

## 10. ACCEPTABILITY ASPECTS

### 10.1. Acceptability of Drinking-water

The most undesirable constituents of drinking-water are those capable of having a direct impact on public health. Guideline values have been developed for many of these.

To a large extent, consumers have no means of judging the safety of their drinking-water themselves, but their attitude towards their water supply and their 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, therefore, for consumers to regard with suspicion water that appears dirty or discolored 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. The supply of water that is aesthetically unsatisfactory will undermine the confidence of consumers, leading to complaints and possibly the use of water from sources that are less safe. It can also result in the use of bottled water, which is expensive and may be of poor quality, and home treatment devices, which are costly and some of which will not guarantee water safety if the incoming water is contaminated or the devices are not properly maintained.

The acceptability of drinking-water to consumers can be influenced by many different constituents; most of the substances for which health-based guideline values have been set, and which also affect the taste or odour of water, have been referred to already (see summaries for individual constituents). 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.

The concentration at which such constituents are objectionable to consumers is dependent on individual and local factors, including the quality of the water to which the community is accustomed and a variety of social, economic, and cultural considerations. It is not therefore appropriate to set Guideline Values directly on the basis of consumer acceptability either for substances which may be of concern for health or for those which are not directly relevant to health.

In the following summaries, 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 much higher levels, depending on individual and local circumstances.

Substances of health concern, whose aesthetic affects would normally lead to rejection of water at concentrations significantly lower than those of concern for health are not normally appropriate to regulate or monitor on a routine basis. In these circumstances, a health based summary statement and guideline value are derived in the usual way. In the summary statement, this is explained and information on aesthetic acceptability described. In the tables of guideline values, the health-based guideline value is designated (c) with a footnote explaining that whilst of health significance, water would normally be rejected by consumers for aesthetic reasons, at concentrations well below health guidelines and it would not normally be considered appropriate for monitoring as part of normal protocols. Monitoring, however, may be undertaken in response to consumer complaints.

## 10.2. Taste and odour

Taste and odour originate from natural inorganic and organic chemical contaminants and biological sources or processes (e.g., aquatic microorganisms), from contamination by synthetic chemicals, or as a by-product 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 malfunction during water treatment or distribution. The cause of tastes and odours should be investigated and the appropriate health authorities should be consulted, particularly if there is a sudden or substantial change. An unusual taste or odour might be an indication of the presence of potentially harmful substances.

The taste and odour of drinking-water should not be offensive to the consumer. However, there is an enormous variation in the taste and odour that are regarded as acceptable by different individuals and different communities. There is also significant variation between individuals in their ability to detect tastes and odours in drinking-water.

### 10.2.1. Biologically derived

There are a number of diverse organisms that may have no public health significance but which are undesirable because they produce taste and odour, for example the production of geosmin and 2-methylisoborneol at ~5-10 ng/L by actinomycetes and cyanobacteria. As well as being aesthetically objectionable, they indicate that water treatment and/or the state of maintenance and repair of the distribution system are insufficient.

### 10.2.2. Disinfectants and disinfection by-products

#### *Chlorine*

Most individuals are able to taste or smell chlorine or chloramine, its reaction product with ammonia, 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 risk of problems with acceptability. The taste threshold is below the health-based guideline concentration (see Chapter 8 summary statement).

#### *Monochloramine*

Monochloramine is increasingly used as a residual disinfectant for drinking-water distribution. Generation of monochloramine from the reaction of chlorine with ammonia requires care in order to prevent the formation of di- and trichloramine, which have lower odour thresholds than monochloramine and which can be a significant cause of consumer complaints.

***Chlorophenols***

Chlorophenols generally have very low organoleptic 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 undue risk to health (see chapter 8 - summary statement). However, on occasion microorganisms in distribution systems may methylate chlorophenols to produce chlorinated anisoles for which the odour threshold is considerably lower.

**10.2.3. Chemicals**

There are considerable uncertainties in data regarding taste and odour thresholds for chemical contaminants in drinking-water. The ability to detect taste and, particularly, odour will depend on many factors, not least of which is variation between individuals and previous recognition of the odour. In addition the quality of much taste and odour data in the literature is uncertain because there may be few details given of the way in which the figures were derived, such as the number of subjects and the structure of the test. The taste and odour thresholds given below can, therefore, only be regarded as approximate guides.

***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 chapter 8 – summary statement).

***Chloride***

High concentrations of chloride give an undesirable 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 consumers may become accustomed to low levels of chloride induced taste.

No health-based guideline value is proposed for chloride in drinking-water (see chapter 8 – summary statement).

***Copper***

The presence of copper in a water supply is usually due to the presence of copper piping and aggressive water within buildings. Concentrations in a particular property 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, it also imparts a colour and an undesirable bitter taste to water.

Although copper can give rise to taste problems, the taste should be acceptable at the health-based provisional guideline value (see chapter 8 – summary statement).

***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 summary statement) far exceed the lowest reported taste and odour thresholds for these compounds.

***Ethylbenzene***

Ethylbenzene has an aromatic odour. The reported odour threshold for ethylbenzene 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 chapter 8 - summary statement). The taste threshold ranges from 72 to 200 µg/litre.

***Hardness***

Hardness 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.

No health-based guideline value has been proposed for hardness (see chapter 8 – summary statement and Section 10.3).

***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 ground waters 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 chapter 8 – summary statement).

***Manganese***

At levels exceeding 0.1 mg/litre, manganese in water supplies causes an undesirable taste in beverages. Although concentrations below 0.1 mg/litre are usually acceptable to consumers, this may vary with local circumstances. The provisional health-based guideline value for manganese is 5 times higher than this acceptability threshold of 0.1 mg/litre (see chapter 8 – summary statement and Section 10.2).

***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. The health-based guideline value derived

for monochlorobenzene (see chapter 8 - summary statement) far exceeds the lowest reported taste and odour threshold in water.

### ***Dissolved oxygen***

The dissolved oxygen content of water is influenced by the source, raw water temperature, treatment, and any 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, the latter giving rise to odour problems. It can also cause an increase in the concentration of ferrous iron in solution with subsequent discolouration at the tap when the water is aerated.

No health-based guideline value has been recommended for dissolved oxygen.

### ***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 is no formal data, experience indicates that these may give rise to lower odour thresholds when several are present as a mixture. The BTEX chemicals are considered individually in this section as health based guideline values have been derived for these substances. However, a number of other hydrocarbons, particularly alkyl benzenes such as trimethylbenzene, may give rise to a very unpleasant 'diesel-like' odour at concentrations of a few micrograms per litre.

### ***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 threshold for sodium is about 200 mg/litre.

As no firm conclusions can be drawn regarding the health effects of sodium for the general population, although some persons with hypertension are salt sensitive, no health-based guideline value has been derived (see chapter 8 – summary statement).

### ***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 chapter 8 - summary statement).

### ***Sulfate***

The presence of sulfate in drinking-water can cause noticeable taste and very high levels might cause a laxative effect. 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 chapter 8 – summary statement).

### ***Synthetic detergents***

In many countries, the earlier, 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. New types of cationic, anionic, and non-ionic detergent have also

been introduced. 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 chapter 8 - summary statement).

### ***Total dissolved solids***

Total dissolved solids (TDS) can have an important effect on the taste of drinking-water. The palatability of water with a TDS level of less than 600 mg/litre is generally considered to be good; drinking-water becomes significantly unpalatable at TDS levels greater than 1200 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. Water with concentrations of TDS below 1000 mg/litre is usually acceptable to accustomed consumers but very undesirable to others, although acceptability may vary according to local circumstances.

No health-based guideline value for TDS has been proposed (see chapter 8 – summary statement).

### ***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. The health-based guideline value derived for total trichlorobenzenes (see chapter 8 - summary statement) exceeds the lowest reported odour threshold in water of 5 µg/litre.

### ***Xylenes***

Xylene concentrations in the range 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 chapter 8 summary statement).

### ***Zinc***

Zinc imparts an undesirable astringent taste to water. Tests indicate a taste threshold concentration of 4 mg/litre (as zinc sulfate). Water containing zinc at concentrations in excess of 5 mg/litre may appear opalescent and develop a greasy film on boiling, although these effects may also be noticeable at concentrations as low as 3 mg/litre. 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 chapter 8 – summary statement).

### 10.3. Appearance

#### 10.3.1. Chemicals

##### *Aluminium*

Aluminium occurs naturally but aluminium sulfate, and other aluminium salts, are widely used in drinking-water treatment as coagulants and this is the most common source of aluminium in drinking-water. The presence of aluminium at concentrations in excess of 0.1 mg/litre to 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 optimise treatment processes in order to minimise any residual aluminium entering supply. Under good operating conditions, concentrations of less than 0.1 mg/l aluminium are achievable in many circumstances.

Available evidence does not support the derivation of a health-based guideline value for aluminium in drinking-water (see chapter 8 – summary statement).

##### *Colour*

Drinking-water should ideally be colourless. The colour of 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 water supply should be investigated, particularly if a substantial change takes place.

Most people can detect colours above 15 TCU (true colour units) in a glass of water. Levels of colour below 15 TCU are usually acceptable to consumers, but acceptability may vary according to local circumstances. High colour could also indicate a high propensity to produce byproducts from disinfection processes.

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

##### *Hardness*

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 in 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 (see Protection and improvement of water quality).

No health-based guideline value is proposed for colour in drinking-water. (See also Section 10.2.3)

##### *Iron*

Anaerobic ground water 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. Iron concentrations in excess of 0.3 mg/litre can be acceptable to consumers in some circumstances.

No health-based guideline value is proposed for iron (see chapter 8 – summary statement).

### ***Manganese***

At levels exceeding 0.1 mg/litre, manganese in water supplies 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. 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. Although concentrations below 0.1 mg/litre are usually acceptable to consumers, this may vary with local circumstances. The provisional health-based guideline value for manganese is 5 times higher than this acceptability threshold of 0.1 mg/litre (see chapter 8 – summary statement see also Section 10.2).

### ***pH***

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. For effective disinfection with chlorine, the pH should preferably be less than 8 however lower pH water is likely 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. Failure to do so 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 chapter 8 – summary statement).

### ***Turbidity***

Turbidity in drinking-water is caused by particulate matter that may be present as a consequence of inadequate filtration treatment or from re-suspension of sediment in the distribution system. It may also be due to the presence of inorganic particulate matter in some ground waters.



High levels of organic turbidity 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 **Chapter 4** (see Protection and improvement of water quality).

Effective disinfection requires that turbidity is less than 1 NTU; ideally, median turbidity should be below 0.1 NTU.

The appearance of water with a turbidity of less than 5 NTU is usually acceptable to consumers, although this may vary with local circumstances. However, because of the possible screening of microorganisms, it is recommended that turbidity be kept as low as possible preferably less than 1 NTU leaving the treatment plant. Turbidity is also an important operational parameter and can indicate problems with treatment processes, particularly coagulation/sedimentation and filtration. No health-based guideline value for turbidity has been proposed.

### 10.3.2. Biologically derived

#### *Cyanobacteria*

Seasonal 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 and 2-methyl-isoborneol which have taste thresholds in drinking-water of a few nanograms per litre (see above).

#### *Iron bacteria*

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

#### *Animal life*

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

Animals may be present in water distribution systems because:

- They enter the distribution system with the incoming water, having passed through treatment processes or colonised parts of the treatment plant;
- They enter through defects in the integrity of the distribution system such as badly screening service reservoirs;
- They form breed populations within the distribution system.

The types of animal concerned can be considered, for control purposes, as belonging to two groups. Firstly, there are free-swimming organisms in the water itself or on water surfaces, such as the crustacea *Gammarus pulex* (freshwater shrimp), *Crangonyx pseudogracilis*, *Cyclops* spp. and *Chydorus sphaericus*. Secondly, there are other animals that either move along surfaces or are anchored to them (such as *Asellus aquaticus* (water louse), snails, *Dreissena polymorpha* (the zebra mussel) and other bivalve molluscs, and the bryozoan *Plumatella* sp.), or inhabit slimes (such as *Nais* spp., nematodes and the larvae of

chironomids) (1). In warm weather, slow sand filters can sometimes discharge the larvae of gnats (*Chironomus* and *Culex* spp.) into the water, if the top layer of the bed collapses, causing draw-down of unfiltered 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, and may reproduce within the supply. 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-water suppliers in temperate regions as an ‘aesthetic’ problem, either directly or through their association with discoloured water. In tropical and sub-tropical countries, there are species of aquatic animal that act as secondary hosts for parasites. For example, the small crustacean *Cyclops* is the intermediate host of *Dracunculus medinensis*, the Guinea worm (see section 8.2.4). However there is no evidence that guinea worm transmission occurs from piped supplies. However the presence of animals in drinking-water, especially if visible, justifiably raises customer concern about the quality of the water supply and should be excluded.

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

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

Bryozoan infestation can be treated with a shock dose of chlorine, maintained at 10 mg/litre for about 24 hours, followed by flushing. Permethrin treatment of water at an average dose of 0.01-0.02 mg/litre for 24-48 hours has been used to destroy *Asellus* and other Crustacea, but treated water must not be discharged into watercourses, as it is rapidly toxic to fish and other aquatic life at this concentration. The most effective procedure is to draw treated water into the main by opening hydrants downstream of the injection point. These are then closed, allowing sufficient contact time (ideally 24 hours) to paralyse the crustacea, after which the mains are cleared by flushing and swabbing. Persons using renal dialysis should not be supplied with permethrin-treated water, and those rearing fish should be warned not to replenish the culture tanks with mains water while it is being treated. The treated water can be safely discharged into sewers for treatment at sewage works.

## 10.4 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 (for example *Legionella* proliferates at temperatures between 25°C and 50°C) and may increase taste, odour, colour, and corrosion problems.