

# 6

## Application of the Guidelines in specific circumstances

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 maintained 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 backflow 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 maintained 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 potentially 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  $\mu\text{l}$  (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 micro-filtration 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 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

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 6 h;
- 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.,

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).

### **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**

Diarrhoea is the most common cause of ill health for travellers; up to 80% of all travellers are affected in high-risk areas. In localities where the quality of potable water and sanitation and food hygiene practices are questionable, the numbers of parasites, bacteria and viruses in water and food can be substantial, and numerous infections can occur. Cases occur among people staying in resorts and hotels in all categories. No vaccine is capable of conferring general protection against diarrhoea, which is caused by many different pathogens. It is important that travellers are aware of possible risks and take appropriate steps to minimize these.

Contaminated food, water and drinks are the most common sources of infections. Careful selection of drinking-water sources and appropriate water treatment offer

## 6. APPLICATION OF THE GUIDELINES IN SPECIFIC CIRCUMSTANCES

significant protection. Preventive measures while living or travelling in areas with unsafe drinking-water include the following:

- Always avoid consumption or use of unsafe water (even when brushing teeth) if you are unsure about water quality.
- Avoid unpasteurized juices and ice made from untreated water.
- Avoid salads or other uncooked meals that may have been washed or prepared with unsafe water.
- Drink water that you have boiled, filtered and/or treated with chlorine or iodine and stored in clean containers.
- Consume ice only if it is known to be of drinking-water quality.
- Drink bottled water if it is known to be safe, carbonated bottled beverages (water and sodas) only from sealed, tamper-proof containers and pasteurized/canned juices and pasteurized milk.
- Drink coffee and tea made from boiled water and served and stored in clean containers.

The greatest health risk from drinking-water for travellers is associated with microbial constituents of water. Water can be treated or re-treated in small quantities to significantly improve its safety. The simplest and most important beneficial treatments for microbially contaminated water are boiling, disinfection and filtration to inactivate or remove pathogenic microorganisms. These treatments will generally not reduce most chemical constituents in drinking-water. However, most chemicals are of health concern only after long-term exposure. Numerous simple treatment approaches and commercially available technologies are also available to travellers to treat drinking-water for single-person use.

Bringing water to a rolling boil is the most effective way to kill disease-causing pathogens, even at high altitudes and even for turbid water. The hot water should be allowed to cool down on its own without the addition of ice. If water for boiling is to be clarified, this should be done before boiling.

Chemical disinfection is effective for killing bacteria, some viruses and some protozoa (but not, for example, *Cryptosporidium* oocysts). Some form of chlorine and iodine are the chemicals most widely used for disinfection by travellers. After chlorination, a carbon (charcoal) filter may be used to remove excess chlorine taste and, in the case of iodine treatment, to remove excess iodine. Silver is not very effective for eliminating disease-causing microorganisms, since silver by itself is slow acting. If water is turbid (not clear or with suspended solid matter), it should be clarified before disinfection; clarification includes filtration, settling and decanting. Portable filtration devices that have been tested and rated to remove protozoa and some bacteria are also available; ceramic filters and some carbon block filters are the most common types. The filter's pore size rating must be 1 µm (absolute) or less to ensure removal of *Cryptosporidium* oocysts (these very fine filters may require a pre-filter to remove larger particles in order to avoid clogging the final filter). A combination of technologies (filtration followed by chemical disinfection or boiling) is recommended, as most filtering devices do not remove viruses.

For people with weakened immune systems, extra precautions are recommended to reduce the risk of infection from contaminated water. While drinking boiled water is safest, certified bottled or mineral water may also be acceptable. Iodine as a water disinfectant is not recommended for pregnant women, those with a history of thyroid disease and those with known hypersensitivity to iodine, unless there is also an effective post-treatment iodine removal system such as granular carbon in use.

#### **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).

### **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

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 bowsers. 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.

### **6.8.3 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.