

## WATER QUALITY PARAMETER FACT SHEETS

### Aluminium

Aluminium can occur naturally in the environment. Typically as water becomes more acidic, levels of aluminium in water will increase if it is present in the natural environment. Aluminium may also be found in water as a result of some treatment processes, although these techniques are normally only used in public water supplies.

There is no defined safe concentration for aluminium in water, thus a precautionary approach has been adopted by the UK, EU and WHO.

Aluminium can be removed from water using cation exchange resins, although these can be difficult to manage in a domestic setting as changes in pH can result in the release of aluminium back into the water. An alternative removal system would be reverse osmosis. Water can also be blended with other sources of water with low aluminium to achieve a target concentration.

### Ammonium

Ammonium naturally occurs in groundwater and surface water, typically at levels below 0.2 mg/litre. Concentrations can be higher where water passes through humic or iron-rich strata, and may also be raised as a result of close hydraulic links between vegetation and forestry settings. Ammonia levels may be linked to water treatment using chlorine based disinfection and can also be leached from concrete water pipes.

Ammonia can be an indication of faecal contamination of water, and therefore it is important to consider the source of water when assessing the implications of high ammonia in samples. Elevated ammonia can reduce the effectiveness of chlorination systems due to a high proportion of the chlorine reacting with the ammonia when concentrations of the latter exceed 0.2 mg/litre. Manganese removal systems can also be adversely affected by high levels of ammonia. Nitrate levels can rise as a result of filters becoming colonised by ammonium-oxidising bacterial and/or catalytic action.

Ammonia can be removed from water or concentrations reduced using carbon filters and water conditioning techniques.

## **Boron**

Boron does not naturally occur in elemental form. Boron has a high affinity for forming very stable bonds with electronegative atoms (atoms that donate electrons), and as a result often exists in compounds bound to oxygen atoms. Boron is found in seawater, and can be found in evaporite deposits and other sedimentary rocks. Boron-containing minerals are common in nature as sodium- and calcium-borates, borosilicate minerals, and boric acid. Examples of natural borate minerals include borax, borax pentahydrate, ulexite, and inyoite. While elemental boron is insoluble in water, borate minerals including borax, borax pentahydrate, and anhydrous borax are extremely soluble in groundwater when derived from leaching of rocks and soils that contain borate and borosilicate minerals. Once boron compounds dissolve, they generally act as a salt (dissolved ion) and are difficult to remove from water. Borate compounds are used in the manufacture of many different commercial products including: insulation and textile-grade fiberglass, borosilicate glass, fire retardants, enamels, ceramic glazes, soaps, laundry bleach/ detergents, agricultural fertilizers and herbicides. Major anthropogenic sources of boron to groundwater include: industrial wastewater discharges, municipal wastewater discharges, and agricultural activities. Power plants can also release boron to the atmosphere.

Most human exposure to boron comes from either boric acid or borax. Boric acid is the form of boron most likely to be encountered in drinking water, and can be lethal at high concentrations. Other symptoms of boric acid ingestion include gastrointestinal tract distress, vomiting, abdominal pain, diarrhoea, and nausea. Animal studies have observed reproductive and developmental effects when boron was ingested at high levels. Boron may also be a trace micronutrient that appears to affect utilization and metabolism of other important substances including calcium, copper, magnesium, nitrogen, glucose, triglycerides, reactive oxygen, and oestrogen.

Conventional water treatment (coagulation, sedimentation, filtration) does not significantly remove boron. Reverse osmosis, ion exchange or distillation units are effective boron treatment methods but are likely to be prohibitively expensive. Distillation involves producing, collecting, and condensing steam; boron and other impurities do not travel with the steam and are left out of the condensate. Reverse osmosis places water under pressure and forces the water through a fine membrane that keeps boron and other minerals out. Both distillation and reverse osmosis are costly, require significant time and energy to operate efficiently, and require approximately three times the amount of water to use. Both methods are low-yield systems, and storage space is needed for the treated water. Additionally, blow-down or reject water must be safely disposed of. Ion exchange with a boron-specific exchange resin has also proven to be effective. Boiling, over-the-counter water filters (pitcher filters or faucet-attachment filters), and water softeners are not effective at removing boron from water. Boiling water does not reduce boron concentrations but will actually increase boron concentrations.

## **Cadmium**

Groundwater and surface water would not normally have high levels of cadmium, typical concentrations would be below 0.2 ug/litre. Where levels are found to be elevated the cause is normally due to some form of pollution although water can have naturally higher levels in some parts of the world.

Cadmium can be found in water as a result of leaching from pipes where it is present as an impurity in zinc galvanized pipes. It can also originate from cadmium-based solders used in the plumbing of pipes, water heaters, water coolers etc. Where the water is soft and acidic water distribution systems can be corroded resulting in higher levels of cadmium. In the natural environment, cadmium can be mobilised within the ground by acidic water, and pollution is one of the most common sources of cadmium in the groundwater environment of the UK.

Cadmium can be removed from water using an ion exchange water softener which can remove up to 99 percent of the cadmium depending on the system used and the conditions present. Reverse osmosis is also capable of removing up to 90 percent of cadmium in drinking water

## **Calcium and Magnesium**

Calcium and Magnesium occur naturally in groundwater and surface water. Where concentrations are elevated, the water may be referred to as “hard water”. Typically, water with a high calcium and magnesium content is neutral or basic water and may originate from limestone or carbonate rich strata.

Calcium and magnesium are important to human health, and relatively large amounts of a person’s daily intake of both calcium and magnesium can come from the water they drink. The effects of consuming hard water are broad. For this reason, they are not detailed in this section, please refer the World Health Organisation document on calcium and magnesium located in the appendix to this document.

Calcium and magnesium concentrations in water can be managed using common water softeners.

## **Chloride**

Chloride is found in groundwater and surface waters naturally, but can also originate from a wide variety of anthropogenic processes. The most common causes for artificially high levels in surface waters (and sometimes groundwater) result from road runoff with high levels of de-icing salt and fertilizers. Elevated levels in groundwater are normally associated with saline intrusion or sources

of groundwater where the water has been isolated for thousands of years, resulting in the water taking on the chemical signature of the host rock.

Due to there being no measured health based level above which adverse effects are known, the drinking water standard for chloride has been set at 250 mg/litre as above this level water can start to taste salty. The only reliable and suitable method for chloride [and sodium] removal from water in a domestic setting is reverse osmosis.

### **Chromium**

Natural chromium concentrations in groundwater tend to be low at levels commonly less than 1 µg/litre, surface water tends to have slightly higher levels at between 0.5 and 2 µg/litre. These levels compare to 0.04 to 0.7 µg/litre in sea water and 0.2 to 1 µg/litre in rainwater. Higher levels of chromium tend to be the result of enriched sources finding their way into surface and groundwater in the form of pollution.

Chromium in different forms can have serious health implication to humans, please refer to the appended World Health Organisation document of chromium. As some forms of chromium may cause cancer and death, the recommended drinking water limit has been set at a low value on the assumption that analysis of chromium in water is unlikely to distinguish between the different forms present.

Removal of chromium from water is most commonly achieved using ion exchange resins.

### **Clostridia perfringens (including spores)**

Clostridia perfringens naturally occur and are widely abundant in the natural world, they occur as a result of decaying organic matter, within soils and saturated sediments and within the intestines of mammals and some insects. Clostridia perfringens is commonly associated with food poisoning and can lead to infections.

Clostridia perfringens is a very good indicator of potential faecal contamination and is able to exist in unfavourable conditions and even pass through different stages of sterilisation or cooking in the production of foods. Other indicators of faecal contamination, such as *E. coli*, are less able to survive in the environment as long as Clostridia perfringens.

Clostridia perfringens is reported to pose a limited risk when found in water, however the risk factor increases significantly when contaminated water comes in contact with food as this provides ideal conditions for it to grow. Clostridia perfringens can be treated by ultraviolet light, although this may only result in a 95% removal.

## Colony Counts

The colony count is a measure of the presence of microorganisms within a sample. The counts are made after 48 hours at 37 degrees centigrade and after 72 hours at 22 degrees centigrade. The counts are not in themselves an indication of potential harm to health, however they are a very important means by which the effectiveness of treatment systems can be assessed, to judge the extent to which a water source is effected by bacteria and in conjunction with other indicators can be used to assess the risk to consumers.

Microorganisms observed can originate from many different sources, some of which may be more or less harmful to human health. Treatment of effected water using a basic water filter and ultraviolet light treatment or another form of sterilisation can easily kill of most if not all of the organisms present.

## Copper

Copper occurs naturally in the environment, although generally a low concentration. Background concentrations of copper are typically between 0.0005 and 1 mg/litre, UK concentrations tend to be in the middle or lower end of the range. Copper may be found in greater concentrations in the environment naturally where the pH and hardness of water can influence the solubility of copper in water. Higher levels of copper are commonly associated with pollution of the ground and water.

The most common reason for elevated levels of copper in a domestic water supply is due to water standing in copper pipes. Again, the pH and hardness of the water determine whether copper can be leached from the supply pipes.

Copper in drinking water has been documented to make humans unwell with low dosages having similar symptoms to food poisoning and high dosages symptoms including gastrointestinal bleeding, haematuria, intravascular haemolysis, methemoglobinemia, hepatocellular toxicity, acute renal failure and oliguria. Evidence suggests that taking a large dose of copper in a short period is more harmful than taking the same amount of copper of a slightly longer period. Copper can be removed from water using ion exchange or reverse osmosis.

## E. coli

*E. coli* is found in all mammal guts and faeces, for this reason the presence of *E. coli* in water is a sure sign that the water has been contaminate by faecal waste. *E. coli* is not able to survive long in the environment which means its presence in water also indicates a relatively recent and possibly a local source of pollution. *E. coli* is potentially very harmful to human health, and contaminated water should not be consumed before treatment.

Treatment can be easily achieved using a basic filter and ultraviolet light treatment or using another form of disinfection.

### **Electrical Conductivity (EC) and Total Dissolved Solids (TDS)**

The electrical conductivity or EC of a water sample is a measure of the concentration of dissolved ions in water. It is also called specific conductance or specific conductivity (i.e. electrical conductivity normalized to 25°C), and in groundwater is directly related to the TDS based on the assumption that TDS in the water consist mainly of ionic constituents that conduct electricity. Total Dissolved Solids (TDS) is therefore a measure of all dissolved substances in water, including salts, organic and suspended particles that can pass through a very small filter. The clarity of water is unrelated to TDS.

TDS in water supplies originate from natural sources, sewage, urban and agricultural run-off, and industrial wastewater. Salts used for road de-icing can also contribute to the TDS loading of water supplies. Concentrations of TDS from natural sources have been found to vary from less than 30 mg/litre to as much as 6,000 mg/litre depending on the solubility of minerals in different geological regions.

Inverse relationships have been reported between TDS concentrations in drinking water and the incidence of cancer, coronary heart disease, arteriosclerotic heart disease, and cardiovascular disease and total mortality rates.

Certain components of TDS affect corrosion or encrustation in water-distribution systems. High TDS levels (greater than 500 mg/litre) result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons. Such scaling can shorten the service life of these appliances. Water containing TDS concentrations below 1000 mg/litre is usually acceptable to consumers. Above TDS concentrations of 1000 mg/litre or at extremely low concentrations, water taste can be affected.

The most common treatment processes for removing TDS are reverse osmosis (RO)/ nanofiltration and electrodialysis reversal. Freezing and distillation can be used for higher concentrations of TDS, as found in sea water or brackish water (less than 3000 mg/litre); ion exchange can also be used but has limited effectiveness in concentrations less than 3000 mg/litre.

## **Enterococci**

Enterococci are faecal pathogen indicators whose microbes may indicate that the water may be contaminated with human or animal wastes. Microbes in these wastes can cause short-term health effects, such as diarrhoea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, some of the elderly, and people with severely compromised immune systems.

Intestinal enterococci are a subgroup of the larger group of organisms defined as faecal streptococci, comprising species of the genus *Streptococcus*. These bacteria are relatively tolerant of sodium chloride and alkaline pH levels, tend to survive longer in water environments than *E. coli* (or thermotolerant coliforms), and are more resistant to drying and chlorination. Some intestinal enterococci isolated from water may occasionally also originate from other habitats, including soil, in the absence of faecal pollution. Intestinal enterococci are typically excreted in the faeces of humans and other warm-blooded animals. Some members of the group have also been detected in soil in the absence of faecal contamination. Intestinal enterococci are present in large numbers in sewage and water environments polluted by sewage or wastes from humans and animals.

Removal of coliforms from groundwater can be completed by chemical (e.g. chlorine-based) and/or ultraviolet (UV) light disinfection, distillation and reverse osmosis (RO). Pre-treatment filters are used to reduce scaling or fouling. Boiling water for at least one minute can also remove coliforms.

## **Hardness (total)**

The hardness of water is a function of the amount of dissolved polyvalent metallic ions within the water. The total hardness of water is the sum of the temporary (carbonate) and permanent (non-carbonate) hardness and is quantified as a concentration in milligrams of calcium carbonate equivalent per litre. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard.

The hardness of water influences the solubility of other elements in water. It also affects the taste of water and can affect health with harder water being better for people with high blood pressure. The harder the water the more soap is needed to generate lather. The hardness of water can be treated using basic water softeners.

### **Iron (total and free)**

Iron is the second most abundant metal on earth, it is thus commonly found in rivers and groundwater. Concentrations tend to be in the order of 0.5 to 10 mg/litre in groundwater and on average 0.7 mg/litre in surface waters. Concentrations can be higher in both environments, depending on the geology of the catchment.

At concentrations normally measured in water, iron does not pose a risk to human health, however too much iron can be a problem for some people with existing illnesses. The drinking water standard for iron has been set based on aesthetics rather than levels harmful to health. Iron in concentrations above 0.2 mg/l can start to give water an unpleasant taste, make discolour the water and can stain surfaces and material.

Iron can be removed from water through aeration and precipitation, using filter beds and by passing it through membranes.

### **Lead**

Although lead occurs naturally in the environment and associated surface or groundwater sources, most lead found in drinking water originates from the materials used within the supply and distribution network. Old pipes, soldered joints on metal pipes and even some PVC pipes are all able to leach lead into water, and the amount depends on the length of time water stands in pipes, oxygen content, acidity, hardness and temperature.

Lead arising from sources other than pipes typically has artificial origins. These may be pollution of surface waters and groundwater by industrial processes and/or pollution incidents. Lead can be removed from water by reverse osmosis, filtration, using some softener systems and through the use of carbon filters. If lead is present due to leaching from pipes, concentrations can be reduced by managing the pH which will reduce the rate at which lead leaches. Regular use/flushing of the pipes will also minimise the standing time of water, thereby minimising the possibility of leaching.

Lead is harmful to health and can accumulate in the body leading to problems over time. Children, the foetus and pregnant women are most susceptible; water with elevated levels of lead should not be consumed.

### **Manganese**

Manganese is naturally occurring in many surface and groundwater sources and in soils that may erode into these waters. Manganese occurs naturally in many food sources, such as leafy vegetables, nuts, grains, animal products and tea. However, human activities are also responsible

for much of the manganese contamination in water in some areas, including industrial effluent, acid-mine drainage, sewage, and landfill leachate. Manganese and its compounds are used mostly in the production of manganese-iron alloy through a smelting process. They are also used in fertilizer, fungicide, varnish, livestock feed and in unleaded petrol as an anti-knock additive in the form of methylcyclopentadienyl manganese tricarbonyl (MMT).

At concentrations as low as 0.02 mg/l, manganese solids can form staining and coatings on water pipes that may later slough off as a black precipitate that give water an unpleasant appearance or taste. These staining and coating can increase the growth of unwanted bacteria that form a slimy coating. Adverse human health effects can be caused by inadequate intake or overexposure, such as a syndrome known as “manganism” which is characterised by a “Parkinson-like syndrome”, including weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless “masklike” facial expression and slow, clumsy movement of the limbs. Adverse neurological effects and symptoms may also be associated with excess manganese. Orally, manganese is one of the least toxic elements.

Manganese can be removed from water by conventional treatment, ion exchange, reverse osmosis, lime softening. Conventional treatment usually includes pre-treatment steps of chemical coagulation, rapid mixing, and flocculation, followed by flocculation removal via sedimentation or flotation. After clarification, the water is then filtered. Ion exchange involves the selective removal of charged inorganic species from water using an ion-specific resin. Reverse osmosis (RO) passes water through a semi-permeable membrane. In the lime-softening process, the pH of the water being treated is raised sufficiently to precipitate calcium carbonate and, if necessary, magnesium hydroxide; precipitates are filtered out. Chemical precipitation is the most effective option.

## Mercury

Naturally occurring mercury has been widely distributed by natural processes such as volcanic activity, and may be found in coal. Naturally occurring levels of mercury in groundwater and surface water are less than 0.5 µg/l, although local mineral deposits may produce higher levels in groundwater. The use of mercury in industrial processes significantly increased following the industrial revolution of the 19th century. Mercury is or has been used for the cathode in the electrolytic production of chlorine and caustic soda, in electrical appliances (lamps, arc rectifiers, mercury cells), in industrial and control instruments (switches, thermometers, barometers), in laboratory apparatus and as a raw material for various mercury compounds. The latter are used as fungicides, antiseptics, preservatives, pharmaceuticals, dentistry, electrodes and reagents, and ethnic and folk remedies. Mercury in the air eventually settles into water or onto land where it can be washed into water. Once deposited, certain micro-organisms can change it via the process of ‘bacterial methylation’ into methylmercury, a highly toxic form that builds up in fish, shellfish and animals that eat fish which can potentially move up the food chain.

Mercury exposure at high levels can harm the brain, heart, kidneys, lungs, and immune system of people of all ages. High levels of methylmercury in the bloodstream of unborn babies and young children may harm the developing nervous system, making the child less able to think and learn.

Mercury can be removed from water by conventional chemical coagulation, sedimentation and filtration can achieve removals of up to 80% for inorganic mercury, but only 20–40% for organic mercury. Bioremediation and aerobic/ anaerobic biological treatment has removed mercury from wastewater. Powdered activated carbon is effective for the removal of inorganic and organic mercury and can be used to enhance removal during coagulation, with granular activated carbon treatment also effective, and ion exchange as a possible alternative method. It should, therefore, be possible to achieve a concentration below 1 µg/litre by treatment of raw waters that are not grossly contaminated with mercury.

### **Nickel**

The primary source of nickel in drinking water is leaching from metals in contact with drinking-water, such as pipes and fittings, heating elements in kettles and stainless steel cooking utensils. However, nickel may also be present in some ground waters as insoluble hydroxides or sulphides as a consequence of dissolution from nickel ore-bearing rocks at pH extremes. Nickel is used principally in its metallic form combined with other metals and non-metals as alloys in the production of stainless steels, non-ferrous alloys, and super alloys. Other uses of nickel and nickel salts are in electroplating, as catalysts, in nickel–cadmium (e.g. ‘NiCd’) batteries, in coins, in welding products, and in certain pigments and electronic products. It has been estimated that 8% of nickel is used for household appliances. Certain stainless steel well materials i.e. ‘type 304’ were identified as the source of increased nickel concentrations in groundwater wells. Nickel is also incorporated in some food supplements, which can contain several micrograms of nickel per tablet. Nickel is found in both human and cow’s milk at concentrations reported to range from 0.001 to over 0.1 mg/litre.

Nickel concentrations in groundwater depend on the soil use, pH, and depth of sampling; acid rain increases the mobility of nickel in the soil and thus might increase nickel concentrations in groundwater.

Drinking of water contaminated with nickel sulphate, nickel chloride and nickel leachate may result in symptoms including nausea, vomiting, diarrhoea, giddiness, lassitude, headache and shortness of breath. Allergic contact dermatitis/ eczema are the most prevalent effects of nickel in the general population.

Conventional surface water treatment, comprising chemical coagulation, sedimentation, and filtration, can achieve 35 to 80% removal of nickel depending on the speciation of nickel; increasing pH and the presence of high turbidity both favour nickel removal. The optimum pH for

removal on activated carbon was reported to be pH 8. Better nickel removal occurs with waters containing high concentrations of suspended solids; for waters low in solids, the addition of powdered activated carbon can be used to enhance nickel removal. In the case of ground waters, effective removal of nickel can be achieved using chelating ion-exchange resins. Also, various adsorbents could potentially be used to remove nickel from ground waters.

### **Nitrate and Nitrite**

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Nitrate is used mainly in inorganic fertilizers, though is also used as an oxidizing agent and in the production of explosives, and purified potassium nitrate is used for glass making. Sodium nitrite is used as a food preservative, especially in cured meats. Nitrate is sometimes also added to food to serve as a reservoir for nitrite. Nitrates occur naturally in plants, for which it is a key nutrient. Nitrate and nitrite are also formed endogenously in mammals, including humans. Nitrate is secreted in saliva and then converted to nitrite by oral microflora. Nitrate can reach groundwater as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures), landfill runoff, from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Nitrite can also be formed chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate-containing and oxygen-poor drinking-water in galvanized steel pipes or if chloramination is used to provide a residual disinfectant and the process is not sufficiently well controlled.

Over the last 20 years, the increasing use of artificial fertilizers, the disposal of wastes (particularly from animal farming) and changes in land use are the main factors responsible for the progressive increase in nitrate levels in groundwater supplies. The presence of high or low water tables, the amount of rainwater, the presence of other organic material and other physicochemical properties are also important in determining the fate of nitrate in soil.

Once taken into the body, nitrates are converted to nitrites. Short-term, infants below six months WHO drink water containing nitrate in excess of 10 mg/l could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome. The serious illness in infants is due to the conversion of nitrate to nitrite by the body, which can interfere with the oxygen-carrying capacity of the child's blood due to the oxidation of normal haemoglobin to methaemoglobin. This can be an acute condition in which health deteriorates rapidly over a period of days. Symptoms include shortness of breath and blueness of the skin. Over longer terms, nitrates and nitrites have the potential to cause the following effects from a lifetime exposure at levels above 10 mg/l and 1 mg/l respectively: diuresis, increased starchy deposits and haemorrhaging of the spleen. Gastrointestinal disturbances can also occur; young infants, pregnant women and people deficient in specific enzymes are more susceptible than older children or other adults. With respect to exposure to nitrate, these young infants are also more at risk because of a relatively high intake of

nitrate in relation to body weight and, under certain conditions, a higher reduction of nitrate to nitrite by gastric bacteria as a result of the low production of gastric acid. Possible links may exist between a result of high intake of nitrate and/or nitrite, and a possible relationship may exist between nitrate intake and effects on the thyroid.

Nitrate concentrations can be mitigated from groundwater by blending with a low nitrate source, and disinfection which may serve to oxidize nitrite to the less toxic nitrate as well as minimize the pathogenic and non-pathogenic reducing bacterial population in the water. Nitrate removal methods include biological denitrification, ion exchange, reverse osmosis/ nanofiltration and electro dialysis.

## **pH**

The pH of water is a measure of the acidity of water, the level is typically governed by the presence and relationship between carbonates, bicarbonate and carbon dioxide. As the latter increases the pH of water decreases, and vice versa. The pH is also influenced by temperature although this is a minor influence on most groundwater and surface water sources of water as their temperature tends to be steadily between 5 and 15 degrees centigrade.

Ideally drinking water should have a pH of between 6.5 and 8.5, if the pH drops the water tends to be characterised as 'aggressive' due to a relative increase in the corrosivity of water.

The pH of water from most sources within the United Kingdom is relative stable and within the recommended range. It is important, however, to monitor and manage pH levels if water is being treated prior to consumption. For chlorination of water to be effective the pH should be less than 8, ideally the pH of water would be close to neutral i.e. 7.0 in order to reduce the corrosivity of water on the distribution system.

## **Potassium**

Potassium occurs widely in the environment, including all natural waters as salt compounds and is essential for dietary requirements. It can also occur in drinking-water as a consequence of the use of potassium permanganate as an oxidant in water treatment. It is present in all animal and plant tissues, with the primary source of potassium for the general population being diet, as potassium is found in all foods, particularly vegetables and fruits. Some food additives are also potassium salts. Potassium nitrates are mainly used as fertilizers and may also be used in heat transfer salts, glass and ceramics, rodenticides, and in matches and fireworks. Potassium contamination in groundwater can also be sourced from farmyard runoff, landspreading and sewage sources.

High doses of salt substitutes have resulted in chest tightness, nausea and vomiting, diarrhoea, hyperkalaemia, shortness of breath and heart failure. Vulnerable groups at high risk when consuming drinking water with unusually high levels of potassium include infants (due to a limited renal reserve and immature kidney function), and individuals with kidney disease, renal insufficiency or with other conditions taking medications that interfere with normal potassium-dependent functions in the body.

The removal of high concentrations of potassium from groundwater can be achieved using reverse osmosis (RO), sometimes combined with a softening treatment.

### **Sodium**

The sodium ion is ubiquitous in water. Saline intrusion, mineral deposits, seawater spray, sewage effluents, and salt used in road de-icing can all contribute significant quantities of sodium to water. Sodium is naturally present in all foods and may be added during food processing, including fresh fruit, vegetables, cereals, cheese and human/ cow's milk.

Metallic sodium is used in the manufacture of tetraethyl lead and sodium hydride, in titanium production, as a catalyst for synthetic rubber, as a laboratory reagent, as a coolant in nuclear reactors, in electric power cables, in non-glare lighting for roads, and as a heat-transfer medium in solar-powered electric generators. Sodium salts are used in water treatment, including softening, disinfection, corrosion control, pH adjustment, and co-agulation, in road de-icing and in the paper, glass, soap, pharmaceutical, chemical, textile/ leather and food industries as a flavouring agent or preservative. In water-treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, can together result in sodium levels as high as 30 mg/litre. Sodium hydroxide may be applied to prevent clogging of sewer pipes. Most water supplies contain less than 20 mg of sodium per litre, though domestic water softeners can give levels of over 300 mg/litre. Sodium may affect the taste of drinking-water at levels above about 200 mg/litre.

A relationship between elevated sodium intake and hypertension/ blood pressure may exist.

Techniques to remove sodium chloride from water include reverse osmosis (RO), electro dialysis, distillation techniques or ion exchange. RO is most economical considering energy and money requirements.

### **Sulphate**

Sulphates occur naturally in numerous minerals, including barite, epsomite and gypsum. These dissolved minerals are highly soluble and contribute to the mineral content of many drinking waters. Sulphates and sulphuric acid products are used in the production of fertilizers, chemicals,

dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics. They are also used in the mining, wood pulp, metal and plating industries, in sewage treatment and in leather processing. Aluminium sulphate or 'alum' is used as a sedimentation agent in the treatment of drinking-water. Copper sulphate has been used for the control of algae in raw and public water supplies. Sulphates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. 'Acid rain' is a dilute form of sulphuric acid.

The presence of sodium-, calcium- and magnesium-sulphates may affect the taste of drinking water at levels above about 250 to 500, 250 to 1,000 and 400 to 600 mg/litre respectively, and this water may taste 'bitter' or 'medicinal'. Cathartic effects are commonly reported to be experienced by people consuming drinking water containing sulphate in concentrations exceeding 600 mg/litre, although it is also reported that humans can adapt to higher concentrations with time. Dehydration has also been reported as a common side-effect following the ingestion of large amounts of magnesium or sodium sulphate. Children, transients and the elderly are potentially vulnerable groups because of the potentially high risk of dehydration from diarrhoea that may be caused by high levels of sulphate in drinking water; an increased laxative effect/ reduced gastrointestinal retention of food may be associated within higher sulphate concentrations in drinking water.

There are three traditional treatment systems that will remove sulphate from drinking water: reverse osmosis (RO), distillation, and ion exchange. Additionally, lower cost removal of higher concentrations of sulphates from drinking water has been achieved by the addition of hydrated lime ( $\text{Ca}(\text{OH})_2$ ), which precipitates calcium sulphate which in turn hydrates to highly soluble gypsum; lime-treated water precipitates sulphate as a nearly insoluble calcium-alumina-sulphate compound known as 'ettringite'. Carbon filters, water softeners and sediment filters will not remove sulphate; water softeners exclusively change magnesium or calcium sulphate into sodium sulphate, which is more laxative.

### **Total Coliforms**

Total coliforms are a group of relatively harmless bacteria commonly found in the environment, for example in soil or vegetation, as well as the intestines of mammals, including humans. Total coliform bacteria are not likely to cause illness and are non-faecal in origin, but their presence indicates that a water supply may be vulnerable to contamination by more harmful microorganisms. *Escherichia coli* (*E. coli*, detailed above) or thermotolerant coliforms are the only member of the total coliform group of bacteria that is found only in the intestines of mammals, including humans. The presence of the coliform sub-group *E. coli* in water indicates recent faecal contamination and may indicate the possible presence of disease-causing pathogens, such as bacteria, viruses, and parasites. Although most strains of *E. coli* bacteria are harmless, certain strains, such as *E. coli* 0157:H7 as found in cattle, sheep, chicken and pigs, may cause intestinal illness, or more rarely hemolytic uremic syndrome, a serious kidney condition. Health symptoms related to drinking water

contaminated with bacteria generally range from no ill effects to cramps and diarrhoea (gastrointestinal distress).

The main source of pathogens in drinking water is through recent contamination from human or animal waste, from improperly treated septic and sewage discharges, leaching of animal manure, storm water runoff and domestic animals or wildlife. During and after precipitation, bacteria and other harmful microorganisms from any of these sources may be washed into rivers, lakes, or groundwater. Poor borehole construction or maintenance can increase the risk of groundwater contamination from these pathogens.

The presence of pathogens is determined with indirect evidence by testing for an "indicator" organism such as coliform bacteria. Coliforms come from the same sources as pathogenic organisms. Coliforms are relatively easy to identify, are usually present in larger numbers than more dangerous pathogens, and respond to the environment, wastewater treatment, and water treatment similarly to many pathogens. As a result, testing for coliform bacteria can be a reasonable indication of whether other pathogenic bacteria are present. Total coliforms include bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste, including thermotolerant coliform and *Escherichia coli* or *E. coli* of faecal-origin.

Removal of coliforms from groundwater can be completed by chemical (e.g. chlorine-based) and/or ultra violet (UV) light disinfection, distillation and reverse osmosis (RO). Pre-treatment filters are used to reduce scaling or fouling. Boiling water for at least one minute can also remove coliforms.

## WHO WATER QUALITY GUIDANCE DOCUMENTS

WHO produces international norms on water quality and human health in the form of guidelines that are used as the basis for regulation and standard setting, in developing and developed countries world-wide. The WHO Guidelines for Drinking-Water Quality include facts and comprehensive review documents for many individual chemicals. For many of these, guideline values are derived. These guidance documents are periodically updated. For the latest guidance and associated documents regarding the parameters detailed in Appendix 2, please visit the following WHO information sources:

1. Guidelines for drinking-water quality:

[http://www.who.int/water\\_sanitation\\_health/dwq/guidelines/en/](http://www.who.int/water_sanitation_health/dwq/guidelines/en/)

2. Guidelines for Drinking-water Quality, 4th Ed, 2011:

[http://whqlibdoc.who.int/publications/2011/9789241548151\\_eng.pdf?ua=1](http://whqlibdoc.who.int/publications/2011/9789241548151_eng.pdf?ua=1)

3. Chemical hazards in drinking-water (for water quality parameters):

[http://www.who.int/water\\_sanitation\\_health/dwq/chemicals/en/](http://www.who.int/water_sanitation_health/dwq/chemicals/en/)

4. Summary tables of guideline values (from ‘Guidelines for Drinking-water Quality’, 4th Ed., Annex 3: Chemical summary tables):

[http://www.who.int/water\\_sanitation\\_health/publications/2011/9789241548151\\_annex.pdf?ua=1](http://www.who.int/water_sanitation_health/publications/2011/9789241548151_annex.pdf?ua=1)