Chapter 18: Aesthetic considerations

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18.1 Introduction

This chapter provides information on the sources and occurrences of the aesthetic determinands discussed briefly in the *Drinking-water Standards for New Zealand 2005, revised 2008* (DWSNZ). Determinands with a Guideline Value (GV) are listed in Table 2.5 of the DWSNZ.

This chapter explains the methods used to derive the Guideline Values for the aesthetic determinands and provides detailed information on how to apply the DWSNZ to these determinands. All the aesthetic determinands with a GV included in the DWSNZ have been derived from the WHO Guidelines.

Information is given on the planning and implementation of monitoring programmes, and how and why to carry out discretionary monitoring.

Information is provided for some treatment processes for the removal of some of the more common taste and odour problems.

Some aesthetic determinands also have a MAV; in most cases the MAV has a lower concentration than the Guideline Value.

The individual aesthetic determinands are described in detail in the Datasheets in Volume 3. Datasheets have also been prepared for determinands that have been reported in scientific literature to have an aesthetic effect in drinking water.

The term Guideline Value has been used for aesthetic determinands. Because they tend to be subjective, only Guideline Values (or ranges for some determinands) are given, rather than Maximum Acceptable Values (MAVs). Guideline Values for aesthetic determinands are mostly based on taste, odour, and appearance.

Corrosion of metallic pipes and fittings can give rise to aesthetically unpleasing water, eg, zinc from galvanised steel and brass, iron from galvanised piping and steel fittings, and copper from copper tubing. In some cases, corrosion can result in a determinand exceeding its MAV (eg, lead and copper), therefore corrosion is discussed in Chapter 10: Chemical Compliance.

The Institute of Environment and Health (IEH 2014) selected for consideration all those substances reported as being involved in taste and odour incidents in a developed country, excluding those for which there was no evidence of UK production or import, as well as those already regulated to a limit value either lower than or close to the reported taste and odour threshold. Other prioritised substances were then categorised according to amounts used and their reported taste and odour threshold. This process gave a list of compounds from which substances formed during water treatment were excluded leaving 18 priority compounds. Eleven of the prioritised taste and odour compounds were found to be fuel additives. Added to this list were the two compounds most commonly associated with taste and odour problems arising from natural sources (geosmin and 2-MIB). Most of the specified substances are discussed in the individual datasheets. The project was undertaken by addressing a series of distinct but inter-related objectives:

Objective 1: Establish a list of substances of interest that have low taste and odour thresholds and could pose a similar problem to water sources as EDD and EMD

Objective 2: Identify the quantities of substances used and the industries that use them; with respect to primary anthropogenic substances, this involves identifying in detail the quantities of substances used and the industries that use them in Europe and, to the extent possible, refining these estimates to England and Wales or UK specific information

Objective 3: Determine the possible routes of entry into the water system

Objective 4: Estimate the likely concentrations of substances of interest found in raw and treated drinking water

> Objective 5: Produce a prioritised short list of substances based on the likelihood of exceeding taste and odour thresholds in treated drinking water in England and Wales that can be used to inform water company risk assessment, monitoring and management
>
> Objective 6: Final report and dissemination of research findings.

A study in Adelaide found that people who indicated they usually drank mains water with or without a point-of-use filter or rainwater showed greater acceptance of metropolitan and regional (River Murray sources) tap water over all others. Commercial spring water was the third most accepted, with regional groundwater the least accepted. Those who usually drank bottled water indicated they had the greatest acceptance for commercial spring water. This suggests that individuals prefer the water they are most used to drinking (Webber et al 2014).

DWI (2014) describes a number of major taste and odour incidents in the UK and elsewhere involving contamination of drinking water by substances released into the environment due to anthropogenic activities, highlighted the need for awareness of potential threats to inform the development of effective risk management practices. These are discussed in individual datasheets.

18.2 Aesthetic determinands

18.2.1 Overview of aesthetic determinands

General remarks

Because the DWSNZ deal only with determinands that have a demonstrated significance for public health, no MAVs have been set for determinands whose undesirable effects are only aesthetic. Drinking-water that complies with the DWSNZ is deemed potable or safe; safe water that also satisfies the Guideline Values is deemed wholesome, see Health Act, 69G: Interpretation. In the UK water supplies provided for cooking, drinking, food preparation, washing and to premises where it is used for food production must meet the wholesomeness requirements of their Regulations regardless of whether the water is supplied from the public piped supply system, tanker, bottle or other container (DWI 2017).

It is recommended that drinking-water supplies should be maintained below the Guideline Values (GVs) given for the aesthetic determinands in Table 2.5 of the DWSNZ. Otherwise the water may be unattractive to consumers who could consequently change to a more attractive, but less safe, alternative.

Because of the link the mind makes between the aesthetic properties of a water and its safety, its appearance, taste and smell are very important to consumers. Most consumer complaints are received because of the aesthetic properties of water, not because trace levels of chemical contaminants have been noticed. A water will most closely meet consumer expectations when it is clear, colourless, odourless, cool and contains no unpleasant taste. This does not mean that a water should not contain any dissolved substances; a very high purity water has an insipid taste and is usually corrosive.

People are naturally wary of any drinking-water that smells, tastes, or looks cloudy or coloured. Although waters that are aesthetically unpleasant are not necessarily unsafe to drink, those characteristics of the water that are apparent to the senses are usually the only guide the public has to the microbiological quality of the water. Conversely, a clear, tasteless, odourless water is not guaranteed to be safe.

Awareness of the importance of minerals and other beneficial constituents in drinking-water has existed for thousands of years, being mentioned in the Vedas of ancient India. In the book Rig Veda, the properties of good drinking-water were described as follows:

> Sheetham (cold to touch), Sushihi (clean), Sivam (should have nutritive value, requisite minerals and trace elements), Istham (transparent), Vimalam lahu Shadgunam (its acid base balance should be within normal limits) (WHO 2005).

WHO (2005) also discusses some negative aspects of drinking deionised, distilled or reverse osmosis water, due to their tastelessness, and loss of essential minerals: mainly calcium and magnesium. This is discussed briefly in Chapter 10: Chemical Compliance, section 10.2.2, and in the respective datasheets.

In a UK survey 5 of the 17 responding Water Companies reported no issues associated with taste and odour. For the 12 companies reporting taste and odour problems, the majority were associated with biologically derived compounds (specifically geosmin and/or methylisoborneol) (7/12), or phenols (6/12) and chlorine (4/12). A number of other taste and odour compounds were identified less frequently (named in the report) (IEH 2014).

Turbidity

The colour and turbidity of drinking-water affect its appearance. Turbidity also influences the safety of the water because particulate matter in the water can make the disinfection process less effective by shielding cells from the disinfectant. Turbidity may arise from clay and silt particles not removed from the raw water, or from the precipitation of insoluble metal compounds such as those of iron and manganese, or aluminium from an inefficient treatment plant using alum or PAC coagulation. Sometimes the iron and manganese can be associated with micro-organisms such as the loosely defined group of iron bacteria; this is usually more common in groundwater systems (see Chapter 3: Source Waters, section 3.2.3.4). Turbidity can also be introduced into the water from the scouring effect in the mains, or from sediments flushing out of service reservoirs.

A common consumer complaint of turbid water can occur after maintenance work on nearby water mains or general pressure problems that causes very fine air bubbles to give the water a milky appearance. This condition can be confirmed by filling a glass and watching the water clear slowly, beginning from the bottom of the glass.

Colour

It is necessary to distinguish between true colour and apparent colour.

True colour arises predominantly from dissolved natural organic matter, mainly humic material (fulvic acids tend to be colourless) formed as a result of the degradation of vegetation. It is the colour the eye would see if there were no turbidity in the water.

If the water is turbid, it affects the colour as seen by the eye, which perceives a different colour, called the apparent colour. When colour is measured routinely in the laboratory it is usually the apparent colour. When measuring apparent colour the analyst attempts to match the colour on the Hazen disc with the colour of the water, including the particulate matter. When the turbidity is high, this colour match can be very difficult and quite misleading. Many people reading colour in a turbid sample report more colour than they should.

A true colour value can be obtained by removal of turbidity before making the colour measurement. Filtration through a 0.45 μm membrane filter or through a Whatman GF/C (or equivalent) filter may provide an acceptable means of doing this, but checks need to be made that the filter material is not also removing true colour from the water, or adding to it. Due to the fairly subjective nature of colour measurement, sometimes there is an advantage in measuring UV absorption at 254 nm; this is a much more reliable test.

Because of the nature of the material that usually gives rise to colour, the presence of colour may affect the taste of the water as well as its appearance.

Standard Methods (APHA 2005, method 2120 B) states that 1 colour unit (CU) = 1 Hazen unit = 1 Pt/Co unit. When reporting colour readings, it is important to state whether apparent or true colour was measured. True and apparent colour is usually indistinguishable in drinking-water samples that are free from corrosion products or that have low turbidity.

The Australian Water Quality Guidelines describe the public’s perception of colour:

> A true colour of 15 Hazen can be detected in a glass of water, and a true colour of 5 Hazen can be seen in larger volumes of water, for instance in a white bath. Few people can detect a true colour level of 3 Hazen, and a true colour of up to 25 Hazen would probably be accepted by most people provided the turbidity was low.

Also, see datasheets for colour and UV absorbance (or UVT).

Temperature

A number of other factors may affect the taste of the water. The most universal of these is temperature. The taste of a water is generally more acceptable when it is cool rather than when it is warm. Generally consumers become increasingly aware of taste as the water warms. Most odorous compounds are volatile so they will become more noticeable as the water warms.

Water can become noticeably warm if drawn from mains or service pipes that are on or near the surface, or from above-ground service reservoirs or tanks. Warm water in the distribution system also encourages the growth of micro-organisms, and accelerates the decomposition of free available chlorine (FAC); therefore pipes need to be buried. Pipes may need to be at least a metre deep in very cold areas to avoid problems related to freezing.

The temperature of surface waters in New Zealand can range quite widely, generally:

- in the summer, as high as 16–25°C in the north, 10–25°C in the south
- in the winter, as low as 8–12°C in the north, 5–10°C in the south.

The temperature of groundwater drawn from near the surface can vary seasonally, but deeper groundwater has a near-constant temperature that is usually close to the mean annual air temperature. Waters drawn from depths greater than about 50 m increase in temperature at about 0.6°C per 30 m increase in depth due to geothermal heat. Any groundwater with a higher than expected temperature may contain water from a hydrothermal source, possibly leading to elevated levels of boron and other geothermal contaminants, such as arsenic, mercury, fluoride, boron and lithium. Bore waters that exhibit a seasonal temperature pattern are not likely to be secure.

Water from unburied service reservoirs with a long detention time can reach 30°C in the summer. Inadequately buried dark coloured service pipes to houses can produce water that is almost too hot to drink!

Water temperatures, particularly of surface waters, can also have an indirect effect on the aesthetic quality of the water by stimulating algal blooms. The seasonal appearance of algae in rivers, lakes or reservoirs can cause tastes due to the exudates released by the organisms.

The WHO (2005) recommends maintaining the water temperature below 20°C to reduce the risk of legionellosis. *Legionella* organisms have been reported growing in hot water systems up to about 60°C. Temperature control of hot water cylinders as required by the New Zealand Building Act/Building Code should control the organism in buildings. See datasheet.

pH

High pH waters (alkaline) have an unpleasant taste, and the high pH can also impart a soapy feel to the water. Low pH levels may influence the taste of the water indirectly by the release of metal corrosion products. Metallic tastes, whether from corrosion products or natural concentrations of metals, iron for example, can be unpleasant. The pH of slow moving water can exceed 10 in some supplies in pipes with concrete linings or made with cementitious material. The same is true of rainwaters stored in concrete tanks. The effect lessens with time as $Ca(OH)_2$ (lime) is leached from the surface of the concrete, or if organic matter in the water coats the surface, although this may take years. Fish placed in high pH water can be affected adversely.

Risk management issues related to pH are discussed in the MoH Public Health Risk Management Plan Guide PHRMP Ref: P8.1: Treatment Processes – pH Adjustment.

Inorganic compounds

Inorganic compounds in high concentrations, such as sodium chloride (salt) or sodium bicarbonate (soda springs may contain high concentrations) which lead to high levels of total dissolved solids, can also influence the taste of water. Very high concentrations of sulphate can cause a laxative effect in unaccustomed consumers, especially when magnesium concentrations in the water are also high.

Water constituents such as calcium carbonate or silica can lead to scale formation or reduce soap lathering, and may also introduce particulate matter into the water, reduce flows through pipes, and lead to the premature burnout of heating elements.

A high chloride and sulphate content (compared with alkalinity) can increase corrosion rates. Corroding fittings can impart a metallic taste to water. Hard or mineralised waters usually require special treatment if used in boilers. However, some people find the high mineral content of some bottled waters to be attractive.

See WHO (2005) and Chapter 10: Chemical Compliance, section 10.2.2 for a discussion on some possible health aspects related to drinking water with low levels of inorganic determinands, particularly calcium and magnesium.

Organic compounds

A wide range of organic substances may influence taste and odour. These include organic compounds that are natural in origin, synthetic compounds, chemicals used in industry that have found their way into the source water, tastes and odours that are derived from organisms living in the raw water or stored treated water, and organic compounds formed as a consequence of reactions between natural (or other) organic matter and disinfectants during treatment.

The AWWA (USA) states that earthy musty odours may usually be attributed to the source water, and their intensity may increase with warmer weather. Customer complaints about this type of odour are second in number only to disinfection-related complaints. The most common source for these odours is geosmin (produced by *Actinomycetes*, *Streptomyces*, *Nocardia*, *Micromonospora*, *Microbispora*, *Oscillatoria*, *Apahizomenon*, and *Phormidium* bacteria); and 2-methylisoborneol (MIB), produced by *Actinomycetes*, *Oscillatoria*, *Phormidium*, *Uroglena americana* and blue-green algae (cyanobacteria). Fishy odours may come from algal products (including n-hexanal, n-heptanal, trimethylamine and trans, trans-2,4-decadienal). Related odours are described as swampy (from bacteria producing dimethyl trisulfide or aldehydes), grassy (from algal production of cis-3-hexen-1-ol), musty (from MIB or 2,4,6-trichloroanisole), or tobacco-like (from production of β-cyclocitral).

Davies et al (2004) report their studies of some odours resulting from lakes and reservoirs in Canada; they list some odour thresholds. Earthy odours were more prevalent in reservoirs and lakes with higher total phosphorus (TP), whereas decomposing vegetation and green vegetation + grassy odours almost exclusively occurred when TP was lower (<0.013 mg P/L).

A preliminary study by Webber et al in Australia indicated that drinking water containing greater than 10 ng/L geosmin or 2-MIB will result in a reduction in acceptance.

Cis-3-hexen-1-ol, which has been found to contribute a grassy odour to water, is thought to arise from green algae (EA 1998, 2004). This chemical is approved as a flavouring agent so presents no health concerns in water. The chemical (CAS No. 928-96-1) is also called (Z)-hex-3-enol and 'green leaf alcohol'. See individual datasheets for further details.

Refer also to colour, in this chapter. Some organic chemicals also leach from plumbing materials, see Chapter 16.2.6: Permeation and leaching.

Risk management issues related to the removal of organic compounds are discussed in the MoH Public Health Risk Management Plan Guide PHRMP Ref: P8.4: Treatment Processes – Trace Organics Removal.

WQRA (2010) reports that a survey of 37 drinking water providers in Australia, representing 5 million customers, found that 78% of the providers had experienced problems with earthy/musty odours and half had not positively identified the problem compounds and were not carrying out routine chemical analysis. Interestingly, only five respondents reported a definite link between algal numbers and T&Os, indicating a need for further investigation. Their study found that loss processes such as biodegradation and volatilisation have a major effect upon the concentration of T&Os in a reservoir. Biodegradation was found to be temperature dependent with optimum rates occurring at 20–25°C. Biodegradation followed a first-order reaction rate and based upon this the half-life of geosmin was approximately 1 day at 20°C. This means that it would take approximately 24 hours for geosmin to reach 50% of its original concentration through biodegradation alone. Volatilisation was also found to be a significant loss factor with the rate directly related to wind speed, whereas photodegradation is not likely to be an important loss mechanism in natural water. The project incorporated all of these processes into a conceptual and mass balance model.

Hydrogen sulphide

Hydrogen sulphide can be smelt in some groundwaters (anoxic, and usually deep), often at concentrations below the analytical detection limit of commonly used tests.

Chlorine

Most individuals are able to taste or smell chlorine in drinking-water at concentrations well below the MAV of 5 mg/L. Many people can detect the odour of chlorine at around 0.2 mg/L and the taste at around 0.4 mg/L, particularly if there are any off-flavours due to chlorine reacting with organic matter. At a free available chlorine (FAC) concentration of between 0.6 and 1.0 mg/L, there is an increasing likelihood that some consumers may object to the taste or odour of FAC. However, some people occasionally complain when they cannot smell chlorine in their drinking-water because they think it has not been disinfected adequately.

A preliminary study by Webber et al in Australia indicated that chlorine taste and odour acceptance decreased above 1 mg/L but retained a volunteer rating of 'acceptable' for all samples in the range tested (maximum 3 mg/L). A statistically significant decrease in acceptance was found between 0 mg/L and 1 mg/L however drinking water at 0 mg/L is unusual as residual chlorine is required throughout the distribution systems.

Chloramines

Monochloramine is not objectionable at concentrations as high as 5 mg/L. It can cause taste and odour problems when in conjunction with FAC, and with some organic substances in the water or associated with plumbing materials. Dichloramine and trichloramine should not occur in drinking-water; both can cause taste and odour complaints. For further discussion, refer to Chapter 15: Treatment Processes, Disinfection, section 15.5.2.

Other tastes and odours

The topic of tastes and odours is rather subjective. What constitutes a taste or odour in drinking-water varies widely amongst people. It can also vary for the individual, depending on mood, motivation, expectation, familiarity and the level of confidence they have with their water supply or supplier.

Some reported tastes are actually odours; if a glass of water is raised to the mouth while the drinker is not breathing in, the sensation may not be noticed until the water is in the mouth.

Drinking-waters produced by distillation, deionisation or reverse osmosis are often described as tasting flat, or being tasteless.

Theoretically, taste refers only to the sensations of bitter, sweet, salty and sour. However, when attempting to describe the taste of water, people actually record flavour, which is an overall effect. Some complaints are difficult to describe other than by saying the water has an unpleasant drying sensation on the tongue and palate, often after swallowing. Standard Methods (APHA 2005) has a section on taste and odour test panels: Methods 2150, 2160 and 2170.

Wildlife

The public usually does not like to see wildlife in their drinking-water. Small numbers of invertebrates may pass through the water treatment process where the barriers to particulate matter are not completely effective and then colonise the distribution system. Their motility (ability to move) may enable them and their larvae to penetrate filters at the treatment plant, and through vents on storage reservoirs. The commonest examples in New Zealand are probably midge and mosquito larvae, nematodes and visible colonial algae such as *Volvox*. Slow sand filters have been reported to produce more organisms than the more traditional treatment processes used in New Zealand. Wildlife can also enter the system through service reservoirs, mains laying and repair, and in roof tanks.

Other comments

Determinands affecting the aesthetic quality of the water can also be linked to other problems related to the use of the water in the home or industry. Some of these problems may have an economic impact. The possibility of corrosion leading to concentrations of metals high enough to cause tastes has been noted above, but the dissolution of pipework, plumbing fittings and hot water cylinders also has economic implications for consumers; a common cause is due to carbon dioxide in groundwater.

Water quality complaints/comments from consumers should be followed up because they often assist in solving other problems, eg, petrol spills. Following up a complaint of a sulphide smell in a surface water public water supply led to the discovery that the house was not even on the town supply, but fed from a bore!

The range over which the concentration of a particular determinand is acceptable may vary from individual to individual, and community to community, and may depend on the concentration of other determinands in the water. The determinands with Guideline Values listed in the DWSNZ are a guide to what may be acceptable to consumers over an extended period. However, problems may occur at higher or lower values according to local circumstances. Consumer complaints may arise from determinands without a GV. Consultation with the community offers a mechanism by which the balance between water quality and cost to the community can be determined.

18.2.2 Rationale for the aesthetic guideline values

While most aesthetic determinands in drinking-water do not have a direct influence on public health at or near their GV, they are largely responsible for determining whether people will drink the water. This decision is usually based on smell, taste and appearance.

The Guideline Values (GVs) for aesthetic determinands given in the DWSNZ are largely based on the World Health Organization (WHO) document *Guidelines for Drinking-water Quality, 2004* and subsequent editions. The WHO GVs were developed to be acceptable internationally. New Zealand being a developed country, it was appropriate to adopt some slightly lower GVs than appear in WHO (2004). These Guideline Values should ensure that drinking-water is aesthetically pleasing and will not cause corrosion or physical problems in the reticulation or domestic plumbing.

The GVs are not absolute values, but have been derived from the consideration of a number of factors. Exceeding the aesthetic GVs for a short period will not necessarily render the water unacceptable. Feedback from the public should provide guidance as to what the customers consider to be acceptable. However, unless the public has already experienced unsatisfactory water, their opinion may not be sufficiently reliable to use as guidance when planning a new scheme or modifications.

Water supply authorities should maintain a register of complaints and enquiries relating to water quality (refer to Chapter 2: Management of Community Supplies and Chapter 16: The Distribution System). Preferably this will involve establishing a team that has been trained in handling consumer complaints. Procedures should be formalised in the WSP or other appropriate documentation. A standard questionnaire provides a consistent approach when interviewing complainants.

Further details on the levels of aesthetic determinands acceptable in water supplies are given in the individual Datasheets in Volume 3. The factors considered when deriving the Guideline Values include:

- taste and odour thresholds, ie, the smallest concentration or amount that would be just detected by smell or taste
- the smallest concentration or amount that would just be visible in a glass of water
- the smallest concentration or amount that would produce noticeable stains on laundry or porcelain
- the minimisation of corrosion or encrustation of pipes or fittings.

Several determinands without an aesthetic GV have been reported to give rise to consumer complaints. Datasheets have been prepared for some of these.

18.3 Water treatment for the removal of aesthetic determinands

Point-of-entry (POE) and point-of-use (POU) systems designed for the removal of aesthetic determinands are covered, for example, by NSF/ANSI 42-2005e. Determinands included are chloramines, chlorine, hydrogen sulphide, iron, manganese, zinc, particulates, and pH adjustment. NSF/ANSI 58-2006 *Reverse Osmosis Drinking Water Treatment Systems* is designated as an ANSI standard for point-of-use units. Tastes and odours can also be addressed by using these systems. POE and POU systems are discussed further in Chapter 19.

Ammonia

A groundwater with say >2 mg/L ammonia at a pH of say 9 may result in enough ammonia gas to be expelled when running the tap for some people to notice:

$$NH_4^+ + OH^- \rightarrow NH_3 \text{ (gas)} + H_2O$$

Ammonia can be removed by breakpoint chlorination, refer to Chapter 15: Treatment Processes, Disinfection, section 15.5.1. This avoids the formation of chloramines, but requires a high dose, theoretically 7.6 parts of chlorine per part of ammonia. The ratio may vary depending on the pH and temperature of the water, and even the mixing efficiency. The process can be rather expensive once the ammonia concentration exceeds say 0.5 mg/L.

Chlorine dioxide does not react with ammonia.

Carbon dioxide (CO_2)

Carbon dioxide is usually removed from groundwater (usually non-secure bores) to reduce or eliminate corrosion of metallic pipes, pumps and fittings, and dissolution of concrete.

It is removed by aeration, or by chemical reaction with calcium hydroxide (hydrated lime) or sodium hydroxide (caustic soda).

Removal of carbon dioxide is discussed in Chapter 12: Treatment Processes, Pretreatment, section 12.2.1.

Chlorine

If there are general taste and odour problems at a chlorine concentration less than approximately 0.5 mg/L, they may be a result of interactions between chlorine and nitrogenous substances, or traces of phenolic substances naturally occurring in the water. Surface waters containing ammonia often also contain traces of amino acids and other nitrogenous compounds that may react with FAC to cause chlorinous tastes and odours at quite low levels of measured FAC. When serious taste and odour problems develop, activated carbon dosage may be needed to remove these at the treatment plant prior to chlorination.

Chlorination of water containing ammonia (usually bore water) can produce chloramines; dichloramine and trichloramine theoretically can be produced if the pH is very low (under 6). Although the pH of the water supply may be above 7, a high chlorine dose into a lightly buffered water may lower the pH to under 6 in localised areas, especially if mixing is poor. Improved mixing, breakpoint chlorination, or simply a higher dose, may overcome these problems. In the absence of any complications such as FAC or dichloramines also being present, monochloramine should not impart a noticeable taste or odour at concentrations normally found in the distribution system (say 0.4–2.0 mg/L). The greatest problems with chloramine formation from ammonia are likely to occur at low pH and high chlorine concentrations, but not high enough to achieve destruction of the chloramines. These situations favour the formation of the more highly chlorinated and more odorous chloramines, dichloramine and trichloramine.

Some taste or odour problems can arise if the chlorine dosing system allows areas of low chlorine concentration to occur, where there may not be instantaneous reaction with organic matter, ie, breakpoint chlorination does not occur, allowing intermediate products to exist in the water.

Localised problems can result from an interaction of FAC with coatings or additives used in or on concrete or plastic piping, etc. Some particularly nasty tastes have been experienced when the water has been in contact with a fire hose. Rubber and plastic hoses used to fill drinking water tanks on ships, coaches, caravans, trains, etc may give rise to taste and/or odour problems, as can hoses used to fill drink-vending machines (EA 1998). All materials used in the water supply should be suitable for use in drinking-water. A simple test routine was explained by Ogilvie (1986). See AS/NZS 4020 (2002) for some information about the testing of products for use in contact with drinking-water. Micro-organisms in the biofilm (slime) on pipe surfaces can also interact with FAC, sometimes causing tastes or odours.

Occasionally some individuals (and aquarium fish) appear to have a very strong objection to chlorine in the water (or whisky!) they are drinking or swimming in. Water that has been in sunlight for some time (several hours) will usually show a large drop in the FAC level. Boiling the water will also reduce the chlorine concentration, and water from the hot tap usually contains very little chlorine. Chlorine can also be removed using point-of-use activated carbon filters; however, these can grow large numbers of micro-organisms so the supplier’s instructions must be followed; see Chapter 19: Small, Individual and Roof Water Supplies, note 1 to Table 19.2 in section 19.2.4.

Further information on chlorination and chloramination appears in Chapter 15: Treatment Processes, Disinfection, section 15.5.

Colour and turbidity

Generally, colour due to natural organic matter (predominantly humic, and to a lesser extent, fulvic material) is removed by chemical coagulation. Chemical oxidation by chlorine, chlorine dioxide or ozone can also reduce colour, but the extent to which this is achieved depends on the oxidant, the nature of the organic matter, and the treatment conditions. An undesirable consequence of reducing colour in this way may be the formation of disinfection by-products.

Turbidity is removed by chemical coagulation followed by sand filtration, or by direct filtration techniques such as diatomaceous earth, cartridge filters or membrane filtration.

These treatment processes are described in Chapters 13: Coagulation with Filtration, Chapter 14: Filtration, and Chapter 15: Disinfection.

Hardness (calcium and perhaps magnesium)

Calcium and magnesium are the main components of water hardness. Hard water can cause calcium carbonate to deposit in pipes, hot water cylinders, boilers, and over kettle elements. In the extreme, it can be tasted. Hard water requires a lot more soap to be used to develop a lather. Surface waters in New Zealand are generally soft because the water has not been in contact with minerals long enough to dissolve large quantities of calcium or magnesium. Groundwaters, on the other hand, that have been in contact with calcium carbonate-containing rocks, such as limestone and marble, are likely to be hard to some degree.

New Zealand's waters are generally softer than those found overseas. More than 90 percent of water supply zones in New Zealand receive water that, according to the hardness scale used by the American Water Works Association, is classified as soft (hardness 0–75 mg/L as $CaCO_3$). As at 2005, no town water supplies in New Zealand are softened regularly.

Calcium is usually the main contributor to hardness, so is usually the substance targeted in the water softening process. Softening can be carried out by ion exchange or the lime process.

Ion exchange (WHO 2004) is a process in which ions of like charge are exchanged between the water phase and the solid resin phase. Water softening can be achieved by cation exchange. Water is passed through a bed of cationic resin, and the calcium ions and magnesium ions in the water are replaced by sodium ions. When the ion exchange resin is exhausted (ie, the sodium ions are depleted), it is regenerated using a solution of sodium chloride.

The process of dealkalisation can also soften water. Water is passed through a bed of weakly acidic resin, and the calcium and magnesium ions are replaced by hydrogen ions. The hydrogen ions react with the carbonate and bicarbonate ions to produce carbon dioxide. The hardness of the water is thus reduced without any increase in sodium levels.

Some care is needed in the use softening by ion exchange, as the very efficient stripping of calcium and magnesium from the water can result in water that is more corrosive than it was before treatment.

An ion exchange plant normally consists of two or more resin beds contained in pressure shells with appropriate pumps, pipework and ancillary equipment for regeneration. The pressure shells are typically up to 4 m in diameter, containing 0.6–1.5 m depth of resin.

Risk management issues related to softening are discussed in the MoH Public Health Risk Management Plan Guide PHRMP Ref: P8.3 Treatment Processes – Softening.

Traditional water softening and softening by ion exchange are discussed a little more fully in Chapter 13: Coagulation Processes, section 13.6. NSF/ANSI 44-2004 *Residential Cation Exchange Water Softeners* is designated as an ANSI standard.

Hydrogen sulphide (H_2S)

H_2S can be found in otherwise quite good quality groundwater. It is formed when soil bacteria reduce sulphate ions in the water percolating through the soil. Groundwater containing H_2S would usually be expected to be anaerobic.

The Guideline Value is 0.05 mg/L in water but some people can smell it at as low as about 0.1 µg/L (0.0001 mg/L). It is readily displaced into the air where it can be detected at as low as 0.8 $\mu g/m^3$.

If the groundwater is aerated the H_2S is usually dispelled quite rapidly (unless the pH is high, say above pH 8), but after aeration the water may require repumping.

To avoid the costs of repumping the H_2S can be oxidised using a low dose of chlorine, with the dose being used for disinfection usually being adequate. Chlorine should only be used if the H_2S concentration is low, otherwise the production of elemental sulphur or polysulphides may noticeably increase the turbidity. The amount of chlorine needed depends on various factors such as pH and temperature, (and probably most importantly) on the accuracy of the sample collection and H_2S testing procedure (which is very difficult). Generally it is best to find the required chlorine dose by trial and error. Two of the more commonly proposed reactions (which are rapid) are:

at pH around 8 or more: $Cl_2 + H_2S \rightarrow 2HCl + S$

at pH nearer 7: $4Cl_2 + H_2S + 4H_2O \rightarrow 8HCl + H_2SO_4$

Surface water supplies should not produce H_2S complaints, so if H_2S is found at a consumer's tap, there must be a serious problem in the distribution system or consumer's plumbing.

Iron

Iron can stain porcelain and clothing. It also builds up on the inside of watermains where it can shield micro-organisms from residual disinfectants. It can build up forming slimes and encrustations that can break off during flow reversal or velocity changes, causing widespread complaints of dirty water.

Iron is usually only a problem in groundwater and spring supplies, unless it is dissolved from iron pipes, such as cast iron or galvanised iron after the galvanising has been removed, by corrosive water. Some groundwaters containing iron can appear to be clear when leaving the bore, but after aeration, it can change to an orange/brown colour due to oxidation of soluble ferrous iron (II) to insoluble ferric iron (III).

Iron also can occur in lakes and reservoirs, particularly during summer and autumn when the water body stratifies and the bottom waters (in the hypolimnion) become anaerobic, in which conditions iron is reduced to the soluble ferrous form. The iron content in the bottom water can exceed 10 mg/L Fe. The problem can be reduced by artificial aeration, or by abstracting through a valve at a higher depth where the iron concentration is manageable. Reservoir and lake waters that produce high concentrations of iron usually undergo chemical coagulation, which is described in Chapter 13: Treatment Processes, Coagulation. Provided the raw water receives sufficient aeration so that the ferrous form is oxidised to ferric, coagulation is usually effective at removing the iron.

Risk management issues related to reservoir destratification are discussed in the MoH Public Health Risk Management Plan Guide PHRMP Ref: P4.2 Pre-treatment Processes – Destratification.

Groundwater does not usually require colour or turbidity removal, as long as the bore has been well developed, so if iron is greater than about 0.2 mg/L as Fe (the Guideline Value), it will require some other form of treatment. The first step is to ensure that the raw water is fully aerated. Sometimes that is enough; the iron content can be so high that, when oxidised, it forms a floc that settles in a clarifier and the small amount remaining is removed by filtration, see Chapter 12: Treatment Processes, Pretreatment, section 12.2.

In some waters the iron is more difficult to remove, often because it forms complexes with natural organic matter that are less easily oxidised. For satisfactory oxidation, these waters may require pH elevation, sometimes to higher than pH 9, depending on the nature of organic matter. After filtration this water will probably need pH correction.

An alternative is to oxidise the ferrous iron with chlorine, chlorine dioxide, ozone or potassium permanganate. The efficacy of chlorine and chlorine dioxide treatment increases with pH. Ozone is more efficacious that the other oxidants when dealing with complexed iron (see further discussion below). Care is needed with potassium permanganate to avoid overdosing, which will cause complaints about the aesthetic properties of the water.

The presence of manganese on the surface of filter medium particles acts as a catalyst for the oxidation of iron. Such a coating can result from the oxidation of naturally occurring manganese in the water, the use of potassium permanganate, or the use of greensand filters.

Manganese

The source of manganese and its treatment options are similar to iron (see above) but it is usually more difficult to deal with, and causes aesthetic problems at lower concentrations. Concentrations of manganese as low as 0.04 mg/L Mn in water in the distribution system can cause periodic staining or discoloration problems, particularly after disturbances in the distribution system. Concrete-lined mains and fibrolite pipes have a high pH at the water/pipe surface interface, so even water with a low manganese content can deposit manganese on the surface.

Soluble manganous manganese (valence 2) frequently exceeds 1 mg/L as Mn in the bottom waters of lakes and reservoirs (hypolimnetic water), which is higher than the MAV (0.4 mg/L). See Chapter 13: Treatment Processes, Coagulation for a discussion on chemical coagulation.

Generally it will need aeration together with chemical oxidation and pH elevation, followed by filtration, in order to achieve satisfactory removal. If the chlorine dose required is too high (ie, requires some subsequent dechlorination) chlorine dioxide, potassium permanganate or ozone may be viable alternatives for oxidising the manganese to the insoluble manganic (valence 4) form. Some stubborn waters may require catalytic filter sand (see the comment regarding the catalytic action of manganese in the section on iron).

The oxidation rate of manganese (II) can be rather slow, so secondary filtration may be useful (and preferable to it precipitating in the distribution system), see Chapter 13, section 13.8.

Iron and manganese removal using ozone

Ozone will oxidise iron and manganese, converting the soluble ferrous iron (Fe^{II}) to the insoluble ferric iron (Fe^{III}), and Mn^{II} to Mn^{IV}.

The dose of ozone required to oxidise 1 mg iron is 0.43 mg. Adding excess ozone has no effect on the oxidation of iron.

There are two possible oxidation reactions for manganese:

$$O_3 + Mn^{2+} + 2H_2O \leftrightarrow MnO_2 + O_2 + 2H^+$$

$$5O_3 + 2Mn^{2+} + 3H_2O \leftrightarrow 5O_2 + 2MnO_4^- + 6H^+$$

The required ozone dose for oxidation to the insoluble Mn^{IV} is 0.88 mg for 1 mg manganese.

The required ozone dose for oxidation to the soluble Mn^{VII} is 2.18 mg for 1 mg manganese.

The production of Mn^{IV} or Mn^{VII} will depend on the ratio of ozone to manganese employed. If Mn^{VII} is produced, it will have to be reduced to Mn^{IV} prior to removal by filtration. This can be achieved by filtering through granular activated carbon filters.

The pH for iron removal using ozone is in the range 6–9; however manganese removal is best achieved at a pH of around 8. Consideration should be given for control of the pH upstream and downstream of the filters, as it is possible to dissolve precipitated and filtered manganese, should the pH be allowed to drop.

Risk management issues related to iron and manganese removal are discussed in the MoH Public Health Risk Management Plan Guide PHRMP Ref: P8.2: Treatment Processes – Iron and Manganese Removal.

Tastes and odours (except hydrogen sulphide)

Other than sulphide, the cause of taste and odour problems is not usually identified in terms of specific determinands. In New Zealand, most sporadic or seasonal taste and odour events are related to biological activity in the river, lake or reservoir source water.

Many chemicals have been identified as the cause of tastes and odours. Those with a biological origin are usually difficult and/or expensive to analyse, and their threshold concentrations are not well documented. They include geosmin (trans-dimethyl-trans-9-decalol), 2-methyl isoborneol (MIB), 2-isopropyl-3-methoxypyrazine (similar to MIB), 2-isobutyl-3-methoxypyrazine, cadin-4-ene-1-ol and 2,3,6-trichloroanisole; these have been reported to arise from bacteria in the actinomycete group; AWWA (2004) and EA (1998 and 2004) discuss biology, ecology, identification and control strategies.

The commoner chemicals that cause tastes and odours, usually with an industrial origin, are included in Table 2.5 of the DWSNZ. Their Guideline Values are based on the WHO Guidelines, and are discussed in the Datasheets.

EA (1998) has copied an excellent *Taste and Odour Wheel* from an American Water Works Association Research Foundation report by Suffet et al (1995), titled *Advances in Taste and Odour Treatment and Control*.

The commonest and most reliable form of treatment is to dose with activated carbon. The process is quite expensive so for temporary dosage, powdered activated carbon (PAC) is preferred. The type of PAC and its dose can only be found by trial and error.

It is used in response to sniffing the raw water or to the public reacting to unpleasant tastes or odours. Some people have a poor sense of smell so those conducting sniff tests should be screened. Many chemicals that contribute to odour in water are volatile and are therefore more pronounced in warm water. Often, the public will be more aware of the odour when in the shower than when drinking the water. A useful device for identifying when the raw water is smelly is to atomise it at 35–40°C into a large glass jar or bottle, with the tester sniffing the bottle opening.

Water supplies that draw from more polluted sources, or water that contains cyanotoxins, may require more regular activated carbon treatment in order to comply with the chemical or cyanobacterial MAVs in the DWSNZ. Because these waters usually also require full chemical treatment, this is discussed in Chapter 13: Treatment Processes, Coagulation.

WHO (2004) states that activated carbon is produced by the controlled thermalisation of carbonaceous material, normally wood, coal, coconut shells or peat. This activation produces a porous material with a large surface area (500–1500 m^2/g) and a high affinity for organic compounds. It is used either in powdered (PAC) or in granular (GAC) form. When the adsorption capacity of the carbon is exhausted, it can be reactivated by burning off the organics in a controlled manner. However, PAC (and some GAC) is normally used only once before disposal. Different types of activated carbon have different affinities for different types of contaminants.

PAC is dosed as a slurry into the water and is removed by subsequent treatment processes together with the waterworks sludge. Its use is therefore restricted to surface water treatment works with existing filters. The choice between PAC and GAC will depend upon the frequency and dose required. PAC would generally be preferred in the case of seasonal or intermittent contamination or where low dosage rates are required. Because prompt delivery of PAC usually cannot be guaranteed, procedures for obtaining PAC at short notice need to be specified in the WSP for those water supplies prone to taste and odour problems.

GAC in fixed-bed adsorbers is used much more efficiently than PAC dosed into the water, and the effective carbon use per water volume treated would be much lower than the dose of PAC required to achieve the same degree of removal.

GAC is normally used in fixed beds, either in purpose-built adsorbers or in existing filter shells by replacement of sand with GAC of a similar particle size. Although at most treatment works it would be cheaper to convert existing filters rather than build separate adsorbers, use of existing filters usually allows only short contact times. It is therefore common practice to install additional GAC adsorbers (in some cases preceded by ozonation) between the rapid gravity filters and final disinfection.

The service life of a GAC bed is dependent on the quality of the feed water, the capacity of the carbon used, the contact time between the water and the carbon, the empty bed contact time (EBCT), controlled by the flow rate of the water. EBCTs are usually in the range 5–30 minutes. GACs vary considerably in their capacity for specific organic compounds, which can have a considerable effect upon their service life. A guide to capacity can be obtained from published isotherm data. Carbon capacity is strongly dependent on the water source and is greatly reduced by the presence of background organic compounds. The properties of a chemical that influence its adsorption on to activated carbon include the water solubility and octanol/water partition coefficient ($\log K_{ow}$). As a general rule, chemicals with low solubility and high $\log K_{ow}$ are adsorbed well.

The use of activated carbon is also discussed in Chapter 14: Treatment Processes, Filtration and Adsorption, section 14.7. Point-of-use/point-of-entry treatment systems are discussed in Chapter 19: Small, Individual and Roof Water Supplies, section 19.3.4.

USEPA (2004) is the Environmental Technology Verification (ETV) Technology Specific Test Plan for evaluation of drinking water treatment equipment utilising fixed bed adsorptive media and aeration plant for volatile organic chemical (VOC) removal.

WRF (2014) reports the results of aeration trials on the removal of several volatile organic contaminants from water. The VOCs' removal efficiencies were studied by collecting operational data from pilot plant operations, under various air-to-water ratios (53–652), three different temperatures (4, 12, and 20°C), and 1 to 6 trays in series.

18.4 Monitoring programme design

Monitoring of some aesthetic determinands is carried out as part of the routine process control of the water treatment process or operation of the distribution system, or to investigate consumer complaints and any subsequent troubleshooting. Process control is discussed in Chapter 17: Monitoring Water Treatment and Drinking-water, section 17.3, and section 17.2 discusses sampling.

Some aesthetic determinands may only reach nuisance level after climatic events such as drought (taste and odour due to low river flows, or changes in the composition of shallow groundwater), or flood (more colour in surface water or more turbidity in shallow groundwater), while others may be seasonal (algal-related taste and odour). A certain amount of routine monitoring may be needed before these relationships are understood. A water supplier needs to know the normal concentration range of aesthetic determinands before they can identify what may have initiated a complaint. Ideally (but rarely), these source water conditions should be understood before a water treatment plant is designed.

The geographical distribution of consumer complaints is likely to act as a good guide for monitoring locations within the distribution system. An understanding of the distribution system is very important. Dirty water complaints predominate in dead end mains, downstream of pump stations, and in areas of flow reversal. Dirty water complaints can also occur in areas served by steel or cast iron mains, and taste and odour complaints can arise in areas with coal tar lined mains (not many left in New Zealand now). Some service reservoirs may only be used during high demand periods, such as a dry summer – the water may have been sitting around for a year and become musty.

Nothing should be taken for granted. There have been occasions when consumers have complained to the water supplier about aesthetic problems, only for the investigations to show that the 'public water supplies' were actually private bore supplies. Also, complaints of slimes and wildlife in tapwater have been traced to a storage tank below the roof; some residents do not even know they have a roof tank.

18.5 Aesthetic guidelines criteria

The following notes have been taken from Appendix B of the Explanatory Notes and Grading Forms of the Public Health Grading of Community Drinking-Water Supplies (MoH 2003).

These criteria are intended for use by a supplier wishing to demonstrate that their water supply meets the aesthetic Guideline Values (GVs) of the DWSNZ, for the purposes of achieving an 'A1' grade for treatment or 'a1' grade for the distribution system. Showing that these criteria are met is not mandatory, other than for gaining an 'A1' or 'a1' grade. Suppliers, however, may wish to demonstrate that their water meets these criteria for other reasons.

A supply will be considered not to have met the aesthetic guidelines if any of the following apply within the year under consideration:

a) complaints about appearance taste and odour have not been recorded and addressed

b) the concentration of any determinand in a monitoring sample exceeds the GV, or is outside the Guideline range stated in the DWSNZ

c) the water has been designated as aggressive (plumbosolvent), and either the pH or CO_2 content is not adjusted or the consumers have not been warned annually (note: although this appeared in the 2003 Grading notes, it is no longer correct. This is now covered in the DWSNZ section 8, Priority 2C)

d) complaints of taste and/or odour are received from an area within the distribution zone and found to be due to the GVs being exceeded

e) complaints of black or brown-staining are received from an area within the distribution zone and found to be due to the GVs being exceeded

f) complaints of discoloured water are received from an area within the distribution zone and found to be due to the GVs being exceeded.

Analyses must be carried out by a Ministry of Health recognised laboratory (field measurements must follow the requirements of the DWSNZ), and records of water quality complaints, and their investigations and follow-up actions, are to be kept.

An exception to these criteria is made for chlorine because of its importance as a disinfectant**.** It is possible that some consumers may object to the taste or odour of chlorine in the water, or that the aesthetic GV has to be exceeded to protect public health. In either case, and assuming all other criteria are being met, the supply will be considered to be meeting the aesthetic GVs.

Sampling for the 'A1' treatment grading should take place at the point where water leaves the treatment plant except when lime treatment is used, in which case turbidity samples may be taken before liming.

For the ’a1’ distribution system grading:

- for bulk water distribution zones, samples should be taken at the point of delivery to the satellite reticulation or tankered supply
- for reticulated or tankered supplies, monitoring samples should be taken at the point of delivery or from randomly selected consumers’ taps. If a sample fails to comply with the aesthetic guidelines a confirmatory sample should be taken from a nearby house in case the problem arises from the domestic plumbing. Some pH and chlorine measurements should be made at a tap of the house closest to the treatment plant. Metal samples should be taken without flushing the tap.

The supplier may choose one of two approaches for monitoring aesthetic determinands.

Approach 1

- At the start of each yearly cycle collect samples for all the aesthetic determinands.
- For the remainder of the year, collect samples at the frequency stated in Table 18.1. By doing the full range of determinands at the beginning of the year, this information can be used to help assess an appropriate sampling frequency for the chemically reduced determinands.

Where historical data are available for a determinand, and they show the determinand to be consistently below 50 percent of the GV, the sampling frequency for monitoring can be reduced to annual. The sampling frequency should be restored to that given in Table 18.1, if any changes to the source, treatment processes, or the distribution system are made which are likely to result in increases in the determinand concentration.

Table 18.1: Sampling frequencies for aesthetic guidelines (ex grading)

Determinand	Group	Monitoring frequency
chloride hardness sodium sulphate TDS	Major ions (significant changes in the concentrations of these determinands are unlikely)	Annually
aluminium chlorine colour pH turbidity	Process-linked determinands.[1] (Concentrations of these determinands may be quite variable depending on the processes in place and the way they are controlled)	Fortnightly[2]
copper iron manganese zinc	Source or corrosion-derived metals (some variation in the concentration of these determinands can be expected depending on the aggressiveness of the water, and the nature of the source water)	Monthly
ammonia hydrogen sulphide	Chemically-reduced determinands	Annually, unless there is evidence of chemically reduced forms of nitrogen or sulphur in the water,[3] in which case, monthly.
	Trace organics	
1,2-dichlorobenzene 1,4-dichlorobenzene monochlorobenzene trichlorobenzenes	Halogenated aromatics	Six monthly – regular monitoring for tastes and odours (see below) can be substituted for chemical analysis for trace organics if preferred.
2 chlorophenol 2,4 dichlorophenol 2,4,6 trichlorophenol	Halophenols	
ethylbenzene styrene toluene xylene	Aromatics	
odour taste	Taste and odour	Fortnightly – if a supplier has a method to determine threshold odour numbers. Otherwise, the acceptability of taste and odour should be judged on the basis of consumer complaints.

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[1] Where a supply is not chlorinated, or not using aluminium-based coagulation, monitoring for chlorine or aluminium is not required. Iron should be included in this group if an iron-based coagulant is in use.

[2] Where these determinands are monitored for compliance with microbiological criteria, the results of the compliance monitoring should be used to assess whether the supply meets the aesthetic guidelines, as these data will be obtained more frequently. Where treatment processes affecting a determinand in this group are under automatic control, its monitoring frequency can be reduced to monthly.

[3] Very low concentrations of nitrate may indicate the presence of ammonia, and hydrogen sulphide is likely to be present if the sulphate concentration is low.

Approach 2

- At the start of each yearly cycle collect samples for all the aesthetic determinands.
- After this, consumer complaints about water quality will be used to assess whether there is a need for chemical analysis of the water, and whether aesthetic GVs are being met.
- When complaints are received, samples should be taken to try to identify the chemical determinand(s) responsible for the complaint, and the reason for its (their) appearance in the water.
- Where complaints of a similar nature occur over an area, and the problem is not specific to particular premises, the supply will be regarded as not having met the aesthetic GVs for that year.

18.6 Analytical details

Some comments on the methods of analysis for the aesthetic determinands appear in the datasheets. *Standard Methods for the Examination of Water and Wastewater* 21st edition (APHA 2005) provides details of suitable methods of analysis for these determinands. In most instances a number of suitable analytical methods for each determinand are provided in *Standard Methods*. The method of choice will depend upon such factors as cost, whether the measurements have to be made in the field, availability of instrumentation, other determinands to be measured on the same sample (multi-determinand methods may be of value), whether the determinand is to be reported as total, soluble, etc, and the required sensitivity and accuracy.

The following discussion relates only to those determinands without compliance issues, ie, only aesthetic determinands. Determinands with compliance issues are discussed in their relevant Chapters (6–11), on bacterial compliance, viral compliance, protozoan compliance, cyanobacterial compliance, chemical compliance and radiological compliance. Where a determinand has both compliance and aesthetic issues, it is discussed in the relevant compliance chapter.

It is not intended to cover all aesthetic determinands here. Standard Methods (APHA 2005) and the datasheets give sufficient information in most cases. Some additional helpful information follows.

Taste and odour

For taste and odour, assessment could be a better word than analysis. It is recommended that a panel be established, comprising people (not necessarily water supply staff) that have demonstrated that they have the ability to reliably recognise different tastes and odours, and to rank these based on strength. Method 2150B in Standard Methods (APHA 2005) gives some advice on odours and Method 2160 covers tastes. Some large water testing laboratories have modern instruments such as mass spectrometers that can be used for testing specific determinands such as those referred to earlier in this chapter.

Total dissolved solids

Direct measurement of total dissolved solids requires a time-consuming evaporation of sample and a series of weight measurements. However, an estimate of total dissolved solids can be obtained from the conductivity measurement, which is simple and rapid. Multiplication of the conductivity (expressed in mS/m) by a factor of seven yields an estimate of the total dissolved solids in mg/L. The accuracy of this approach is adequate for most measurements required in potable waters, provided the temperature of the conductivity test is reported, and the units are correct (a common error). Note that the conversion factor is less accurate for groundwaters that have a high concentration of silica. Making total dissolved solids and conductivity measurements on a series of samples of the water of interest, and using the refined multiplicative factor obtained from these data can obtain a more accurate estimate.

Hardness and alkalinity

Both hardness and alkalinity results can be expressed in different units. To avoid confusion, it is important that the units are clearly stated with the measurement result.

Total hardness is usually reported in units of mg/L as $CaCO_3$. This is equal to the sum of calcium hardness and magnesium hardness, when both are expressed in units of mg/L as $CaCO_3$. Often, calcium and magnesium are reported in concentrations of mg of Ca/L and mg of Mg/L respectively. The following factors are needed for the conversions:

Ca in mg/L as $CaCO_3$ = Ca in mg of Ca/L x 100/40

Mg in mg/L as $CaCO_3$ = Mg in mg of Mg/L x 100/24.3

The total alkalinity of a water is usually reported in units of mg of HCO_3^-/L or mg/L as $CaCO_3$. Conversion is done as follows:

alkalinity in mg of HCO_3^-/L = alkalinity in mg/L as $CaCO_3$ x 1.22

In waters with pH higher than 8.3, the alkalinity to 8.3 may be reported. This value can also be reported in mg/L as $CaCO_3$, or in mg of CO_3^{2-}/L.

It is important to understand that although an alkalinity value may be reported in terms $CaCO_3$, the value gives no indication of the amount of calcium present in the water.

Field or treatment plant analyses

The use of sophisticated instrumentation for analysis of samples should allow good analytical results to be obtained when samples can be returned to the laboratory for analysis, and when measured online. There are often times however, when it is more appropriate for an analysis to be carried out in the field. Such situations arise when measurements have to be made in a plant for the monitoring of process performance, ie, if the result is needed very quickly. These measurements are not usually intended to determine compliance with the DWSNZ, rather they help assess the improvement, or otherwise, of process performance while changes to operating conditions are being made, or indicate at a complainant’s premises, the degree of a problem with an aesthetic determinand. While laboratory analysis is perhaps more accurate, it is usually too slow for this type of work. The relatively simple field tests can provide rapid feedback.

The detailed procedures for field analyses will be set out either in the analytical reference book from which they are taken, or in the manufacturers' instructions if a commercial test kit or online system is being used. The discussion that follows is intended to inform those without analytical training of aspects of testing that are of importance, and need to be emphasised, or that are not explicitly noted in method procedures. Although there is a small number of field tests that are carried out almost universally, a wide range of tests might be used in the field depending on the quality of the source water, and the treatment processes employed. Rather than discuss each determinand separately, the tests will be grouped according to the type of measurement method used. Field tests should be standardised regularly in the laboratory against the referee method, or against the method calibrated against the referee method.

Titrations

Determinands not related to compliance issues that may be measured in the field by titration include chloride, hardness and alkalinity.

The titrants (solutions of known concentration contained in the burette for titration) and indicators used in titration measurements will have limited lifetimes with some being very much shorter than others. Care must be taken to ensure that they are stored correctly and renewed as required by the method. The expected lifetime of titrants should be noted in the method and on the reagent bottle. Some solutions can be obtained from chemical manufacturers, otherwise a reliable analytical laboratory should be requested to prepare the necessary solutions on a regular basis.

The capacity of the burette used and the concentration of the titrant must be matched with the typical concentrations of the determinand being measured, if results of value are to be obtained. It would, for example, be inadvisable to use a 50 mL burette, graduated to 0.1 mL, if the titre (volume of titrant dispensed from the burette during the measurement) is typically 1.0 mL; the precision of these measurements would be very poor. This situation would be better approached by obtaining a smaller volume burette, say 5 mL graduated to 0.02 mL, and adjusting the concentration of the titrant to obtain larger titres so that the percentage errors in the reading are smaller.

Where a colour change in an indicator is used as the end-point of a titration, the titration should be performed on a white surface, preferably in natural light, to ensure that the end-point is seen clearly.

Comparators and Nesslerisers

Comparators are often used for field measurements. Comparator kits are available for a range of determinands, including pH, aluminium and hardness. Colour is read using a Nessleriser.

To obtain the best results from comparators and Nesslerisers, the cells or tubes must be kept clean and unscratched, the comparator or Nessleriser is stored so the colour plates in the disc do not fade, and the correct background lighting used. Some manufacturers produce lighting units that will ensure that the appropriate background lighting is available. Natural light is usually required for accurate results (fluorescent lighting changes the apparent hue of some colours). Readings outside should be taken facing away from the sun. The instructions in many units produced in the northern hemisphere state to face north; for use in New Zealand the appropriate direction is south.

Analysts should be checked for colour blindness, and their ability to see colours reliably under different lighting conditions. Do not use people who cannot distinguish 10 and 20 Hazen units (for example). Apart from people needing to have a natural ability, the colour test is straightforward. There is usually enough technical information provided with the disc, but the method 2120B in APHA (2005) is recommended.

If the colour of the sample (for any test) approaches the upper limit of the disc, dilute the sample with clean distilled or deionised water and repeat the analysis. Multiply the recorded result by the dilution factor to obtain the final result.

Colorimetry

Colorimetry measures the intensity of colour in solution electronically rather than estimating the colour intensity by eye. In the past, these measurements have generally had to be made in the laboratory because few treatment plants were equipped with the spectrophotometers necessary to make the measurements. There are now small, relatively inexpensive spectrophotometers available for use on the bench, and there are also portable spectrophotometers for hand use. Many of these purport to measure a very wide range of determinands, and come pre-calibrated.

All analytical instruments should be standardised, even those that are stated to be pre-calibrated. Where an instrument comes with the calibration internally set by the factory, the instrument should be sent to a qualified laboratory from time-to-time, starting when the instrument is first delivered, to determine how the reading of the instrument correlates with more reliable laboratory measurements. In addition, standard solutions of known concentration should be obtained and used to check the calibration regularly.

If the colour of the sample approaches the upper limit of the calibration limit, dilute the sample and repeat the analysis. Multiply the recorded result by the dilution factor to obtain the final result.

General comments

See Chapter 17: Monitoring Water Treatment and Drinking-water, section 17.5 for a discussion on analytical quality control.

Chemical cleanliness is required whenever analyses are being undertaken to ensure that results are not invalidated by contamination. This is not an easy task when analyses are being performed in a water treatment plant or in the field because of the large quantities of treatment chemicals present, such as aluminium salts and lime, or dust in the air or in a vehicle during transport. The dust from these compounds, either in the air, on working surfaces, or on hands during analyses can produce misleading results.

The comments above have referred to hand-held instruments, or instruments that would be used on a lab bench. A number of determinands that can be measured by these methods can also be used online. In these instances the regular calibration of the probe, or instrument, is as important as it is for the methods used for discrete sample analysis.

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