitoring programmes be carried out through a building-specific WSP. It may be appropriate to display maintenance and monitoring programmes and certification of compliance at a conspicuous location within the building. Compliance could be verified and certified by an independent auditor.
6.1.1 Health risk assessment

The principal hazards that may accrue in the drinking-water systems of large buildings are ingress of microbial contamination (which may affect only the building or also the wider supply), proliferation and dispersal of bacteria growing on water contact surfaces (especially Legionella) and addition of chemical substances from piping, jointing and plumbing materials.

Faecal contamination may occur through cross-connection and backflow and from buried/immersed tanks and pipes, especially if not maintained with positive internal water pressure.

Legionella bacteria are the cause of legionellosis, including legionnaires’ disease. They are ubiquitous in the environment and can proliferate at temperatures experienced at times in piped distribution systems. The route of infection is by inhalation of droplets or aerosols; however, exposure from piped water systems is preventable through the implementation of basic water quality management measures, including maintaining water temperature outside the range at which Legionella proliferates (25–50°C) and maintaining disinfectant residuals throughout the piped distribution system.

Devices such as cooling towers and hot or warm water systems, if not appropriately maintained, can provide suitable conditions for the survival and growth of Legionella. In large buildings, there is increased potential for growth of Legionella in long water distribution systems, and maintenance of these systems needs particular attention. In addition to supporting the growth of Legionella, devices such as cooling towers and hot or warm water systems can disseminate contaminated water in aerosols.

For further information on Legionella in drinking-water, see section 11.1.9 and the supporting document Legionella and the Prevention of Legionellosis (see section 1.3).

Hospitals, nursing care homes, other health care facilities, schools, hotels and some other large buildings are high-risk environments, because of both the complex nature of their drinking-water systems and the sensitivities of their occupants. Requirements similar to those outlined above for other large buildings apply, but heightened vigilance in control measure monitoring and verification is generally justified.

6.1.2 System assessment

Because WSPs for large buildings are limited to the building environment and since dose–response is not easily described for bacteria arising from growth, adequate control measures are defined in terms of practices that have been shown to be effective.

In undertaking an assessment of the building’s distribution system, a range of specific issues must be taken into consideration. These factors relate to ingress and proliferation of contaminants and include:

—pressure of water within the system;
—intermittent supplies;
— temperature of water;
— cross-connections, especially in mixed systems;
— backflow prevention; and
— system design to minimize dead/blind ends (i.e., a length of pipe, closed at one
  end, through which no water passes) and other areas of potential stagnation.

6.1.3 Management

The aim of a distribution system within a large building is to supply safe drinking-
water at adequate pressure and flow. Pressure is influenced by the action of friction
at the pipe wall, flow rate and pipe length, gradient and diameter. For the purposes
of maintaining drinking-water quality, it is important to minimize transit times and
avoid low flows and pressures. Pressure at any point in the system should be main-
tained within a range whereby the maximum pressure avoids pipe bursts and the
minimum pressure ensures that water is supplied at adequate flow rates for all
expected demands. In some buildings, this may require pressure boosting in the
network.

Where piped water is stored in tanks to reduce the effect of intermittent supplies,
and particularly where water is supplied directly to equipment, the potential for back-
flow of water into the mains network exists. This may be driven by high pressures
generated in equipment connected to mains water supplies or by low pressures in the
mains. Water quality in intermittent systems may deteriorate on recharging,
where surges may lead to leakage and dislodgement of biofilm and acceptability
problems.

A backflow event will be a sanitary problem if there is cross-connection between
the potable supply and a source of contamination. Positive pressure should be main-
tained throughout the piped distribution system. Effective maintenance procedures
should be implemented to prevent backflow. In situations where backflow is of
particular concern, backflow prevention devices may be used in addition to the
primary objective of reducing or eliminating backflow. Situations presenting a poten-
tially high public health risk (e.g., dental chairs, laboratories) should receive special
attention.

Significant points of risk exist in areas where pipes carrying drinking-water
pass through drains or other places where stagnant water pools. The risk associated
with ingress of contamination in these situations may be controlled by reducing the
formation of such stagnant pools and by routing pipework to avoid such areas.
The design and management of piped water systems in buildings must also take
into account the impact of slow flows and dead ends.

Wherever possible, drinking-water taps should be situated in areas where the pipes
are well flushed to minimize leaching from pipes, materials and plumbing fittings.

6.1.4 Monitoring

Monitoring of control measures includes:
— temperature, including frequent (e.g., weekly) monitoring of remote areas;
— disinfectants and pH, when employed (e.g., weekly to monthly); and
— microbial quality of water, particularly following system maintenance or repairs.

Daily monitoring may be necessary in the presence of suspected water-related cases of illness.

Monitoring of drinking-water quality is required to be more frequent when the building is new or recently commissioned or following maintenance of the system. When the building’s drinking-water system has not stabilized, monitoring should be more frequent until the water quality has stabilized.

6.1.5 Independent surveillance and supporting programmes
Independent surveillance is a desirable element in ensuring continued water safety within a large building and should be undertaken by the relevant health agency or other independent authority.

In order to ensure safety of drinking-water within buildings, supportive activities of national regulatory agencies include the following:

— specific attention to application of codes of good practice (e.g., at commissioning and in contracting construction and rehabilitation);
— suitable training for engineers and plumbers;
— regulation of the plumbing community;
— effective certification of materials and devices in the marketplace; and
— inclusion of WSPs as an essential component of building safety provision.

A WSP would normally document its use of and reliance on such measures – for instance, in using only approved professionals to conduct maintenance and in insisting on their use of certified materials.

6.1.6 Drinking-water quality in health care facilities
Health care facilities include hospitals, health centres and hospices, residential care, dental offices and dialysis units. Drinking-water should be suitable for human consumption and for all usual domestic purposes, including personal hygiene. However, it may not be suitable for all uses or for some patients within health care facilities, and further processing or treatment or other safeguards may be required.

Drinking-water can contain a range of microorganisms, including *Pseudomonas aeruginosa*, non-tuberculous *Mycobacterium* spp., *Acinetobacter* spp., *Aeromonas* spp. and *Aspergillus*. There is no evidence that these microorganisms represent a health concern through water consumption by the general population, including most patients in health care facilities. However, additional processing may be required to ensure safety for consumption by severely immunosuppressed persons, such as those with neutrophil counts below 500 per μl (see the supporting document *Heterotrophic Plate Counts and Drinking-water Safety*; section 1.3).
Microorganisms in drinking-water also have the potential to cause infections if drinking-water is used to wash burns or to wash medical devices such as endoscopes and catheters. Water used for such purposes needs to be of a higher quality than described in these Guidelines and may require additional processing, such as microfiltration or sterilization, depending on use.

Health care facilities may include environments that support the proliferation and dissemination of *Legionella* (see section 11.1.9 and the supporting document *Legionella and the Prevention of Legionellosis;* section 1.3).

Renal dialysis requires large volumes of water that exceed the chemical and microbial quality requirements for drinking-water. Water used for dialysis requires special processing to minimize the presence of microorganisms, endotoxins, toxins and chemical contaminants. The vulnerability of renal dialysis patients was demonstrated in 1996 by the death of 50 such patients after exposure to water contaminated by high levels of microcystin (Jochimsen et al., 1998; Pouria et al., 1998). Dialysis patients are also sensitive to chloramines, and this needs to be considered when chloramination is used to disinfect drinking-water supplies, particularly in areas where there are home dialysis patients.

All health care facilities should have specific WSPs as part of their infection control programme. These plans should address issues such as water quality and treatment requirements, cleaning of specialized equipment and control of microbial growth in water systems and ancillary equipment.

### 6.1.7 Drinking-water quality in schools and day care centres

A long-term approach to improving hygiene in the community includes working with children in schools. This enables the concept of good hygiene, of which drinking-water safety is a part, to become part of a general understanding of health and the influence of the environment. Schoolchildren can relay hygiene concepts to family and households. As young children learn from what they see around them, the school environment itself should meet the requirements of good hygiene – for example, by providing toilets or latrines, water for hand-washing, generally clean surroundings and hygienic facilities for the preparation and serving of school meals. Visual demonstration of the presence of bacteria on unwashed hands has been shown to be valuable (e.g., using UV fluorescence of bacteria or the hydrogen sulfide paper strip method).

One of the most important characteristics of effective health education is that it builds on concepts, ideas and practices that people already have. Hygiene education programmes should be based on an understanding of the factors that influence behaviour at the community level. These might include:

— enabling factors, such as money, materials and time to carry out appropriate patterns of behaviour;
— pressure from particular members of the family and community (e.g., elders, traditional healers, opinion leaders);
beliefs and attitudes among community members with respect to hygienic behaviour, especially the perceived benefits and disadvantages of taking action; and
— the understanding of the relationship between health and hygiene.

An understanding of the factors that influence hygiene-related behaviours will help in identifying the resources (e.g., soap, storage containers), the key individuals in the home and community and the important beliefs that should be taken into account. This will help to ensure that the content of the hygiene education is relevant to the community. Good advice should:

— result in improved health;
— be affordable;
— require a minimum of effort and time to put into practice;
— be realistic;
— be culturally acceptable;
— meet a perceived need; and
— be easy to understand.

### 6.2 Emergencies and disasters

Drinking-water safety is one of the most important public health issues in most emergencies and disasters. The greatest waterborne risk to health in most emergencies is the transmission of faecal pathogens, due to inadequate sanitation, hygiene and protection of water sources. Some disasters, including those caused by or involving damage to chemical and nuclear industrial installations or spillage in transport or volcanic activity, may create acute problems from chemical or radiological water pollution.

Different types of disaster affect water quality in different ways. When people are displaced by conflict and natural disaster, they may move to an area where unprotected water sources are contaminated. When population density is high and sanitation is inadequate, unprotected water sources in and around the temporary settlement are highly likely to become contaminated. If there is a significant prevalence of disease cases and carriers in a population of people with low immunity due to malnutrition or the burden of other diseases, then the risk of an outbreak of waterborne disease is increased. The quality of urban drinking-water supplies is particularly at risk following earthquakes, mudslides and other structurally damaging disasters. Water treatment works may be damaged, causing untreated or partially treated water to be distributed, and sewers and water transmission pipes may be broken, causing contamination of drinking-water in the distribution system. Floods may contaminate wells, boreholes and surface water sources with faecal matter washed from the ground surface or from overflowing latrines and sewers. During droughts, people may be forced to use unprotected water supplies when normal supplies dry up; as more people and animals use fewer water sources, the risk of contamination is increased.

Emergency situations that are appropriately managed tend to stabilize after a matter of days or weeks. Many develop into long-term situations that can last for
several years before a permanent solution is found. Water quality concerns may change over that time, and water quality parameters that pose long-term risks to health may become more important.

6.2.1 Practical considerations
Available sources of water are very limited in most emergency situations, and providing a sufficient quantity of water for personal and domestic hygiene as well as for drinking and cooking is important. Guidelines and national drinking-water quality standards should therefore be flexible, taking into consideration the risks and benefits to health in the short and long term, and should not excessively restrict water availability for hygiene, as this would often result in an increased overall risk of disease transmission.

There are a number of factors to take into consideration when providing drinking-water for a population affected by a disaster, including the following:

- **The quantity of water available and the reliability of supply** – This is likely to be the overriding concern in most emergency situations, as it is usually easier to improve water quality than to increase its availability or to move the affected population closer to another water source.

- **The equitability of access to water** – Even if sufficient water is available to meet minimum needs, additional measures may be needed to ensure that access is equitable. Unless water points are sufficiently close to their dwellings, people will not be able to collect enough water for their needs. Water may need to be rationed to ensure that everyone’s basic needs are met.

- **The quality of the raw water** – It is preferable to choose a source of water that can be supplied with little or no treatment, provided it is available in sufficient quantity.

- **Sources of contamination and the possibility of protecting the water source** – This should always be a priority in emergencies, whether or not disinfection of the water supply is considered necessary.

- **The treatment processes required for rapidly providing a sufficient quantity of potable water** – As surface water sources are commonly used to provide water to large populations in emergencies, clarification of the raw water – for example, by flocculation and sedimentation and/or by filtration – is commonly required before disinfection.

- **The availability of bottled or packaged water** – The provision of bottled or packaged water from a reliable source is often an effective way to quickly provide safe, potable water in emergencies and disasters. However, getting bottled or packaged water to the area and people in need may be a significant challenge. In such circumstances, one approach to providing bottled water is through the use of local small treatment plants. Care should be taken to protect bottled water from recontamination during its storage, distribution and use. See section 6.5 for further details on sources, safety and certification of packaged drinking-water.
• The treatment processes appropriate for post-emergency situations – The affordability, simplicity and reliability of water treatment processes in the longer term should be considered early on in the emergency response.

• The need to disinfect drinking-water supplies – In emergencies, hygiene conditions are normally poor and the risk of disease outbreaks is high, particularly in populations with low immunity. It is therefore crucial to disinfect the water supplies, ensuring a residual disinfection capacity in the water. This practice would
considerably reduce the likelihood of disease transmission through contamination of water in the home.

- **Acceptability** – It is important to ensure that drinking-water provided in emergencies is acceptable to the consumers, or they may resort to water from unprotected or untreated supplies.

- **The need for vessels to collect and store water** – Vessels that are hygienic and appropriate to local needs and habits are needed for the collection and storage of water to be used for washing, cooking and bathing.

- **Epidemiological considerations** – Contamination of water may occur during collection, storage and use in the home, as a result of lack of sanitation or poor hygiene due to an insufficient quantity of water. Other transmission routes for major waterborne and sanitation-related diseases in emergencies and disasters include person-to-person contact, aerosols and food intake. The importance of all routes should be considered when applying the Guidelines, selecting and protecting water sources and choosing options for water treatment.

In many emergency situations, water is collected from central water collection points, stored in containers and then transferred to cooking and drinking vessels by the affected people. This process provides many opportunities for contamination of the water after it leaves the supply system. It is therefore important that people are aware of the risks to health from contamination of water from the point of collection to the moment of consumption and have the means to reduce or eliminate these risks. When water sources are close to dwelling areas, they may easily be contaminated through indiscriminate defecation, which should be strongly discouraged. Establishing and maintaining water quality in emergencies require the rapid recruitment, training and management of operations staff and the establishment of systems for maintenance and repairs, consumable supplies and monitoring. Communication with the affected population is extremely important for reducing health problems due to poor water quality. Detailed information may be found in Wisner & Adams (2003).

### 6.2.2 Monitoring

Water safety should be monitored during emergencies. Monitoring may involve sanitary inspection and one or more of:

- sanitary inspection and water sampling and analysis;
- monitoring of water treatment processes, including disinfection;
- monitoring of water quality at all water collection points and in a sample of homes; and
- water quality assessment in the investigation of disease outbreaks or the evaluation of hygiene promotion activities, as required.

Monitoring and reporting systems should be designed and managed to ensure that action is swiftly taken to protect health. Health information should also be monitored
6. APPLICATION OF THE GUIDELINES IN SPECIFIC CIRCUMSTANCES

to ensure that water quality can be rapidly investigated when there is a possibility that water quality might contribute to a health problem and that treatment processes – particularly disinfection – can be modified as required.

6.2.3 Microbial guidelines

The objective of zero *E. coli* per 100 ml of water is the goal for all water supplies and should be the target even in emergencies; however, it may be difficult to achieve in the immediate post-disaster period. This highlights the need for appropriate disinfection.

An indication of a certain level of faecal indicator bacteria *alone* is not a reliable guide to microbial water safety. Some faecal pathogens, including many viruses and protozoal cysts and oocysts, may be more resistant to treatment (e.g., by chlorine) than common faecal indicator bacteria. More generally, if a sanitary survey suggests the risk of faecal contamination, then even a very low level of faecal contamination may be considered to present a risk, especially during an outbreak of a potentially waterborne disease, such as cholera.

Drinking-water should be disinfected in emergency situations, and an adequate disinfectant residual (e.g., chlorine) should be maintained in the system. Turbid water should be clarified wherever possible to enable disinfection to be effective. Minimum target concentrations for chlorine at point of delivery are 0.2 mg/litre in normal circumstances and 0.5 mg/litre in high-risk circumstances. Local actions that should be considered in response to microbial water quality problems and emergencies are further discussed in section 7.6.

Where there is a concern about the quality of drinking-water in an emergency situation that cannot be addressed through central services, then the appropriateness of household-level treatment should be evaluated, including, for example:

— bringing water to a rolling boil and cooling before consumption;
— adding sodium or calcium hypochlorite solution, such as household bleach, to a bucket of water, mixing thoroughly and allowing to stand for about 30 min prior to consumption; turbid water should be clarified by settling and/or filtration before disinfection;
— vigorously shaking small volumes of water in a clean, transparent container, such as a soft drink bottle, for 20 s and exposing the container to sunlight for at least 6h;
— applying products such as tablets or other dosing techniques to disinfect the water, with or without clarification by flocculation or filtration; and
— end-use units and devices for field treatment of drinking-water.

Emergency decontamination processes may not always accomplish the level of disinfection recommended for optimal conditions, particularly with regard to resistant pathogens. However, implementation of emergency procedures may reduce numbers of pathogens to levels at which the risk of waterborne disease is largely controlled.
The parameters most commonly measured to assess microbial safety are as follows:

- **E. coli (see above):** Thermotolerant coliforms may provide a simpler surrogate.
- **Residual chlorine:** Taste does not give a reliable indication of chlorine concentration. Chlorine content should be tested in the field with, for example, a colour comparator, generally used in the range of 0.2–1 mg/litre.
- **pH:** It is necessary to know the pH of water, because more alkaline water requires a longer contact time or a higher free residual chlorine level at the end of the contact time for adequate disinfection (0.4–0.5 mg/litre at pH 6–8, rising to 0.6 mg/litre at pH 8–9; chlorination may be ineffective above pH 9).
- **Turbidity:** Turbidity adversely affects the efficiency of disinfection. Turbidity is also measured to determine what type and level of treatment are needed. It can be carried out with a simple turbidity tube that allows a direct reading in nephelometric turbidity units (NTU).

### 6.2.4 Sanitary inspections and catchment mapping

It is possible to assess the likelihood of faecal contamination of water sources through a sanitary inspection. Sanitary inspection and water quality testing are complementary activities; the findings of each assists the interpretation of the other. Where water quality analysis cannot be performed, sanitary inspection can still provide valuable information to support effective decision-making. A sanitary inspection makes it possible to see what needs to be done to protect the water source. This procedure can be combined with bacteriological, physical and chemical testing to enable field teams to assess and act on risks from contamination and to provide the basis for monitoring water supplies in the post-disaster period.

Even when it is possible to carry out testing of microbial quality, results are not instantly available. Thus, the immediate assessment of contamination risk may be based on gross indicators such as proximity to sources of faecal contamination (human or animal), colour and smell, the presence of dead fish or animals, the presence of foreign matter such as ash or debris or the presence of a chemical or radiation hazard or wastewater discharge point upstream. Catchment mapping involving the identification of sources and pathways of pollution can be an important tool for assessing the likelihood of contamination of a water source.

It is important to use a standard reporting format for sanitary inspections and catchment mapping to ensure that information gathered by different staff is reliable and that information gathered on different water sources may be compared. For an example format, see WHO (1997) and Davis & Lambert (2002). For more information on catchment mapping, see House & Reed (1997).

### 6.2.5 Chemical and radiological guidelines

Many chemicals in drinking-water are of concern only after extended periods of exposure. Thus, to reduce the risk of outbreaks of waterborne and water-washed (e.g.,
6. APPLICATION OF THE GUIDELINES IN SPECIFIC CIRCUMSTANCES

trachoma, scabies, skin infections) disease, it is preferable to supply water in an emergency, even if it significantly exceeds the guideline values for some chemical parameters, rather than restrict access to water, provided the water can be treated to kill pathogens and can be supplied rapidly to the affected population. Where water sources are likely to be used for long periods, chemical and radiological contaminants of more long-term health concern should be given greater attention. In some situations, this may entail adding treatment processes or seeking alternative sources. Local actions that can be considered in the event of a short-term guideline exceedance or emergency are discussed in section 8.6.

Water from sources that are considered to have a significant risk of chemical or radiological contamination should be avoided, even as a temporary measure. In the long term, achieving the guidelines should be the aim of emergency drinking-water supply programmes based on the progressive improvement of water quality. Procedures for identifying priority chemicals in drinking-water are outlined in the supporting document *Chemical Safety of Drinking-water* (section 1.3).

There are occasions when chemicals may be a threat to drinking-water for short periods following unusual circumstances, such as a spill of a chemical to a surface water source. Under these circumstances, guidance will be sought as to whether water is safe to drink or use for other domestic purposes, such as showering or bathing. These Guidelines can be used to support an initial evaluation of the situation, assuming that guidance is given on the chemical of concern. This is described in detail in section 8.6.5. It is important to seek specialist advice if the guideline value is exceeded by a significant amount or if the period for which it is exceeded is more than a few days. It is important to take local circumstances into account, including the availability of alternative water supplies and exposure to the contaminant from other sources, such as food. It is also important to consider what water treatment is available and whether this will reduce the concentration of the substance. For example, substances that are of low solubility in water and that tend to partition out of the water will tend to adsorb to particles and may be removed by treatment processes that are designed to remove particles, including coagulation, flocculation, filtration and adsorption by powdered (PAC) and granular activated carbon (GAC).

Short-term exposure guidance values are developed for key substances – for example, chemicals that are used in significant quantities and that may be more prone than others to be implicated in the contamination of a surface water source. The methods used to derive such guidance values are outlined in section 8.2.10.

6.2.6 Testing kits and laboratories

Portable testing kits allow the determination in the field of key water quality parameters, such as thermotolerant coliform count, free residual chlorine, pH, turbidity and filterability.

Where large numbers of water samples need testing or a broad range of parameters is of interest, laboratory analysis is usually most appropriate. If the drinking-water
supplier’s laboratories or laboratories at environmental health offices and universities no longer function because of the disaster, then a temporary laboratory may need to be set up. Where samples are transported to laboratories, handling is important. Poor handling may lead to meaningless or misleading results.

Workers should be trained in the correct procedures for collecting, labelling, packing and transporting samples and in supplying supporting information from the sanitary survey to help interpret laboratory results. For guidance on methods of water sampling and testing, see WHO (1997) and Bartram & Ballance (1996).

6.3 Safe drinking-water for travellers

The most common source of exposure to disease-causing organisms for travellers is ingestion of contaminated drinking-water and food. Diarrhoea is the most common symptom of waterborne infection, affecting 20–50% of all travellers or about 10 million people per year. Cases can occur even among people staying in high-quality resorts and hotels. In some parts of the world, tap or bottled water that has not been produced under proper conditions may not be safe, even if it is clear and colourless.

No vaccine is capable of conferring general protection against infectious diarrhoea, which is caused by many different pathogens. It is important that travellers be aware of the possibility of illness and take appropriate steps to minimize the risks.

Preventive measures while living or travelling in areas with questionable drinking-water quality include the following:

- Drink only bottled water or other beverages (carbonated beverages, pasteurized juices and milk) provided in sealed tamper-proof containers and bottled/canned by known manufacturers (preferably certified by responsible authorities). Hotel personnel or local hosts are often good sources of information about which local brands are safe.
- Drink water that has been treated effectively at point of use (e.g., through boiling, filtration or chemical disinfection) and stored in clean containers.
- Drink hot beverages such as coffee and tea that are made with boiled water and are kept hot and stored in clean containers.
- Avoid brushing the teeth with unsafe water.
- Avoid consumption of homemade or unpasteurized juices and unpasteurized milk.
- Avoid ice unless it has been made from safe water.
- Avoid salads or other uncooked foods that may have been washed or prepared with unsafe water.

Water can be treated in small quantities by travellers to significantly improve its safety. Numerous simple treatment approaches and commercially available technologies are available to travellers to disinfect drinking-water for single-person or family use. Travellers should select a water treatment approach that removes or inactivates all classes of pathogens. Technologies should be certified by a credible organization, and manufacturer’s instructions should be followed carefully.
Bringing water to a rolling boil is the simplest and most effective way to kill all disease-causing pathogens, even in turbid water and at high altitudes. The hot water should be allowed to cool without the addition of ice. If the water is turbid and needs to be clarified for aesthetic reasons, this should be done before boiling.

If it is not possible to boil water, chemical disinfection of clear, non-turbid water is effective for killing bacteria and most viruses and protozoa (but not, for example, *Cryptosporidium* oocysts). Certain chlorine- or iodine-based compounds are most widely used for disinfection of drinking-water by travellers. Silver is sometimes promoted as a disinfectant, but its efficacy is uncertain, and it requires lengthy contact periods. It is not recommended for treating contaminated drinking-water. Following chlorination or iodination, an activated carbon (charcoal) filter may be used to remove excess taste and odour from the water.

While iodine deficiency is a significant public health issue in many parts of the world, excess iodine may interfere with the functioning of the thyroid gland. Therefore, the use of iodine as a disinfectant is not recommended for infants, pregnant women, those with a history of thyroid disease and those with known hypersensitivity to iodine, unless treatment includes an effective post-disinfection iodine removal device, such as activated carbon. Travellers intending to use iodine treatment daily for all water consumed for more than 3–4 weeks should consult their physician beforehand and not use it in excessive amounts.

Suspended particles in water reduce the effectiveness of disinfectants. Turbid water (i.e., containing suspended particles) should be clarified or filtered before disinfection. Chemical products that combine clarification (coagulation and flocculation to remove particles) with chlorine disinfection are available.

Portable point-of-use filtration devices tested and rated to remove protozoa and some bacteria are also available; ceramic, membrane (mainly reverse osmosis) and activated carbon block filters are the most common types. A pore size rating of 1 μm or less is recommended to ensure removal of *Cryptosporidium* oocysts. These filters may require a pre-filter to remove suspended particles in order to avoid clogging the final filter.

Unless water is boiled, a combination of techniques (e.g., clarification and/or filtration followed by chemical disinfection) is recommended. This combination provides a multiple treatment barrier that removes significant numbers of protozoa in addition to killing bacteria and viruses.

For people with weakened immune systems, pregnant women and infants, extra precautions are recommended to reduce the risk of infection from contaminated water. *Cryptosporidium*, for example, is a special danger. Boiling and storing water in a protected container are recommended, although internationally or nationally certified bottled or mineral water may also be acceptable.

The treatment methods described here will generally not reduce levels of most chemical contaminants in drinking-water, with the possible exception of carbon filtration and reverse osmosis. However, in most cases, levels of chemicals in drinking-water are not of health concern in the short term.
Further information on household water treatment of microbial and chemical contaminants of water can be found in sections 7.3.3 and 8.4.14, respectively.

Table 6.1 provides a summary of drinking-water disinfection methods that can be used by travellers.

**Table 6.1 Drinking-water disinfection methods for use by travellers**

<table>
<thead>
<tr>
<th>Method</th>
<th>Recommendation</th>
<th>What it does</th>
<th>What it does not do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiling</td>
<td>Bring water to a rolling boil and allow to cool</td>
<td>Kills all pathogens</td>
<td>Does not remove turbidity/cloudiness, Does not provide residual chemical disinfectant, such as chlorine, to protect against contamination</td>
</tr>
<tr>
<td>Chlorine compounds:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Unscented household bleach (sodium hypochlorite)</td>
<td>For typical room temperature and water temperature of 25°C, minimum contact time should be 30 min; increase contact time for colder water – e.g., double time for each 10°C less than 25°C</td>
<td>Effective for killing most bacteria and viruses</td>
<td>Not effective against Cryptosporidium; not as effective as iodine when using turbid water</td>
</tr>
<tr>
<td>2. Sodium dichloroisocyanurate tablet</td>
<td>Prepare according to instructions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Calcium hypochlorite</td>
<td>Should be added to clear water or after settling or clarification to be most effective</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flocculant-chlorine tablet or sachet</td>
<td>Dose per package directions</td>
<td>Effective for killing or removing most waterborne pathogens (coagulant-flocculants partially remove Cryptosporidium)</td>
<td>Flocculated water must be decanted into a clean container, preferably through a clean fabric filter</td>
</tr>
<tr>
<td>Iodine:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Tincture of iodine (2% solution)</td>
<td>25°C – minimum contact for 30 min; increase contact time for colder water</td>
<td>Kills most pathogens</td>
<td>Not effective against Cryptosporidium</td>
</tr>
<tr>
<td>2. Iodine (10% solution)</td>
<td>Prepare according to package instructions</td>
<td>Longer contact time is required to kill Giardia cysts, especially when water is cold</td>
<td></td>
</tr>
<tr>
<td>3. Iodine tablet</td>
<td>Type and typical dosage:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 6.1 Continued

<table>
<thead>
<tr>
<th>Method</th>
<th>Recommendation</th>
<th>What it does</th>
<th>What it does not do</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Iodinated (triiodide or pentaiodide) resin</td>
<td>1. Tincture of iodine (2% solution) – 5 drops per litre</td>
<td>Carbon filtration after an iodine resin will remove excess iodine from the water; replace the carbon filter regularly</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Iodine (10% solution) – 8 drops per litre</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Iodine tablet – 1 or 2 tablets per litre</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Iodinated (triiodide or pentaiodide) resin – room temperature according to directions and stay within rated capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Caution:</strong> Not recommended for pregnant women, for people with thyroid problems or for more than a few months’ time. For pregnant women who may be more sensitive, a carbon filter or other effective process should be used to remove excess iodine after iodine treatment.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable filtering devices:</td>
<td>1. Ceramic filters for different pathogens remove Giardia, Cryptosporidium and other protozoa provided by manufacturer and certified by a national or international certification agency. Filter media pore size must be rated at 1 µm (absolute) or less. Note that water must be clear to prevent clogging of pores.</td>
<td>1 µm or less filter pore size will remove Giardia, Cryptosporidium and other protozoa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Carbon filters; (viruses, bacteria and some carbon protozoa) provided by manufacturer and certified by a national or international certification agency. Filter media pore size must be rated at 1 µm (absolute) or less. Note that water must be clear to prevent clogging of pores.</td>
<td>Approved reverse osmosis device can remove almost all pathogens</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Membrane filter (microfilter, ultra-filter, nanofilter and reverse osmosis) type devices</td>
<td>Some filters include a chemical disinfectant such as iodine or chlorine to kill microbes; check for manufacturer’s claim and documentation from an independent national or international certification agency</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Check pore size rating and reported removal efficiencies for different pathogens (viruses, bacteria and protozoa) provided by manufacturer and certified by a national or international certification agency. Filter media pore size must be rated at 1 µm (absolute) or less. Note that water must be clear to prevent clogging of pores.</td>
<td>Most bacteria and viruses will not be removed by filters with a pore size larger than 1 µm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Filtration or settling of turbid water to clarify it is recommended before disinfection with chlorine or iodine if water is not boiled</td>
<td>Microfilters may not remove viruses, especially from clear waters; additional treatment such as chemical disinfection or boiling/pasteurization may be needed to reduce viruses</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Most carbon block filters do not remove pathogens, other than possibly protozoa, even if carbon is impregnated with silver, because pore size is too large (&gt;1 µm)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a* To make a 1% stock solution of calcium hypochlorite, add (to 1 litre of water) 28 g if chlorine content is 35%, 15.4 g if chlorine content is 65% or 14.3 g if chlorine content is 70%.
6.4 Desalination systems

The principal purpose of desalination is to enable sources of brackish or salty water, otherwise unacceptable for human consumption, to be used for this purpose.

The use of desalination to provide drinking-water is increasing and is likely to continue to increase because of water scarcity driven by pressures arising from population growth, over-exploitation of water resources and pollution of other water sources. While most (around 60%) of currently constructed capacity is in the eastern Mediterranean region, desalination facilities exist all over the world, and their use is likely to increase in all continents.

Most present applications of desalination are for estuarine water, coastal water and seawater. Desalination may also be applied to brackish inland waters (both surface water and groundwater) and may be used on board vessels. Small-scale desalination units also exist for household and community use and present specific challenges to effective operation and maintenance.

Further guidance on desalination for safe drinking-water supply is available in the supporting document Desalination for Safe Drinking-water Supply (section 1.3).

In applying the Guidelines to desalinated water supply systems, account should be taken of certain major differences between these and systems abstracting water from freshwater sources. These differences include the factors described below. Once taken into account, the general requirements of these Guidelines for securing microbial, chemical and radiological safety should apply.

Brackish water, coastal water and seawater sources may contain hazards not encountered in freshwater systems. These include diverse harmful algal events associated with micro- and macroalgae and cyanobacteria; certain free-living bacteria (including Vibrio spp., such as V. parahaemolyticus and V. cholerae); and some chemicals, such as boron and bromide, that are more abundant in seawater.

Harmful algal events may be associated with exo- and endotoxins that may not be destroyed by heating, are inside algal cells or are free in the water. They are usually non-volatile, and, where they are destroyed by chlorination, this usually requires extremely long contact times. Although a number of toxins have been identified, it is possible that there are other unrecognized toxins. Minimizing of the potential for abstracting water containing toxic algae through location/siting and intake design plus effective monitoring and intake management is an important control measure.

Other chemical issues, such as control of “additives,” DBPs and pesticides, are similar to those encountered in fresh waters (see chapter 8), except that a larger variety
and greater quantities may be involved in desalination. Due to the presence of bromide in seawater, the distribution of DBPs will likely be dominated by brominated organics.

Approaches to monitoring and assessing the quality of freshwater sources may not be directly applicable to sources subject to desalination. For example, many faecal indicator bacteria die off more rapidly than pathogens (especially viruses) in saline than in fresh water.

The effectiveness of some of the processes employed in desalination to remove some substances of health concern remains inadequately understood. Examples of inefficiencies include imperfect membrane and/or membrane seal integrity (membrane treatment); bacterial growth through membranes/biofilm development on membranes (in membrane treatment systems); and carry-over, especially of volatile substances (with vapour).

Because of the apparently high effectiveness of some of the processes used in removal of both microorganisms and chemical constituents (especially distillation and reverse osmosis), these processes may be employed as single-stage treatments or combined with only a low level of residual disinfectant. The absence of multiple barriers places great stress on the continuously safe operation of that process and implies that even a short-term decrease in effectiveness may present an increased risk to human health. This, in turn, implies the need for on-line monitoring linked to rapid management intervention. For further information, see the supporting document Water Treatment and Pathogen Control (section 1.3).

Water produced by desalination is “aggressive” towards materials used, for example, in water supply and domestic plumbing and pipes. Special consideration should be given to the quality of such materials, and normal procedures for certification of materials as suitable for potable water use may not be adequate for water that has not been “stabilized.”

Because of the aggressivity of desalinated water and because desalinated water may be considered bland, flavourless and unacceptable, desalinated water is commonly treated by adding chemical constituents such as calcium and magnesium carbonate with carbon dioxide. Once such treatment has been applied, desalinated waters should be no more aggressive than waters normally encountered in the drinking-water supply. Chemicals used in such treatment should be subject to normal procedures for certification.

Desalinated waters are commonly blended with small volumes of more mineral-rich waters to improve their acceptability and particularly to reduce their aggressivity to materials. Blending waters should be fully potable, as described here and elsewhere in the Guidelines. Where seawater is used for this purpose, the major ions added are sodium and chloride. This does not contribute to improving hardness or ion balance, and only small amounts (e.g., 1–3%) can be added without leading to problems of acceptability. Blended waters from coastal and estuarine areas may be more susceptible to contamination with petroleum hydrocarbons, which could give rise to taste and
odour problems. Some groundwaters or surface waters, after suitable treatment, may be employed for blending in higher proportions and may improve hardness and ion balance.

Desalinated water is a manufactured product. Concern has been expressed about the impact of extremes of major ion composition or ratios for human health. There is limited evidence to describe the health risk associated with long-term consumption of such water, although concerns regarding mineral content may be limited by the stabilization processes outlined above (see WHO, 2003b).

Desalinated water, by virtue of its manufacture, often contains lower than usual concentrations of other ions commonly found in water, some of which are essential elements. Water typically contributes a small proportion of these, and most intake is through food. Exceptions include fluoride, and declining dental health has been reported from populations consuming desalinated water with very low fluoride content where there is a moderate to high risk of dental caries (WHO, 2003b).

Desalinated water may be more subject to “microbial growth” problems than other waters as a result of one or more of the following: higher initial temperature (from treatment process), higher temperature (application in hot climates) and/or the effect of aggressivity on materials (thereby releasing nutrients). The direct health significance of such growth (see the supporting document *Heterotrophic Plate Counts and Drinking-water Safety*; section 1.3), with the exception of *Legionella* (see chapter 11), is inadequately understood. Nitrite formation by organisms in biofilms may prove problematic where chloramination is practised and excess ammonia is present. Precaution implies that preventive management should be applied as part of good management practice.

### 6.5 Packaged drinking-water

Bottled water and ice are widely available in both industrialized and developing countries. Consumers may have various reasons for purchasing packaged drinking-water, such as taste, convenience or fashion; for many consumers, however, safety and potential health benefits are important considerations.

#### 6.5.1 Safety of packaged drinking-water

Water is packaged for consumption in a range of vessels, including cans, laminated boxes and plastic bags, and as ice prepared for consumption. However, it is most commonly prepared in glass or plastic bottles. Bottled water also comes in various sizes, from single servings to large carboys holding up to 80 litres.

In applying the Guidelines to bottled waters, certain chemical constituents may be more readily controlled than in piped distribution systems, and stricter standards may therefore be preferred in order to reduce overall population exposure. Similarly, when flexibility exists regarding the source of the water, stricter standards for certain naturally occurring substances of health concern, such as arsenic, may be more readily achieved than in piped distribution systems.
However, some substances may prove to be more difficult to manage in bottled water than in tap water. Some hazards may be associated with the nature of the product (e.g., glass chips and metal fragments). Other problems may arise because bottled water is stored for longer periods and at higher temperatures than water distributed in piped distribution systems or because containers and bottles are reused without adequate cleaning or disinfection. Control of materials used in containers and closures for bottled water is, therefore, of special concern. Some microorganisms that are normally of little or no public health significance may grow to higher levels in bottled water. This growth appears to occur less frequently in gasified water and in water bottled in glass containers than in still water and water bottled in plastic containers. The public health significance of this microbial growth remains uncertain, especially for vulnerable individuals, such as bottle-fed infants and immunocompromised individuals. In regard to bottle-fed infants, as bottled water is not sterile, it should be disinfected – for example, by boiling – prior to its use in the preparation of infant formula. For further information, see the supporting document *Heterotrophic Plate Counts and Drinking-water Safety* (section 1.3).

Ozone is sometimes used as an oxidant before bottling to prevent precipitation of iron and manganese, including natural mineral water. Where the water contains naturally occurring bromide, this can lead to the formation of high levels of bromate unless care is taken to minimize its formation. When ozone is used after the addition of the minerals to demineralized water, the presence of bromide in the additives may also lead to the formation of bromate.

### 6.5.2 Potential health benefits of bottled drinking-water

There is a belief by some consumers that natural mineral waters have medicinal properties or offer other health benefits. Such waters are typically of high mineral content, sometimes significantly higher than concentrations normally accepted in drinking-water. Such waters often have a long tradition of use and are often accepted on the basis that they are considered foods rather than drinking-water *per se*. Although certain mineral waters may be useful in providing essential micro-nutrients, such as calcium, these Guidelines do not make recommendations regarding minimum concentrations of essential compounds, because of the uncertainties surrounding mineral nutrition from drinking-water.

Packaged waters with very low mineral content, such as distilled or demineralized waters, are also consumed. Rainwater, which is similarly low in minerals, is consumed by some populations without apparent adverse health effects. There is insufficient scientific information on the benefits or hazards of regularly consuming these types of bottled waters (see WHO, 2003b).

### 6.5.3 International standards for bottled drinking-water

The *Guidelines for Drinking-water Quality* provide a basis for derivation of standards for all packaged waters. As with other sources of drinking-water, safety is pursued
through a combination of safety management and end product quality standards and testing. The international framework for packaged water regulation is provided by the Codex Alimentarius Commission (CAC) of WHO and the FAO. CAC has developed a *Standard for Natural Mineral Waters* and an associated Code of Practice. The Standard describes the product and its compositional and quality factors, including limits for certain chemicals, hygiene, packaging and labelling. The CAC has also developed
6. APPLICATION OF THE GUIDELINES IN SPECIFIC CIRCUMSTANCES

a Standard for Bottled-Packaged Waters to cover packaged drinking-water other than natural mineral waters. Both relevant CAC standards refer directly to these Guidelines.

The CAC Code of Practice for Collecting, Processing and Marketing of Natural Mineral Waters provides guidance on a range of good manufacturing practices and provides a generic WSP applied to packaged drinking-water.

Under the existing CAC Standard for Natural Mineral Waters and associated Code of Practice, natural mineral waters must conform to strict requirements, including collection and bottling without further treatment from a natural source, such as a spring or well. In comparison, the CAC Standard for Bottled/Packaged Waters includes waters from other sources, in addition to springs and wells, and treatment to improve their safety and quality. The distinctions between these standards are especially relevant in regions where natural mineral waters have a long cultural history.

For further information on CAC, its Codex Committee on Natural Mineral Waters, the CAC Standard for Natural Mineral Waters and its companion Code of Practice, readers are referred to the CAC website (http://www.codexalimentarius.net/).

6.6 Food production and processing

The quality of water defined by the Guidelines is such that it is suitable for all normal uses in the food industry. Some processes have special water quality requirements in order to secure the desired characteristics of the product, and the Guidelines do not necessarily guarantee that such special requirements are met.

Deterioration in drinking-water quality may have severe impacts on food processing facilities and potentially upon public health. The consequences of a failure to use water of potable quality will depend on the use of the water and the subsequent processing of potentially contaminated materials. Variations in water quality that may be tolerated occasionally in drinking-water supply may be unacceptable for some uses in the food industry. These variations may result in a significant financial impact on food production – for example, through product recalls.

The diverse uses of water in food production and processing have different water quality requirements. Uses include:

— irrigation and livestock watering;
— those in which water may be incorporated in or adhere to a product (e.g., as an ingredient, or where used in washing or “refreshing” of foods);
— misting of salad vegetables in grocery stores; and
— those in which contact between the water and foodstuff should be minimal (as in heating and cooling and cleaning water).

To reduce microbial contamination, specific treatments (e.g., heat) capable of removing a range of pathogenic organisms of public health concern may be used. The effect of these treatments should be taken into account when assessing the impacts of deterioration in drinking-water quality on a food production or processing facility.
Information on deterioration of the quality of a drinking-water supply should be promptly communicated to vulnerable food production facilities.

6.7 Aircraft and airports

6.7.1 Health risks
The importance of water as a potential vehicle for infectious disease transmission on aircraft has been well documented. In general terms, the greatest microbial risks are those associated with ingestion of water that is contaminated with human and animal excreta.

If the source of water used to replenish aircraft supplies is contaminated, and unless adequate precautions are taken, disease can be spread through the aircraft water. It is thus imperative that airports comply with Article 14.2 (Part III – Health Organization) of the International Health Regulations (1969) and be provided with potable drinking-water from a source approved by the appropriate regulatory agency (WHO, 1983).

A potable water source is not a safeguard if the water is subsequently contaminated during transfer, storage or distribution in aircraft. Airports usually have special arrangements for managing water after it has entered the airport. Water may be delivered to aircraft by water servicing vehicles or water bowser. Transfer of water from the water carriers to the aircraft provides the opportunity for microbial or chemical contamination (e.g., from water hoses).

A WSP covering water management within airports from receipt of the water through to its transfer to the aircraft, complemented by measures (e.g., safe materials and good practices in design, construction, operation and maintenance of aircraft systems) to ensure that water quality is maintained on the aircraft, provides a framework for water safety in aviation.

6.7.2 System risk assessment
In undertaking an assessment of the general airport/aircraft water distribution system, a range of specific issues must be taken into consideration, including:

— quality of source water;
— design and construction of airport storage tanks and pipes;
— design and construction of water servicing vehicles;
— water loading techniques;
— any treatment systems on aircraft;
— maintenance of on-board plumbing; and
— prevention of cross-connections, including backflow prevention.

6.7.3 Operational monitoring
The airport authority has responsibility for safe drinking-water supply, including for operational monitoring, until water is transferred to the aircraft operator. The primary
emphasis of monitoring is as a verification of management processes. Monitoring of control measures includes:

— quality of source water;
— hydrants, hoses and bowsers for cleanliness and repair;
— disinfectant residuals and pH;
— backflow preventers;
— filters; and
— microbial quality of water, particularly after maintenance or repairs.

6.7.4 Management
Even if potable water is supplied to the airport, it is necessary to introduce precautions to prevent contamination during the transfer of water to the aircraft and in the aircraft drinking-water system itself. Staff employed in drinking-water supply must not be engaged in activities related to aircraft toilet servicing without first taking all necessary precautions (e.g., thorough handwashing, change of outer garments).

All water servicing vehicles must be cleansed and disinfected frequently.

Supporting programmes that should be documented as part of a WSP for airports include:

— suitable training for crews dealing with water transfer and treatment; and
— effective certification of materials used on aircraft for storage tanks and pipes.

6.7.5 Surveillance
Independent surveillance resembles that described in chapter 5 and is an essential element in ensuring drinking-water safety in aviation. This implies:

— periodic audit and direct assessment;
— review and approval of WSPs;
— specific attention to the aircraft industry’s codes of practice, the supporting document Guide to Hygiene and Sanitation in Aviation (section 1.3) and airport health or airline regulations; and
— responding, investigating and providing advice on receipt of report on significant incidents.

6.8 Ships
6.8.1 Health risks
The importance of water as a vehicle for infectious disease transmission on ships has been clearly documented. In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human and animal excreta. Water-borne transmission of the enterotoxigenic *E. coli*, Norovirus, *Vibrio* spp., *Salmonella typhi*, *Salmonella* spp. (non-typhi), *Shigella* spp., *Cryptosporidium* spp., *Giardia lamblia* and *Legionella* spp. on ships has been confirmed (see Rooney et al., in press).
Chemical water poisoning can also occur on ships. For example, one outbreak of acute chemical poisoning implicated hydroquinone, an ingredient of photo developer, as the disease-causing agent in the ship’s potable water supply. Chronic chemical poisoning on a ship could also occur if crew or passengers were exposed to small doses of harmful chemicals over long periods of time.

The supporting document *Guide to Ship Sanitation* (section 1.3) describes the factors that can be encountered during water treatment, transfer, production, storage or distribution in ships. This revised Guide includes description of specific features of the organization of the supply and the regulatory framework.

The organization of water supply systems covering shore facilities and ships differs considerably from conventional water transfer on land. Even though a port authority may receive potable water from a municipal or private supply, it usually has special arrangements for managing the water after it has entered the port. Water is delivered to ships by hoses or transferred to the ship via water boats or barges. Transfer of water from shore to ships can provide possibilities for microbial or chemical contamination.

In contrast to a shore facility, plumbing aboard ships consists of numerous piping systems, carrying potable water, seawater, sewage and fuel, fitted into a relatively confined space. Piping systems are normally extensive and complex, making them difficult to inspect, repair and maintain. A number of waterborne outbreaks on ships have been caused by contamination of potable water after it had been loaded onto the ship – for example, by sewage or bilge when the water storage systems were not adequately designed and constructed. During distribution, it may be difficult to prevent water quality deterioration due to stagnant water and dead ends.

Water distribution on ships may also provide greater opportunities for contamination to occur than onshore, because ship movement increases the possibility of surge and backflow.

### 6.8.2 System risk assessment

In undertaking an assessment of the ship’s drinking-water system, a range of specific issues must be taken into consideration, including:

- quality of source water;
- water loading equipment;
- water loading techniques;
- design and construction of storage tanks and pipes;
- filtration systems and other treatment systems on board the ship;
- backflow prevention;
- pressure of water within the system;
- system design to minimize dead ends and areas of stagnation; and
- residual disinfection.
6. APPLICATION OF THE GUIDELINES IN SPECIFIC CIRCUMSTANCES

6.8.3 Operational monitoring

The ship’s master is responsible for operational monitoring. The primary emphasis of monitoring is as a verification of management processes. Monitoring of control measures includes:

— quality of source water;
— hydrants and hoses for cleanliness and repair;
— disinfectant residuals and pH (e.g., daily);
— backflow prevention devices (e.g., monthly to yearly);
— filters (before and during each use); and
— microbial quality of treated water, particularly after maintenance or repairs.

The frequency of monitoring should reflect the probable rate of change in water quality. For example, monitoring of drinking-water on ships may be more frequent when the ship is new or recently commissioned, with frequencies decreasing in the light of review of results. Similarly, if the ship’s water system has been out of control, monitoring following restoration of the system would be more frequent until it is verified that the system is clearly under control.

6.8.4 Management

The port authority has responsibility for providing safe potable water for loading onto vessels. The ship’s master will not normally have direct control of pollution of water supplied at port. If water is suspected to have come from an unsafe source, the ship’s master may have to decide if any additional treatment (e.g., hyperchlorination and/or filtration) is necessary. When treatment on board or prior to boarding is necessary, the treatment selected should be that which is best suited to the water and which is most easily operated and maintained by the ship’s officers and crew.

During transfer from shore to ship and on board, water must be provided with sanitary safeguards through the shore distribution system, including connections to the ship system, and throughout the ship system, to prevent contamination of the water.

Potable water should be stored in one or more tanks that are constructed, located and protected so as to be safe against contamination. Potable water lines should be protected and located so that they will not be submerged in bilge water or pass through tanks storing non-potable liquids.

The ship’s master should ensure that crew and passengers receive a sufficient and uninterrupted drinking-water supply and that contamination is not introduced in the distribution system. The distribution systems on ships are especially vulnerable to contamination when the pressure falls. Backflow prevention devices should be installed to prevent contamination of water where loss of pressure could result in backflow.

The potable water distribution lines should not be cross-connected with the piping or storage tanks of any non-potable water system.
Water safety is secured through repair and maintenance protocols, including the ability to contain potential contamination by valving and the cleanliness of personnel, their working practices and the materials employed.

Current practice on many ships is to use disinfectant residuals to control the growth of microorganisms in the distribution system. Residual disinfection alone should not be relied on to “treat” contaminated water, since the disinfection can be readily overwhelmed by contamination.

Supporting programmes that should be documented as part of the WSP for ships include:

— suitable training for crew dealing with water transfer and treatment; and
— effective certification of materials used on ships for storage tanks and pipes.

6.8.5 Surveillance
Independent surveillance is a desirable element in ensuring drinking-water safety on ships. This implies:

— periodic audit and direct assessment;
— review and approval of WSPs;
— specific attention to the shipping industry’s codes of practice, the supporting document Guide to Ship Sanitation (section 1.3) and port health or shipping regulations; and
— responding, investigating and providing advice on receipt of report on significant incidents.

6.9 Temporary water supplies
Temporary water supply systems may transmit disease unless they are properly designed and managed. “Temporary water supplies” in these Guidelines refers to water supplies for planned seasonal or time-limited events (e.g., festivals, markets and summer camps). Water supplies for holiday towns are not covered because they are not truly “temporary” supplies, although substantial seasonal variations in demand will bring specific problems.

A systematic approach to drinking-water safety is needed for temporary water supplies, as for permanent ones. Chapter 4 (Water safety plans), along with sections 6.2 (Emergencies and disasters) and 6.3 (Safe drinking-water for travellers), also provide useful information. It is also important to ensure that adequate water supplies are available.

A temporary water supply may be independent – i.e., not connected with any other water supply system and with its own facilities from source to taps; or dependent – i.e., receiving treated water from an existing water supply system but with independent distribution facilities. The risk of drinking-water contamination is usually lower in dependent systems, if there is access to the technologies, expertise and management of the permanent system.
For temporary water supplies, a contract is often made between the organizer of an event (e.g., a festival) and a water supply entity. The most important issues that should be included in such a contract are water quantity supplied by the entity, the roles and responsibilities of each party (i.e., the event organizer and the entity) in water quality management, and the locations and frequency of water quality monitoring. Coordination among an event organizer, a water supply entity and the relevant health authority is also very important for ensuring drinking-water safety. It is recommended that sanitary inspection and surveillance by a health authority be included in the contract.

6.9.1 Planning and design
Temporary water supply systems can vary in terms of their scale, period of operation, water use, time-dependent water demand and dependence on an existing permanent water supply system. These factors should be taken into consideration during the planning and design stages. In the case of an independent system, adequate consideration should be given to the selection of a water source and treatment processes. The plan and design of a temporary water supply system should be agreed with the appropriate local authority before construction begins.

A temporary water supply system should be planned and designed so as to meet potentially large and frequent fluctuations in water demand without compromising water quality (e.g., intrusion of contaminated water from outside the system in response to a pressure drop). To this end, distribution reservoirs and booster pumps with adequate capacities should be installed. Where a temporary system is directly connected to a mains water supply, it is important to prevent the accidental contamination of the mains water supply through backflow during construction and operation of the temporary system. If necessary, drinking-water supply can be increased through the use of mobile tanker trucks or the provision of bottled water.

Water consumption for fire-fighting, hand-washing and toilet flushing should be taken into account in estimating total water demand where there are no other water sources available for such a purpose.

Water quality targets for temporary supplies should be the same as those for permanent water supplies. Disinfection should be considered indispensable in a temporary supply, and it is preferable to maintain a certain level of disinfectant residual (e.g., chlorine residual) at service taps. If the supply is not for potable uses, then appropriate action should be taken to ensure that it is not taken for drinking.

If a temporary water supply is used recurrently, it is essential to fully flush the entire system with water containing a disinfectant residual before the start of operation. When planning installation on site, positioning of pipes, hoses and particularly connections should take risks of contamination into account – for example, avoiding the placement of hosing and fittings on the ground near sites of potential faecal contamination or storage tanks in direct sunlight where rising temperatures support microbial growth. It is also important to ensure that the facility has no defects, including
leakage, that could cause the deterioration of water quality and that water quality at every service tap satisfies the required quality target. Important control measures during dismantling and transport of installations include emptying hoses, preferably drying them and storing them so that ingress of contamination is avoided.

Care should be taken in planning and designing wastewater management and disposal facilities, particularly to ensure that lavatories and disposal facilities are located so as to avoid any risk of adversely affecting source water quality. The source, treatment facilities and distribution reservoirs should also be well protected from access by humans and animals (e.g., bird faeces) by covers or roofs.

6.9.2 Operation and maintenance
A temporary system is usually more vulnerable to accidental and deliberate contamination than an existing permanent water supply system; therefore, attention needs to be paid to security, ensuring the primary importance of adequate disinfection and other protective measures. To this end, an operation and maintenance manual should be prepared before the temporary water supply system begins operation. All water treatment facilities should be thoroughly inspected at least every day.

Signboards should be installed beside each service tap with instructions on the purposes for which the water can and cannot be used, along with additional instructions when warranted – for example, on hand-washing before preparing foods and beverages. Suitable signs should be installed around water sources indicating requirements for source water protection, including protection from animal and human faeces. Humans should be required to use proper sanitary facilities.

6.9.3 Monitoring, sanitary inspection and surveillance
Water quality and appearance should be routinely monitored at the service tap of a temporary water supply system. It is recommended that, at the very least, water temperature and disinfectant residual should be monitored every day as simple rapid tests that act as indicators of possible problems. Other basic parameters that should be regularly monitored include pH, conductivity, turbidity, colour and E. coli (or, alternatively, thermotolerant coliforms), as in an ordinary permanent water supply. Routine sanitary inspection of a temporary water supply by the appropriate health authority is very important. If any problem related to water quality arises, remedial actions should be taken promptly. If a temporary water supply system is to be used for a period of more than several weeks, regular surveillance by the appropriate health authority should be implemented.

6.10 Vended water
Vended water is common in many parts of the world where scarcity of supplies or lack of infrastructure limits access to suitable quantities of safe drinking-water. Although water vending is more common in developing countries, it also occurs in developed countries.
In the context of these Guidelines, water vending implies private vending of drinking-water (e.g., sold from kiosks, standpipes or tanker trucks, or delivered to households), not including bottled or packaged water (which is considered in section 6.5) or water sold through vending machines.

Water vending may be undertaken by formal bodies, such as water utilities or registered associations, by contracted suppliers or by informal and independent suppliers. Where formal vending is practised, the water typically comes from treated utility supplies or registered sources and is supplied in tankers or from standpipes and water kiosks. Informal suppliers tend to use a range of sources – protected as well as unprotected, including untreated surface water, dug wells and boreholes – and deliver small volumes for domestic use, often in containers loaded into donkey carts, hand carts or tanker trucks.

Both the quality and adequacy of vended supplies can vary. Vended water has been associated with outbreaks of diarrhoeal disease (Hutin et al., 2003). Water supplied to users should be suitable for drinking and comply with national or regional guidelines and regulatory requirements. The chemical and microbial quality of untreated or private sources of water should be tested to determine their suitability for use and to identify appropriate control measures, including treatment requirements. Surface water and some dug well and borehole waters are not suitable for drinking unless subject to treatment. Disinfection is the minimum requirement, and filtration, with or without coagulation, is often required when surface water is used.

In many developing countries, consumers purchase water from kiosks and then carry the water home. Water can be transported in a variety of ways, including containers on wheelbarrows, trolleys and animal-drawn or mechanized carts. Measures should be taken to protect vended water from contamination during transport as well as storage in the home. These include transporting and storing water in enclosed containers or containers with narrow openings, ideally fitted with a dispensing device such as a spigot that prevents hand access and other sources of extraneous contamination. Good hygiene is required and should be supported by educational programmes.

In other cases, particularly in developed countries, vendors transport and deliver the water to users in tanker trucks. If large volumes are being transported in water tankers, chlorine should be added to provide a free residual chlorine concentration of at least 0.5 mg/litre at the point of delivery to users. Tankers should also be used solely for water or, if this is not possible, should be thoroughly cleaned prior to use to ensure that there is no residual contamination.

All components of systems associated with supplying and delivering vended water need to be designed and operated in a manner that protects water quality. This includes ensuring that water storages, pipework and fittings do not include defects such as structural faults that allow leakage and permit the entry of contaminants. Cleanliness of storages, standpipes, taps and hoses needs to be maintained. Hoses used to transfer water at kiosks or used on carts and tanker trucks should be protected from
contamination by avoiding contact of openings with the ground. Hoses should be drained when not in use. The area around standpipes should include drainage or be constructed in a manner to prevent pooling of water. Materials used in all components, including pipework, storages, hoses and containers, need to be suitable for use in contact with drinking-water and should not result in contamination of the water with hazardous compounds or with compounds that could adversely affect the taste of the water.

All components of water vending, including sources, methods of abstraction and transport, should be incorporated within WSPs. Where vendors are registered or have a contract with a water utility, implementation and operation of the WSP should be regularly checked by the utility. WSPs and the operation of water vendors should also be subject to independent surveillance.

6.10.1 System risk assessment
In undertaking a risk assessment of vended water supplies, a range of issues should be considered, including:

— the nature and quality of source water. Sources can include surface water, dug wells, boreholes or standpipes associated with piped water supplies. The quality of these sources should be assessed and the likelihood of contamination determined.

— control measures, including protection of source waters and treatment. Where untreated sources are used, they should be protected from human and animal excreta and domestic, industrial and agricultural chemicals.

— mechanisms for abstraction and storage, including hoses, hydrants and pipework. Water should be abstracted and delivered in a manner that protects water quality and does not permit entry of contamination. Materials should be suitable for use with drinking-water. Where mains water is used, backflow prevention will ensure that abstraction does not lead to ingress of contamination.

— design and characteristics of containers used to transport and deliver water. Containers should be dedicated to transport of drinking-water and made of suitable material for contact with drinking-water. Containers should be enclosed and designed to prevent entry of contaminants.

6.10.2 Operational monitoring
Vendors have a responsibility to ensure that control measures operate effectively. Operational monitoring of control measures could include:

— sanitary surveys of source water, abstraction devices and hoses for protection from external sources of contamination;

— integrity, cleanliness and maintenance of equipment and devices such as hydrants, standpipes, backflow preventers, storages, hoses, containers and bulk water tankers;
— appropriate use of equipment, such as avoiding contact of hose outlets with the ground and draining of hoses when not in use;
— disinfectant residuals and pH;
— performance and maintenance of filters;
— integrity, cleanliness and maintenance of containers and tankers;
— chlorine residuals at point of delivery.

6.10.3 Management
Management plans should document system assessment and operational monitoring requirements associated with abstraction, transport and delivery of water. Procedures associated with performing and monitoring these tasks need to be included. For example, procedures for cleaning and disinfection of hydrants, hoses and bulk water tankers should be documented.

Supporting programmes should also be documented, including personal hygiene requirements associated with water vending and education and training programmes to support water hygiene in homes.

Volumes of vended water and customer details should be recorded.

6.10.4 Surveillance
Independent surveillance is an important element of ensuring that vended drinking-water is safe. One of the barriers to effective surveillance can be a lack of records and documentation identifying water vendors. Implementation of registration systems should be considered.

Surveillance should include:
— direct assessment of water quality;
— review of WSPs and auditing of implementation;
— sanitary surveys of source waters, abstraction and delivery systems;
— responding to, investigating and providing advice on receipt of reports of significant incidents.

Surveillance should include an assessment of household storage practices and the effectiveness of hygiene education programmes. Where consumers carry vended water home, hygienic practices associated with the collection and transport of water should be assessed.

6.11 Rainwater harvesting
6.11.1 Water quality and health risk
Rainwater is relatively free from impurities, except those picked up by the rain from the atmosphere. However, the quality of rainwater may deteriorate during harvesting, storage and household use. Wind-blown dirt, leaves, faecal droppings from birds and other animals, insects and contaminated litter on the catchment areas and in cisterns can be sources of contamination of rainwater, leading to health risks from the con-
SUMPTION of contaminated water from storage tanks. Poor hygiene in water storage and water abstraction from tanks or at the point of use can also represent a health concern. However, risks from these hazards can be minimized by good design and practice. Well designed rainwater harvesting systems with clean catchments, covered cisterns and storage tanks, and treatment, as appropriate, supported by good hygiene at point of use, can offer drinking-water with very low health risk. In contrast, a poorly designed and managed system can pose high health risks.

Microbial contamination of collected rainwater, indicated by *E. coli* (or, alternatively, thermotolerant coliforms), is quite common, particularly in samples collected shortly after rainfall. Pathogens such as *Cryptosporidium*, *Giardia*, *Campylobacter*, *Vibrio*, *Salmonella*, *Shigella* and *Pseudomonas* have also been detected in collected rainwater. However, the occurrence of pathogens is generally lower in rainwater than in unprotected surface waters, and the presence of non-bacterial pathogens, in particular, can be minimized. Higher microbial concentrations are generally found in the first flush of rainwater, and the level of contamination decreases as the rain continues. A significant reduction of microbial contamination can be found in rainy seasons when catchments are frequently washed with fresh rainwater. Storage tanks can present breeding sites for mosquitoes, including species that transmit dengue virus (see section 8.5.5).

Rainwater is slightly acidic and very low in dissolved minerals; as such, it is relatively aggressive and can dissolve metals and other impurities from materials of the catchment and storage tank. In most cases, chemical concentrations in rainwater are within acceptable limits; however, elevated levels of zinc and lead have sometimes been reported. This could be from leaching from metallic roofs and storage tanks or from atmospheric pollution.

Rainwater lacks minerals, but some minerals in appropriate concentrations are essential for health, such as calcium, magnesium, iron and fluoride. Although most essential nutrients are derived from food, the lack of minerals, including calcium and magnesium, in rainwater may represent a concern for those on a mineral-deficient diet (see the supporting document *Calcium and Magnesium in Drinking-water*; section 1.3). In this circumstance, the implications of using rainwater as the primary source of drinking-water should be considered. The absence of minerals also means that rainwater has a particular taste or lack of taste that may not be acceptable to people used to drinking other mineral-rich natural waters.

Water quality should be managed through the development and application of WSPs that deal with all components of the rainwater harvesting system, from catchment areas to point of supply.

**6.11.2 System risk assessment**

Important factors in collecting and maintaining good-quality rainwater include proper design and installation or construction of rainwater harvesting systems. Materials used in the catchment and storage tank should be specifically suitable and approved for use in contact with drinking-water and should be non-toxic to humans.
Rainwater can be harvested using roof and other above-ground catchments and stored in tanks for use. The roof catchment is connected with a gutter and down-pipe system to deliver rainwater to the storage tank. The quality of rainwater is directly related to the cleanliness of catchments, gutters and storage tanks. Rooftop catchment surfaces may collect dust, organic matter, leaves, and bird and animal droppings, which can contaminate the stored water and cause sediment buildup in the tank. Care should also be taken to avoid materials or coatings that may cause adverse taste or odour. Most solid roof materials are suitable for collecting rainwater. However, roofs coated with bitumen-based coatings are generally not recommended, as they may leach hazardous substances or cause taste problems. Similarly, metals can leach from some roofs, resulting in high metal concentrations in the water. Care should be taken to ensure that lead-based paints are not used on roof catchments. Thatched roofs can cause discoloration or deposition of particles in collected water. Regular cleaning of catchment surfaces and gutters should be undertaken to minimize the accumulation of debris. Wire meshes or inlet filters should be placed over the top of down-pipes to prevent leaves and other debris from entering storages. These meshes and filters should be cleaned regularly to prevent clogging.

The first flush of rainwater carries most contaminants into storages. A system to divert the contaminated first flow of rainwater from roof surfaces is therefore necessary. Automatic devices that prevent the first flush of runoff from being collected in storages are recommended. If diverters are not available, a detachable down-pipe can be used manually to provide the same result. Even with these measures in place, storages will require periodic cleaning to remove sediment.

Storages without covers or with unprotected openings will encourage mosquito breeding, and sunlight reaching the water will promote algal growth. Covers should be fitted, and openings need to be protected by mosquito-proof mesh. Cracks in the tank and water withdrawal using contaminated pots can contaminate stored water. Storages should preferably be fitted with a mechanism such as a tap or outlet pipe that enables hygienic abstraction of water. Some households incorporate cartridge filters or other treatments at the point of consumption to ensure better quality of drinking-water and reduce health risk. Solar water disinfection or point-of-use chlorination are examples of low-cost disinfection options for the treatment of stored rainwater. These and other household water treatment technologies are discussed in more detail in sections 7.3.3 (microbial) and 8.4.14 (chemical).

**6.11.3 Operational monitoring**

Sanitary inspections should be a focus of operational monitoring. These should include checking the cleanliness of the catchment area and storage, the structural integrity of the system and the physical quality of the rainwater (turbidity, colour and smell). The pH level should be monitored frequently where new concrete, ferro-cement or masonry storage tanks are being used, as leaching of carbonates will produce water with high pH.
6.11.4 Verification
The microbial quality of rainwater needs to be monitored as part of verification. Rainwater, like all water supplies, should be tested for E. coli or thermotolerant coliforms. The levels of lead, zinc or other heavy metals in rainwater should also be measured occasionally if the water is in contact with metallic surfaces during collection or storage.

6.11.5 Management
Management plans should document all procedures applied during normal operation as well as actions to be taken in the event of failures. Remedial actions will generally involve physical repair of faults and cleaning of catchment areas, filters or storage systems. Disinfection of rainwater should be practised when microbial contamination is detected or sanitary inspections indicate a likelihood of contamination.

6.11.6 Surveillance
Independent surveillance is desirable for ensuring the quality, safety and acceptability of water supply based on rainwater. Apart from verification of compliance, the principal focus of surveillance should be towards the evaluation of hygienic practices in collection, storage and use of rainwater in order to develop and refine requirements for improving water safety through a WSP.

6.12 Non-piped water supplies
Non-piped water supplies, such as roof catchments (rainwater harvesting), surface waters and water collected from wells or springs, can apply the same health risk-based framework of these Guidelines as is applied to piped water supplies, including use of health-based targets, use of the highest-quality water source, treatment appropriate to source water quality to achieve a tolerable level of risk, and protection of water during storage, distribution or handling. Determination of water quality is recommended in order to best implement WSPs based on this framework.

Management of non-piped water supplies at the household level is often focused on achieving microbiologically safe water, as waterborne pathogens are a ubiquitous global risk. Methods for the treatment of microbial contaminants at the household level are described in section 7.3.3.

Some non-piped household water supplies uniquely pose risks of chemical and radiological contamination, from chemicals such as arsenic and fluoride and radiological contaminants such as radon, especially in certain groundwater sources. Risks of excessive chemical and radiological contamination must be considered and appropriate actions taken to avoid the use of such sources or to apply effective treatment that reduces risks from these sources to tolerable levels. Methods for treatment of chemical and radiological contaminants at the household or other local level at point of use are described in section 8.4.14.