

# 10

## Acceptability aspects

The most undesirable constituents of drinking-water are those capable of having a direct adverse impact on public health. Many of these are described in other chapters of these Guidelines.

To a large extent, consumers have no means of judging the safety of their drinking-water themselves, but their attitude towards their drinking-water supply and their drinking-water suppliers will be affected to a considerable extent by the aspects of water quality that they are able to perceive with their own senses. It is natural for consumers to regard with suspicion water that appears dirty or discoloured or that has an unpleasant taste or smell, even though these characteristics may not in themselves be of direct consequence to health.

The provision of drinking-water that is not only safe but also acceptable in appearance, taste and odour is of high priority. Water that is aesthetically unacceptable will undermine the confidence of consumers, lead to complaints and, more importantly, possibly lead to the use of water from sources that are less safe.

The appearance, taste and odour of drinking-water should be acceptable to the consumer.

It is important to consider whether existing or proposed water treatment and distribution practices can affect the acceptability of drinking-water. For example, a change in disinfection practice may generate an odorous compound such as trichloramine in the treated water. Other effects may be indirect, such as the disturbance of internal pipe deposits and biofilms when changing between or blending waters from different sources in distribution systems.

The acceptability of drinking-water to consumers is subjective and can be influenced by many different constituents. The concentration at which constituents are objectionable to consumers is variable and dependent on individual and local factors, including the quality of the water to which the community is accustomed and a variety of social, environmental and cultural considerations. Guideline values have not been established for constituents influencing water quality that have no direct link to adverse health impacts.

In the summaries in this chapter and chapter 12, reference is made to levels likely to give rise to complaints from consumers. These are not precise numbers, and problems may occur at lower or higher levels, depending on individual and local circumstances.

It is not normally appropriate to directly regulate or monitor substances of health concern whose effects on the acceptability of water would normally lead to rejection of the water at concentrations significantly lower than those of concern for health; rather, these substances may be addressed through a general requirement that water be acceptable to the majority of consumers. For such substances, a health-based summary statement and guideline value are derived in these Guidelines in the usual way. In the summary statement, this is explained, and information on acceptability is described. In the tables of guideline values (see chapter 8 and Annex 4), the health-based guideline value is designated with a “C,” with a footnote explaining that while the substance is of health significance, water would normally be rejected by consumers at concentrations well below the health-based guideline value. Monitoring of such substances should be undertaken in response to consumer complaints.

There are other water constituents that are of no direct consequence to health at the concentrations at which they normally occur in water but which nevertheless may be objectionable to consumers for various reasons.

## **10.1 Taste, odour and appearance**

Taste and odour can originate from natural inorganic and organic chemical contaminants and biological sources or processes (e.g., aquatic microorganisms), from contamination by synthetic chemicals, from corrosion or as a result of water treatment (e.g., chlorination). Taste and odour may also develop during storage and distribution due to microbial activity.

Taste and odour in drinking-water may be indicative of some form of pollution or of a malfunction during water treatment or distribution. It may therefore be an indication of the presence of potentially harmful substances. The cause should be investigated and the appropriate health authorities should be consulted, particularly if there is a sudden or substantial change.

Colour, cloudiness, particulate matter and visible organisms may also be noticed by consumers and may create concerns about the quality and acceptability of a drinking-water supply.

### **10.1.1 Biologically derived contaminants**

There are a number of diverse organisms that may have no public health significance but which are undesirable because they produce taste and odour. As well as affecting the acceptability of the water, they indicate that water treatment and/or the state of maintenance and repair of the distribution system are insufficient.

### Actinomycetes and fungi

Actinomycetes and fungi can be abundant in surface water sources, including reservoirs, and they also can grow on unsuitable materials in the water supply distribution systems, such as rubber. They can give rise to geosmin, 2-methyl isoborneol and other substances, resulting in objectionable tastes and odours in the drinking-water.

### Animal life<sup>1</sup>

Invertebrate animals are naturally present in many water resources used as sources for the supply of drinking-water and often infest shallow, open wells. Small numbers of invertebrates may also pass through water treatment works where the barriers to particulate matter are not completely effective and colonize the distribution system. Their motility may enable them and their larvae to penetrate filters at the treatment works and vents on storage reservoirs.

The types of animal concerned can be considered, for control purposes, as belonging to two groups. First, there are free-swimming organisms in the water itself or on water surfaces, such as the crustaceans *Gammarus pulex* (freshwater shrimp), *Crangonyx pseudogracilis*, *Cyclops* spp. and *Chydorus sphaericus*. Second, there are other animals that either move along surfaces or are anchored to them (e.g., water louse *Asellus aquaticus*, snails, zebra mussel *Dreissena polymorpha*, other bivalve molluscs and the bryozoan *Plumatella* sp.) or inhabit slimes (e.g., *Nais* spp., nematodes and the larvae of chironomids). In warm weather, slow sand filters can sometimes discharge the larvae of gnats (*Chironomus* and *Culex* spp.) into the water.

Many of these animals can survive, deriving food from bacteria, algae and protozoa in the water or present on slimes on pipe and tank surfaces. Few, if any, water distribution systems are completely free of animals. However, the density and composition of animal populations vary widely, from heavy infestations, including readily visible species that are objectionable to consumers, to sparse occurrences of microscopic species.

The presence of animals has largely been regarded by piped drinking-water suppliers in temperate regions as an acceptability problem, either directly or through their association with discoloured water. In tropical and subtropical countries, on the other hand, there are species of aquatic animal that act as secondary hosts for parasites. For example, the small crustacean *Cyclops* is the intermediate host of the guinea worm *Dracunculus medinensis* (see sections 7.1.1 and 11.4). However, there is no evidence that guinea worm transmission occurs from piped drinking-water supplies. The presence of animals in drinking-water, especially if visible, raises consumer concern about the quality of the drinking-water supply and should be controlled.

Penetration of waterworks and mains is more likely to be a problem when low-quality raw waters are abstracted and high-rate filtration processes are used. Pre-chlorination assists in destroying animal life and in its removal by filtration.

<sup>1</sup> The section was drawn largely from Evins (2004).

Production of high-quality water, maintenance of chlorine residuals in the distribution system and the regular cleaning of water mains by flushing or swabbing will usually control infestation.

Treatment of invertebrate infestations in piped distribution systems is discussed in detail in chapter 6 of the supporting document *Safe, Piped Water* (section 1.3).

### Cyanobacteria and algae

Blooms of cyanobacteria and other algae in reservoirs and in river waters may impede coagulation and filtration, causing coloration and turbidity of water after filtration. They can also give rise to geosmin, 2-methyl isoborneol and other chemicals, which have taste thresholds in drinking-water of a few nanograms per litre. Some cyanobacterial products – cyanotoxins – are also of direct health significance (see section 8.5.6).

### Iron bacteria

In waters containing ferrous and manganous salts, oxidation by iron bacteria (or by exposure to air) may cause rust-coloured deposits on the walls of tanks, pipes and channels and carry-over of deposits into the water.

## **10.1.2 Chemically derived contaminants**

### Aluminium

Naturally occurring aluminium as well as aluminium salts used as coagulants in drinking-water treatment are the most common sources of aluminium in drinking-water. The presence of aluminium at concentrations in excess of 0.1–0.2 mg/litre often leads to consumer complaints as a result of deposition of aluminium hydroxide floc in distribution systems and the exacerbation of discoloration of water by iron. It is therefore important to optimize treatment processes in order to minimize any residual aluminium entering the supply. Under good operating conditions, aluminium concentrations of less than 0.1 mg/litre are achievable in many circumstances. Available evidence does not support the derivation of a health-based guideline value for aluminium in drinking-water (see sections 8.5.4 and 12.5).

### Ammonia

The threshold odour concentration of ammonia at alkaline pH is approximately 1.5 mg/litre, and a taste threshold of 35 mg/litre has been proposed for the ammonium cation. Ammonia is not of direct relevance to health at these levels, and no health-based guideline value has been proposed (see sections 8.5.3 and 12.6).

### Chloride

High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/litre for sodium, potassium and calcium chloride. Concentrations in

excess of 250 mg/litre are increasingly likely to be detected by taste, but some consumers may become accustomed to low levels of chloride-induced taste. No health-based guideline value is proposed for chloride in drinking-water (see sections 8.5.4 and 12.22).

### Chlorine

Most individuals are able to taste or smell chlorine in drinking-water at concentrations well below 5 mg/litre, and some at levels as low as 0.3 mg/litre. At a residual free chlorine concentration of between 0.6 and 1.0 mg/litre, there is an increasing likelihood that some consumers may object to the taste. The taste threshold for chlorine is below the health-based guideline value (see sections 8.5.4 and 12.23).

### Chlorophenols

Chlorophenols generally have very low taste and odour thresholds. The taste thresholds in water for 2-chlorophenol, 2,4-dichlorophenol and 2,4,6-trichlorophenol are 0.1, 0.3 and 2 µg/litre, respectively. Odour thresholds are 10, 40 and 300 µg/litre, respectively. If water containing 2,4,6-trichlorophenol is free from taste, it is unlikely to present a significant risk to health (see section 12.26). Microorganisms in distribution systems may sometimes methylate chlorophenols to produce chlorinated anisoles, for which the odour threshold is considerably lower.

### Colour

Drinking-water should ideally have no visible colour. Colour in drinking-water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. Colour is also strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. It may also result from the contamination of the water source with industrial effluents and may be the first indication of a hazardous situation. The source of colour in a drinking-water supply should be investigated, particularly if a substantial change has taken place.

Most people can detect colours above 15 true colour units (TCU) in a glass of water. Levels of colour below 15 TCU are usually acceptable to consumers, but acceptability may vary. High colour could also indicate a high propensity to produce by-products from disinfection processes. No health-based guideline value is proposed for colour in drinking-water.

### Copper

Copper in a drinking-water supply usually arises from the corrosive action of water leaching copper from copper pipes. Concentrations can vary significantly with the period of time the water has been standing in contact with the pipes; for example, first-draw water would be expected to have a higher copper concentration than a fully flushed sample. High concentrations can interfere with the intended domestic uses of

the water. Copper in drinking-water may increase the corrosion of galvanized iron and steel fittings. Staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/litre. At levels above 5 mg/litre, copper also imparts a colour and an undesirable bitter taste to water. Although copper can give rise to taste, it should be acceptable at the health-based guideline value (see sections 8.5.4 and 12.31).

#### Dichlorobenzenes

Odour thresholds of 2–10 and 0.3–30 µg/litre have been reported for 1,2- and 1,4-dichlorobenzene, respectively. Taste thresholds of 1 and 6 µg/litre have been reported for 1,2- and 1,4-dichlorobenzene, respectively. The health-based guideline values derived for 1,2- and 1,4-dichlorobenzene (see sections 8.5.4 and 12.42) far exceed the lowest reported taste and odour thresholds for these compounds.

#### Dissolved oxygen

The dissolved oxygen content of water is influenced by the source, raw water temperature, treatment and chemical or biological processes taking place in the distribution system. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulfate to sulfide. It can also cause an increase in the concentration of ferrous iron in solution, with subsequent discoloration at the tap when the water is aerated. No health-based guideline value is recommended.

#### Ethylbenzene

Ethylbenzene has an aromatic odour; the reported odour threshold in water ranges from 2 to 130 µg/litre. The lowest reported odour threshold is 100-fold lower than the health-based guideline value (see sections 8.5.4 and 12.60). The taste threshold ranges from 72 to 200 µg/litre.

#### Hardness

Hardness caused by calcium and magnesium is usually indicated by precipitation of soap scum and the need for excess use of soap to achieve cleaning. Public acceptability of the degree of hardness of water may vary considerably from one community to another, depending on local conditions. In particular, consumers are likely to notice changes in hardness.

The taste threshold for the calcium ion is in the range of 100–300 mg/litre, depending on the associated anion, and the taste threshold for magnesium is probably lower than that for calcium. In some instances, consumers tolerate water hardness in excess of 500 mg/litre.

Depending on the interaction of other factors, such as pH and alkalinity, water with a hardness above approximately 200 mg/litre may cause scale deposition in the treatment works, distribution system and pipework and tanks within buildings. It will also result in excessive soap consumption and subsequent “scum” formation. On heating, hard waters form deposits of calcium carbonate scale. Soft water, with a hardness of

less than 100 mg/litre, may, on the other hand, have a low buffering capacity and so be more corrosive for water pipes.

No health-based guideline value is proposed for hardness in drinking-water.

### Hydrogen sulfide

The taste and odour thresholds of hydrogen sulfide in water are estimated to be between 0.05 and 0.1 mg/litre. The “rotten eggs” odour of hydrogen sulfide is particularly noticeable in some groundwaters and in stagnant drinking-water in the distribution system, as a result of oxygen depletion and the subsequent reduction of sulfate by bacterial activity.

Sulfide is oxidized rapidly to sulfate in well aerated or chlorinated water, and hydrogen sulfide levels in oxygenated water supplies are normally very low. The presence of hydrogen sulfide in drinking-water can be easily detected by the consumer and requires immediate corrective action. It is unlikely that a person could consume a harmful dose of hydrogen sulfide from drinking-water, and hence a health-based guideline value has not been derived for this compound (see sections 8.5.1 and 12.71).

### Iron

Anaerobic groundwater may contain ferrous iron at concentrations of up to several milligrams per litre without discoloration or turbidity in the water when directly pumped from a well. On exposure to the atmosphere, however, the ferrous iron oxidizes to ferric iron, giving an objectionable reddish-brown colour to the water.

Iron also promotes the growth of “iron bacteria,” which derive their energy from the oxidation of ferrous iron to ferric iron and in the process deposit a slimy coating on the piping. At levels above 0.3 mg/litre, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/litre, although turbidity and colour may develop. No health-based guideline value is proposed for iron (see sections 8.5.4 and 12.74).

### Manganese

At levels exceeding 0.1 mg/litre, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. The presence of manganese in drinking-water, like that of iron, may lead to the accumulation of deposits in the distribution system. Concentrations below 0.1 mg/litre are usually acceptable to consumers. Even at a concentration of 0.2 mg/litre, manganese will often form a coating on pipes, which may slough off as a black precipitate. The health-based guideline value for manganese is 4 times higher than this acceptability threshold of 0.1 mg/litre (see sections 8.5.1 and 12.79).

### Monochloramine

Most individuals are able to taste or smell monochloramine, generated from the reaction of chlorine with ammonia, in drinking-water at concentrations well below

5 mg/litre, and some at levels as low as 0.3 mg/litre. The taste threshold for monochloramine is below the health-based guideline value (see sections 8.5.4 and 12.89).

### Monochlorobenzene

Taste and odour thresholds of 10–20 µg/litre and odour thresholds ranging from 40 to 120 µg/litre have been reported for monochlorobenzene. A health-based guideline value has not been derived for monochlorobenzene (see sections 8.5.4 and 12.91), although the health-based value that could be derived far exceeds the lowest reported taste and odour threshold in water.

### Petroleum oils

Petroleum oils can give rise to the presence of a number of low molecular weight hydrocarbons that have low odour thresholds in drinking-water. Although there are no formal data, experience indicates that these may have lower odour thresholds when several are present as a mixture. Benzene, toluene, ethylbenzene and xylenes are considered individually in this section, as health-based guideline values have been derived for these chemicals. However, a number of other hydrocarbons, particularly alkylbenzenes such as trimethylbenzene, may give rise to a very unpleasant “diesel-like” odour at concentrations of a few micrograms per litre.

### pH and corrosion

Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection (see the supporting document *Safe, Piped Water*; section 1.3). For effective disinfection with chlorine, the pH should preferably be less than 8; however, lower-pH water is likely to be corrosive. The pH of the water entering the distribution system must be controlled to minimize the corrosion of water mains and pipes in household water systems. Alkalinity and calcium management also contribute to the stability of water and control its aggressiveness to pipe and appliance. Failure to minimize corrosion can result in the contamination of drinking-water and in adverse effects on its taste and appearance. The optimum pH required will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is usually in the range 6.5–8. Extreme values of pH can result from accidental spills, treatment breakdowns and insufficiently cured cement mortar pipe linings or cement mortar linings applied when the alkalinity of the water is low. No health-based guideline value has been proposed for pH (see sections 8.5.1 and 12.100).

### Sodium

The taste threshold concentration of sodium in water depends on the associated anion and the temperature of the solution. At room temperature, the average taste thresh-

old for sodium is about 200 mg/litre. No health-based guideline value has been derived (see sections 8.5.1 and 12.108).

### Styrene

Styrene has a sweet odour, and reported odour thresholds for styrene in water range from 4 to 2600 µg/litre, depending on temperature. Styrene may therefore be detected in water at concentrations below its health-based guideline value (see sections 8.5.2 and 12.109).

### Sulfate

The presence of sulfate in drinking-water can cause noticeable taste, and very high levels might cause a laxative effect in unaccustomed consumers. Taste impairment varies with the nature of the associated cation; taste thresholds have been found to range from 250 mg/litre for sodium sulfate to 1000 mg/litre for calcium sulfate. It is generally considered that taste impairment is minimal at levels below 250 mg/litre. No health-based guideline value has been derived for sulfate (see sections 8.5.1 and 12.110).

### Synthetic detergents

In many countries, persistent types of anionic detergent have been replaced by others that are more easily biodegraded, and hence the levels found in water sources have decreased substantially. The concentration of detergents in drinking-water should not be allowed to reach levels giving rise to either foaming or taste problems. The presence of any detergent may indicate sanitary contamination of source water.

### Toluene

Toluene has a sweet, pungent, benzene-like odour. The reported taste threshold ranges from 40 to 120 µg/litre. The reported odour threshold for toluene in water ranges from 24 to 170 µg/litre. Toluene may therefore affect the acceptability of water at concentrations below its health-based guideline value (see sections 8.5.2 and 12.114).

### Total dissolved solids

The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/litre. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. No health-based guideline value for TDS has been proposed (see sections 8.5.1 and 12.115).

### Trichlorobenzenes

Odour thresholds of 10, 5–30 and 50 µg/litre have been reported for 1,2,3-, 1,2,4- and 1,3,5-trichlorobenzene, respectively. A taste and odour threshold concentration of

30 µg/litre has been reported for 1,2,4-trichlorobenzene. A health-based guideline value was not derived for trichlorobenzenes, although the health-based value that could be derived (see sections 8.5.2 and 12.117) exceeds the lowest reported odour threshold in water of 5 µg/litre.

### Turbidity

Turbidity in drinking-water is caused by particulate matter that may be present from source water as a consequence of inadequate filtration or from resuspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some groundwaters or sloughing of biofilm within the distribution system. The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances.

Particulates can protect microorganisms from the effects of disinfection and can stimulate bacterial growth. In all cases where water is disinfected, the turbidity must be low so that disinfection can be effective. The impact of turbidity on disinfection efficiency is discussed in more detail in section 4.1.

Turbidity is also an important operational parameter in process control and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration.

No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection, and changes in turbidity are an important process control parameter.

### Xylenes

Xylene concentrations in the range of 300 µg/litre produce a detectable taste and odour. The odour threshold for xylene isomers in water has been reported to range from 20 to 1800 µg/litre. The lowest odour threshold is well below the health-based guideline value derived for the compound (see sections 8.5.2 and 12.124).

### Zinc

Zinc imparts an undesirable astringent taste to water at a taste threshold concentration of about 4 mg/litre (as zinc sulfate). Water containing zinc at concentrations in excess of 3–5 mg/litre may appear opalescent and develop a greasy film on boiling. Although drinking-water seldom contains zinc at concentrations above 0.1 mg/litre, levels in tap water can be considerably higher because of the zinc used in older galvanized plumbing materials. No health-based guideline value has been proposed for zinc in drinking-water (see sections 8.5.4 and 12.125).

#### **10.1.3 Treatment of taste, odour and appearance problems**

The following water treatment techniques are generally effective in removing organic chemicals that cause tastes and odours:

- aeration (see section 8.4.6);
- activated carbon (GAC or PAC) (see section 8.4.8); and
- ozonation (see section 8.4.3).

Tastes and odours caused by disinfectants and DBPs are best controlled through careful operation of the disinfection process. In principle, they can be removed by activated carbon.

Manganese can be removed by chlorination followed by filtration. Techniques for removing hydrogen sulfide include aeration, GAC, filtration and oxidation. Ammonia can be removed by biological nitrification. Precipitation softening or cation exchange can reduce hardness. Other taste- and odour-causing inorganic chemicals (e.g., chloride and sulfate) are generally not amenable to treatment (see the supporting document *Chemical Safety of Drinking-water*; section 1.3).

## 10.2 Temperature

Cool water is generally more palatable than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature enhances the growth of microorganisms and may increase taste, odour, colour and corrosion problems.