

## Appendix 4: Practical comments on selected parameters

### Introduction

This appendix gives some practical comments on selected chemicals and parameters, based on broad experience worldwide. It may be used as a supporting document for risk-management planning; however, it provides general guidance only, and the comments provided should be considered in this light. In addition to chemicals of health concern, this appendix also includes other chemicals and physical parameters that may give rise to consumer complaints or act as indicators of other chemicals of concern listed in the World Health Organization's (WHO's) *Guidelines for Drinking-water Quality* (WHO, 2004). It also comments on monitoring of treated water. As noted in Chapter 3, monitoring is only one part of risk management, and the resources required need to be considered carefully, because monitoring of final drinking-water may not be the most cost-effective approach.

The WHO guidelines provide additional information for most of the parameters discussed below.

### Adipates and phthalates

Adipates and phthalates are widely used in industry, and are widespread in the environment. They are encountered in raw surface water and may be found (usually at low concentrations) in treated drinking-water. Few countries have considered it necessary to set standards for these substances, and they are not usually monitored on a routine basis.

Adipates and phthalates are used in the manufacture of polyacrylamides and water treatment resins. They are extremely difficult to analyse in water at trace concentrations. Control of these substances is through specifications on product quality and on the way that the products are used in contact with water.

### Algal toxins

Blue-green algae (cyanobacteria) can occur in surface water bodies used for water supply. Some species of cyanobacteria contain toxins of concern to human health (e.g. microcystins), and these can be released when algal cell walls are ruptured. There is a wide range of potential toxins and it appears that not all of the possible toxins have been identified.

Toxins such as microcystin LR and associated substances can be very difficult to analyse at low concentrations in water. Therefore, it is preferable to control blue-green algae by preventing algal blooms in source waters. There are treatment options for microcystin LR and related substances, but these require careful assessment; for example, it is particularly important to ensure that algal cells are removed.

Blooms of blue-green algae occur in appropriate weather conditions in still or slow-flowing bodies of water with high phosphorus concentrations that either occur naturally or are from a number of possible human-made sources.

Every effort should be made to prevent blooms forming, and this is the primary management approach. Where there are heavy algal blooms, it is best to consider an alternative source of water unless appropriate treatment is available.

### **Aluminium (Al)**

Aluminium is one of the most common elements in the earth's crust; it occurs in a large variety of minerals in almost all geological environments. Aluminium from natural sources is therefore often found in raw waters, but only soluble forms of aluminium are likely to reach drinking-water. One of the major potential sources is aluminium salts, which are widely used as coagulants in drinking-water treatment.

Although there is no health-based guideline value for aluminium, high concentrations reaching distribution systems can result in deposits of aluminium flocs, which can cause subsequent problems of dirty water. Concentrations can normally be maintained below 0.2 mg/l, and 0.1 mg/l should be achievable in well-run large treatment works. Monitoring is normally carried out in final water from the treatment works, but control is best achieved by optimizing coagulation and filtration, and by using operational monitoring for parameters such as turbidity.

### **Ammonia (NH<sub>3</sub>)**

Ammonia is not of direct health concern but can compromise disinfection efficiency because it exerts a significant chlorine demand, reacting rapidly with chlorine.

Although ammonia is not toxic at concentrations generally found in water, its presence in raw water often indicates that the water is contaminated by sewage, by leachate from waste-disposal sites or by animal waste from agricultural activities. Ammonia may also occur naturally in groundwater from peaty sediments, or in slow-moving or stagnant surface water bodies that contain a lot of organic matter and are poorly aerated.

Ammonia is occasionally found in distribution systems where chloramine is used as a residual disinfectant, if the process of producing chloramine is not sufficiently well controlled. Monitoring could be carried out in the final water from the treatment works, but other parameters (e.g. free chlorine) are normally considered to be more important.

### **Antimony**

High concentrations of antimony may occur in acidic drainage from mining areas, in groundwater known to contain high concentrations of arsenic, and in groundwater in active volcanic areas.

Antimony is not usually found in significant concentrations in drinking-water. Concerns that antimony-tin solders would be widely used in place of lead solders have not materialised. Should monitoring be required, this would normally need to be at the tap unless a specific source of antimony in raw water is identified.

## **Arsenic**

Arsenic naturally occurs in a number of geological environments, but is particularly common in regions with active volcanism, where it is found in geothermal fluids. It also occurs in sulfide minerals (principally arsenopyrite) precipitated from hydrothermal fluids in metamorphic environments. Arsenic can also accumulate in some sedimentary rocks. High concentrations of arsenic may occur in groundwater in areas where soils naturally contain high concentrations of sulfides, near mines with sulfide mineralisation, and in areas with volcanic or metamorphic rocks.

High arsenic concentrations in groundwater do not necessarily correspond with areas where rock or sediment has the highest arsenic levels; rather, they occur where chemical conditions are most suitable for leaching. Arsenic is highly mobile in groundwater under a wide range of chemical conditions (Table A4.1).

**Table A4.1 Summary of documented cases of naturally-occurring arsenic problems in groundwater throughout the world**

Country/ region	Area (km <sup>2</sup> )	Concentration ranges (µg/l)	Aquifer type	Groundwater conditions
Bangladesh	150,000	<0.5–2500	Alluvial/deltaic sediments. Abundance of solid organic matter	Strongly reducing, neutral pH, high alkalinity, slow groundwater flow rates
West Bengal	23,000	<10–3200	As above	As above
China:				
Taiwan	4000	10–1820	Sediments, including black shale	Strongly reducing, artesian conditions, some groundwaters contain humic acid
Inner Mongolia (Huhhot Basin (HB), Bayingao, Hexi, Ba Meng, Tumet Plain)	4300 (HB) ?30,000 total	<1–2400	Alluvial and lacustrine sediments	Strongly reducing conditions, neutral pH, high alkalinity. Deep groundwaters often artesian, some have high concentrations of humic acid
Xinjiang (Tianshan Plain)	38,000	40–750	Alluvial plain	Reducing, deep wells (up to 660 m) are artesian
Shanxi			Alluvial plain	?Reducing
Hungary, Romania (Danube Basin)	110,000	<2–176	Alluvial plain	Reducing groundwater, some artesian. Some high in humic acid
Argentina (Chaco- Pampean Plain)	10 <sup>6</sup>	<1–5300 (7800 mg/L As in some porewaters)	Loess with rhyolitic volcanic ash	Oxidising, neutral to high pH, high alkalinity. Groundwaters often saline. As(V), accompanied by high B, V, Mo, U. Also high As concentrations in some river waters
Northern Chile (Antofagasta)	125,000	100–1000	Volcanogenic sediment	Generally oxidising. Arid conditions, high salinity, high B. Also high-As river waters
South-west USA: Basin & Range, Arizona Tulare Basin, San Joaquin Valley, California Southern Carson Desert, Nevada Salton Sea Basin	200,000 5000 1300	up to 1300 <1–2600 up to 2600	Alluvial basins, some evaporites Holocene and older basin-fill sediments Holocene mixed aeolian, alluvial, lacustrine sediments, some thin volcanic ash bands	Oxidising, high pH. As (mainly As(V)) correlates positively with Mo, Se, V, F Internally-drained basin. Mixed redox conditions. Proportion of As(III) increases with well depth. High salinity in some shallow groundwaters. High Se, U, B, Mo Largely reducing, some high pH. Some with high salinity due to evaporation. Associated high U, P, Mn, (Fe to a lesser extent)
Mexico (Lagunera)	32,000	8–620	Volcanic sediments	Oxidising, neutral to high pH, As mainly as As(V)

Source: BGS (2001)

Concentrations of arsenic can be significant, and major health effects can occur due to exposure through drinking-water. Therefore, arsenic has been included in the list of “must consider” chemicals noted in Chapter 2. It is especially important to consider arsenic before establishing a new drinking-water source.

The concentrations of arsenic are usually, but not always, stable. Where concentrations are likely to be stable (i.e. deep groundwater) monitoring would normally only need to take place infrequently. Samples are normally best taken at the treatment works. If there is treatment to remove arsenic, more frequent monitoring of final water to ensure that the treatment is working may be required.

### **Asbestos**

Asbestos can arise from natural sources and from asbestos cement pipe. Exposure to asbestos fibres through drinking-water is not considered to cause health effects in humans; also, the analysis is difficult and expensive.

### **Barium (Ba)**

High concentrations of barium may occur in groundwater in areas with granitic rocks, felsic metamorphic rocks or sedimentary rocks. Concentrations may be high where groundwater contains little or no sulfate (generally where chloride is the dominant anion). There is no evidence to date that exposure to barium through drinking-water has caused health effects in consumers. Should monitoring be required, it would normally be most appropriate at the treatment works or the source.

### **Beryllium (Be)**

Beryllium is primarily found in effluent from specialist metalworking. No formal guideline value has been proposed in the WHO guidelines because beryllium is considered unlikely to occur in drinking-water. It is, therefore, unusual for monitoring to be required.

### **Boron (B)**

Boron concentrations may commonly exceed drinking-water guideline values in groundwater in areas with granitic or volcanic rocks. In areas where there are large accumulations of evaporites, boron concentrations may be high, but in these areas water is sometimes too saline for drinking without advanced drinking-water treatment (e.g. desalination). Boron can also result from wastewater discharges.

Boron is very difficult to remove from water and is not usually encountered at concentrations of concern. Should monitoring be required this is likely to be infrequent and at the treatment works or the source.

### **Bromate**

See disinfectants and disinfection by-products.

### **Cadmium (Cd)**

Cadmium is a heavy metal with similar chemical properties to zinc, but is much less common in the environment than zinc. Cadmium occurs in igneous rocks and some sedimentary rocks, and is generally associated with zinc ore minerals like sphalerite, and with a range of copper ore minerals. Traces of cadmium are often present in artificial fertilizers, and this heavy metal may accumulate in soils in areas that have been used for agriculture for long periods.

Concentrations of cadmium in water are only likely to be of health concern in environments where pH is less than 4.5.

Other cadmium sources can include solder, galvanised pipes and metal fittings, due to pollution from disposal of cadmium-containing materials and from mining operations (see Chapter 7). However, concentrations of cadmium in drinking-water above the guideline value are unusual.

### **Chloride**

Chloride can originate from natural and human-made sources, such as sewage and industrial effluents. Where salt is used for de-icing, chloride can contaminate groundwater through road drainage. Upland and mountain water supplies are usually low in chlorides; whereas, concentrations are generally higher in rivers and groundwater. The main operational issue for chloride is its ability to increase the corrosiveness of water, particularly in low alkalinity water. High concentrations of chloride may result in a detectable taste in water, but consumer acceptability varies widely depending on the form of chloride (e.g. NaCl, KCl and CaCl<sub>2</sub>). Should monitoring be necessary, this would usually be at the treatment works. The frequency would depend on the variability in the source water, but would normally be low.

### **Chlorinated alkanes and alkenes**

Chlorinated alkanes are usually found as contaminants only in groundwater. They are generally present due to careless use or disposal to the soil surface of the chlorinated alkanes used as solvents in industrial processes. These chemicals do not degrade readily in groundwater and can be present for long periods. An assessment of whether such solvents are used in the catchment would be appropriate before considering a monitoring programme.

Chlorinated alkenes are similar to chlorinated alkanes. The two chlorinated solvents most frequently found in groundwater are trichloroethene and tetrachloroethene. Although not used as a solvent, 1,2-dichloroethene may be found due to the breakdown of other alkenes. Vinyl chloride may occur as a breakdown product of other chlorinated alkenes, but is most likely to be found in water as a consequence of the leaching from polyvinylchloride (PVC) water pipes, which contain high residuals of vinyl chloride. This chemical is usually best controlled through product specifications.

### **Chlorinated benzenes**

Chlorinated benzenes are widely used in industry and are sometimes encountered in drinking-water from surface sources. They usually give rise to taste and odour problems at concentrations below the health based guideline value, where one has been proposed.

### **Chlorite and chlorate**

See disinfectants and disinfection by-products

## **Chromium (Cr)**

High concentrations of chromium may occur naturally in groundwater in areas with mafic or ultramafic volcanic or metamorphic rocks (i.e. rocks that consist mainly of ferromagnesian minerals with no quartz).

Chromium is usually found in drinking-water at concentrations well below guideline values. However, it has been found at higher concentrations from industrial pollution or mining discharges (See Chapter 7). Generally, it would only require investigation for monitoring if there were indications that a problem might exist. Measurement would normally take place in final water from the treatment works.

## **Conductivity**

Conductivity is included as an indicator parameter. The electrical conductivity of water is easily measured in the field using a conductivity electrode. It is an indirect measure of the total dissolved solids (TDS) content of water, and there is usually an approximately linear relationship between TDS and conductivity. Increasing conductivity over time in water indicates that one or more inorganic constituents are also increasing; this situation should trigger further investigations.

## **Copper (Cu)**

Copper is usually found at very low concentrations in final drinking-water, but concentrations can increase significantly in buildings with copper pipes if the water is aggressive (dissolves metals from pipes and fittings). Concentrations are most likely to increase after the water has stood in the pipes for a few hours. Copper has been shown to cause acute gastrointestinal discomfort and nausea at concentrations above about 3 mg/l. Monitoring for copper therefore needs to take place at the tap. However, meaningful monitoring usually requires a specific strategy to be developed because concentrations will vary from property to property. High copper levels give rise to staining of sanitary ware. Unless a particular problem has been demonstrated, monitoring would not normally be considered to be necessary or would at least be infrequent.

## **Cyanide**

Cyanide occurs naturally only in geothermal water in volcanic areas. However, it is a common contaminant in groundwater and surface water in gold mining areas, particularly near deposits of processed tailings.

Cyanide can also be found as a consequence of industrial discharges (see Chapter 7).

There is no evidence that cyanide in drinking-water has caused human health problems. Exposure, especially from industrial activity, would generally only be intermittent. This means that monitoring is difficult and would normally only be carried out in response to a particular incident or circumstance where cyanide was known to be present. Fish can be used as an indicator of high cyanide levels, because they are particularly sensitive to its effects.

## **Disinfectants and disinfection by-products**

Disinfectants are usually only monitored to ensure that disinfection has taken place. Certain disinfectants, such as chlorine, are sometimes monitored at the tap or in the distribution system, as a measure of the quality in distribution. A wide range of potential by-products of disinfection may be formed in treatment, particularly if natural organic matter is present at high concentrations. The most commonly monitored by-products are the trihalomethanes (THM) formed through chlorination; THMs are normally considered to be an adequate marker of the total disinfection by-products from chlorination. Some countries also monitor haloacetic acids, but these are difficult and expensive to analyse because of their high polarity. Bromate is sometimes measured when ozone is used, but its formation relates to bromide concentrations in the raw water and the conditions of ozonation. Analysis can be extremely difficult and monitoring is not usually considered except where standards have been set or on an infrequent basis.

When chlorine dioxide is used as a disinfectant, chlorite and chlorate are formed as by-products. These are sometimes monitored, but control can be achieved by control of the dose of chlorine dioxide applied. Chlorate may also form in hypochlorite that is stored for an extended period; again, it is best controlled by management procedures.

## **Dissolved oxygen**

Dissolved oxygen is included as an indicator parameter. It can be measured in the field using a dissolved-oxygen electrode. The dissolved-oxygen content of water depends on its source, temperature, and chemical and biological processes taking place in the water distribution system. Therefore, measurements can only be used in a relative, not an absolute, sense. However, large declines in dissolved oxygen in a water source could indicate high levels of microbiological activity, and should trigger further sampling for microorganisms.

Dissolved oxygen is not usually a candidate for routine monitoring unless a specific problem is recognized

## **Edetic acid and nitrilotriacetic**

Edetic acid (EDTA) and nitrilotriacetic (NTA) have been widely used as sequestering agents for calcium and other metals. They are very soluble in water and difficult to analyse. However, they are of relatively low toxicity and are unlikely to require routine monitoring except in exceptional circumstances.

## **Eh (oxidation-reduction or redox potential)**

Many chemical reactions in water involve the transfer of electrons between chemical constituents. Electron transfer is measured with an electrode assembly that includes an inert metallic electrode (usually platinum). Eh is a measure of the extent to which these reactions can take place. A high positive Eh potential indicates oxidizing conditions where chemical species such as oxygen, nitrate and sulfate may be present in water. Very low negative Eh values indicate reducing conditions with no oxygen and where chemical species such as ferrous iron and hydrogen sulfide are frequently present. Very low Eh values in water are often indicative of pollution containing large amounts of organic carbon, such as leachate

from septic tanks or landfill sites. Rapid changes in Eh should trigger an investigation as to the cause.

### **Fluoride (F)**

Fluoride occurs in rocks in many geological environments. High concentrations of fluoride may occur in groundwater in areas with granitic, acid volcanic, sodium-rich (alkaline) igneous or volcanic rocks, and in some sedimentary and metamorphic terrains. Widespread dental mottling is a health indicator that water contains high concentrations of fluoride, although other sources (e.g. food) may be equally important.

Fluoride is one of the chemical contaminants that must be considered, because high fluoride levels in drinking-water are a major source of adverse human health effects in some parts of the world.

### **Haloacetic acids**

See disinfectants and disinfection by-products

### **Hardness**

Hardness is a natural feature of waters, reflecting calcium and magnesium, as carbonates, bicarbonates and sulfates. It is normally very stable and would only require analysis if there was concern about scale formation in distribution and in plumbing in buildings. Low hardness may be a consideration if assessing the level of plumbing-related metals in water at the tap.

### **Hexachlorobutadiene**

Hexachlorobutadiene is widely used as an industrial chemical. It has been identified in effluent from chemical manufacturing, but has also been found as a contaminant in chlorine gas used for disinfection. Control should, therefore, be primarily through specifications on the quality of chlorine gas. Monitoring would normally be considered only if a specific problem was identified by catchment assessment.

### **Hydrocarbons**

Aromatic hydrocarbons are used as solvents; they are found in petrol and diesel. They are not normally found in drinking-water except as a consequence of spills and or leaking storage facilities. Aromatic hydrocarbons are usually detected by taste and odour at concentrations well below the health-based guideline value. Styrene is sometimes found due to the use of certain pipeline materials (e.g. glass-reinforced plastic) that has not been cured properly. Routine monitoring is normally unnecessary, unless a potential problem has been recognized. Aromatic hydrocarbons are sometimes found, having leached from polyethylene pipes. Thus, monitoring in response to an incident or problem may be more effective at the tap rather than at the treatment works.

Polycyclic aromatic hydrocarbons (PAH) are usually only found in drinking-water as a consequence of leaching from coal-tar linings on cast-iron water mains. The PAH of greatest concern is benzo(a)pyrene, but the most commonly encountered is fluoranthene. Benzo(a)pyrene is normally only detected at significant concentrations in water when particles of coal tar are present.

### **Hydrogen sulfide**

Hydrogen sulfide arises in anaerobic conditions when sulfides are hydrolysed. It causes an unpleasant odour of rotten eggs at very low concentrations as it is lost to air. It is not normally monitored because it is not found in well-aerated systems. If it is detected by smell, it indicates that the system is anaerobic.

### **Iron (Fe)**

There is no health-based guideline value for iron, although high concentrations do give rise to consumer complaints because the iron discolours aerobic waters at concentrations above about 0.3 mg/l. Iron is found in natural freshwaters and in some groundwaters. It may also be present from its use as a coagulant in water treatment or through corrosion of cast-iron water pipes. It is controlled at the treatment works by optimizing treatment, and in distribution systems by a structured programme of maintenance.

### **Lead (Pb)**

Lead is widely dispersed in the environment, occurring in a variety of sedimentary rocks, and in felsic igneous and metamorphic rocks, where it may reach high concentrations in veins associated with hydrothermal fluids. Under pH conditions generally found in natural waters, lead has a low solubility. Concentrations of lead in water are only likely to be of significance in environments where pH is less than 4.5, and it is very rarely found in water at treatment works.

When found in drinking-water, lead usually arises from lead pipes and lead solder, mostly from plumbing in buildings. Monitoring is quite difficult and requires samples to be taken at the tap. Assessment of the presence of lead pipes, or the ability of the water to dissolve lead, are the most appropriate management approaches. Monitoring is only considered if significant resources are available.

### **Manganese (Mn)**

Manganese occurs in groundwaters and surface waters that are low in oxygen; it often occurs with iron. When it is oxidised in aerobic waters, manganese precipitates as a black slimy deposit, which can build up in distribution to cause severe discolouration at concentrations above about 0.05 mg/l. The health based guideline value is 0.4 mg/l. Monitoring is only likely to be required for operational reasons where a potential problem had been identified, in which case, final water from the treatment works would normally be the most appropriate sample site.

### **Mercury (Hg)**

Mercury is a rare element in the earth's crust. It is only relatively concentrated in some volcanic areas and in mineral deposits as a trace constituent of ores of other heavy metals. Mercury concentrations in groundwater and surface waters rarely exceed 1 µg/l.

High concentrations of mercury may occur in groundwater and surface water supplies in gold-mining areas where mercury has been used for gold extraction.

The guideline value for mercury is conservative because it is based on the provisional tolerable weekly intake (PTWI) for methylmercury, which is more toxic than mercury. Monitoring would normally only be justified if mercury were known to be present due to unusual circumstances, such as an industrial or mining discharge.

### **Molybdenum (Mo)**

Molybdenum is a relatively rare element in the earth's crust, but is commonly associated with base metal sulfide deposits, usually being present as the mineral molybdenite MoS<sub>2</sub>.

High concentrations of molybdenum may occur in groundwater in mining areas where sulfide ores contain the mineral molybdenite.

Monitoring would normally not be justified unless there were clear indications that high levels of molybdenum were likely to be present

### **Nickel (Ni)**

Nickel has a similar chemical behaviour to iron and cobalt, and commonly substitutes for iron in ferromagnesian minerals.

High concentrations of nickel may occur in groundwater in areas with mafic or ultramafic rocks. Concentrations of nickel in water from natural occurrences are only likely to be of health concern in environments where pH is less than 4.5 or where groundwater pumping has introduced oxygen into an anaerobic aquifer.

Nickel may also be released from some industrial sources (e.g. nickel plating) and from chromium plating of taps and fittings in which nickel is the base layer. A monitoring programme for nickel in drinking-water would generally only be required if a specific source of pollution were known.

### **Nitrate/nitrite**

Naturally high nitrate concentrations may occur in groundwater in semiarid or arid areas where there is widespread termite activity, or where natural vegetation is dominated by leguminous species such as acacias. Nitrate can also be found in groundwater and surface water due to agricultural activity and leaking effluent from on-site sanitation.

High nitrate concentrations can cause methaemoglobinaemia (blue-baby syndrome) in bottle-fed infants. This condition is also associated with the simultaneous presence of bacterial

contamination. In the absence of bacterial contamination, water with nitrate concentrations of greater than 100 mg/l should not normally be used for bottle-fed infants. At nitrate concentrations of 50–100 mg/l, it is normally considered appropriate to inform medical authorities, to increase vigilance.

Nitrite has a similar action to nitrate, but is usually only found at very low concentrations. It is sometimes formed in water distribution systems when monochloramine is used as a residual disinfectant. Nitrite and nitrate need to be considered together, but monitoring for nitrite is difficult because formation will be in the distribution system. Nitrate levels in surface waters can change quite quickly, but levels in groundwater usually change very slowly unless the groundwater is heavily influenced by surface water.

### **Organotins**

The dialkyltins can be used as stabilisers in PVC pipes. They normally leach in very low concentrations, but if control were required, this would be through product specification.

### **Pesticides**

See Appendix 3.

### **pH**

pH is important as an operational parameter, particularly in terms of the efficacy of chlorination or optimizing coagulation. Additionally, dissolution and mobility of metals in natural waters are greatly influenced by the pH.

### **Radon (Ra)**

Radon is a colourless, odourless gas that is produced by the radioactive decay of radium that occurs naturally in minerals.

Groundwater may contain high concentrations of radon and its daughters in areas where bedrock naturally contains high levels of radioactivity. This includes areas with granitic rocks, and sediments with phosphate nodules or heavy mineral sand deposits. Management of radon in drinking-water is by aeration; in which case it is important that there is adequate ventilation of houses, because a significant proportion of radon in water will be lost to the atmosphere.

### **Selenium**

Selenium has a similar chemical behaviour to sulfur, and often occurs associated with sulfide minerals in a wide range of rocks.

High concentrations of selenium may occur in groundwater in semiarid or arid areas, near known mineral deposits containing sulfide minerals of uranium and vanadium. Irrigated

agriculture may substantially increase concentrations in groundwater in areas with high selenium levels in soil.

High selenium concentrations are generally only found in groundwater with oxidizing conditions in arid areas (Hem, 1989). In areas where there is a large amount of organic matter in soils, selenium is generally relatively immobile in water.

Selenium is one of the few substances that has been shown to cause adverse human health effects as a consequence of exposure through drinking-water, although it is an essential element and in many parts of the world there is deficiency. It is, therefore, important to consider selenium in developing new sources in areas where selenium is suspected. Where selenium is present, monitoring at the treatment works would be appropriate.

### **Silver (Ag)**

Silver is not normally found at significant concentrations in drinking-water, but it is sometimes used as a bacteriostat impregnated in activated carbon used in point-of-use filters. It is very unlikely that monitoring of drinking-water would be appropriate.

### **Sodium (Na)**

Sodium can be found in drinking-water at concentrations in excess of 20 mg/l as a consequence of the use of more saline waters. There is no indication of health effects in the general population associated with high sodium levels in drinking-water, although such water may not be suitable for bottle-fed infants. Concentrations in excess of 200 mg/l may give rise to taste problems. Routine monitoring for sodium is unlikely to be a high priority.

### **Sulfates**

The sulfate anion ( $\text{SO}_4^{2-}$ ) is a common constituent in natural water and is usually present in at least mg/litre concentrations. The WHO has not developed a health-based drinking-water guideline value for this anion, but at concentrations in excess of 500 mg/l, sulfate may cause noticeable taste.

### **Tin (Sn)**

Inorganic tin has not been found at concentrations of concern in drinking-water. No guideline value was considered necessary and tin is not discussed further in this document.

### **Total dissolved solids**

Total dissolved solids (TDS) primarily consist of inorganic salts. Although there are no direct health concerns, high concentrations may be objectionable through taste. Regular monitoring is not usually considered a high priority.

### **Tributyltin oxide**

Tributyltin oxide (TBTO) was widely used as a wood preservative and antifungal agent. It is less widely used now because of its extremely high toxicity to shellfish and its potential impact on the aquatic environment. It has rarely been identified in drinking-water and therefore no health-based guideline value has been proposed. Monitoring would not normally be considered unless a specific problem had been identified.

### **Trihalomethanes**

See disinfectants and disinfection by-products.

### **Uranium**

Uranium is widely distributed in the geological environment, but concentrations are particularly high in granitic rocks and pegmatites, and in areas where there is sulfide mineralisation. The WHO provisional drinking-water guideline value for uranium is 15 µg/l but there are uncertainties regarding whether concentration above this would be of concern. Some countries have drinking-water standards for uranium of up to 30 µg/l.

Uranium has been found in many parts of the world at concentrations in excess of 30 µg/l and so is considered a high priority constituent.

### **Zinc (Zn)**

Zinc is usually only found at very low concentrations in raw waters but can be increased by dissolution of zinc from galvanised pipes. Concentrations above about 3 mg/l can give rise to problems with appearance and taste of the water. A monitoring programme for zinc is unlikely to be necessary unless particular problems have been encountered.

### **Reference**

WHO (2004). *Guidelines for drinking-water quality*, 3rd ed., World Health Organization, Geneva.