

## **2. Properties and contaminants of water**

### **2.1 Introduction**

The methods used to treat raw water will depend on the properties of the water and the presence and concentrations of any contaminants. Groundwater usually has low levels of colour and turbidity and consistent microbiological quality, although water from shallow wells and some springs may be more variable. Particular problems may include high or low pH and alkalinity and high concentrations of iron, manganese, nitrate, chlorinated solvents or pesticides. Surface water may have high levels of colour and turbidity and exhibit poor microbiological quality. Quality may be variable and deteriorate following periods of heavy rainfall. Other problems may include low pH and alkalinity and high concentrations of aluminium, iron, manganese, nitrate or pesticides.

### **2.2 Microbiological parameters**

Water used as a source for any private supply of drinking water may be of unknown origin and originate from a catchment prone to persistent or intermittent microbiological contamination. This may be derived from an environmental source, such as soil, the faeces of livestock or other domestic animals, wildlife or sanitation systems such as septic tanks. Consequently it is essential that raw water is adequately treated before it is used for domestic purposes (as defined in the Water industry Act 1991). Because no single method of treatment can be expected to remove all types of pathogenic agents, a multiple barrier approach in the form of two or more sequential treatment processes is recommended.

The microbiological quality of drinking water has traditionally been assessed by monitoring indicator bacteria (coliforms, *E. coli*, and enterococci). Indicator bacteria comprise a range of environmental and enteric bacterial species that are themselves not necessarily pathogenic, but their presence in drinking water is regarded as being indicative of poor quality and/or a potential microbiological health risk. *E. coli* is a thermotolerant coliform, the presence of which is specifically an indicator of faecal pollution. Similarly, although not in the coliform group, the presence of enterococci in a sample indicates faecal contamination. Although indicator organisms are adequate for monitoring purposes, their absence in a sample cannot completely be relied upon to indicate that the water is compliant with quality standards and free of pathogens at all times. This is especially true of pathogens that are environmentally more robust, or can better survive treatment than the indicators. In these circumstances an indicator may be absent, but low numbers of pathogens could still be present.

An example of such a pathogen is *Cryptosporidium*. This micro-organism is very much more resistant than faecal indicators, such as *E. coli* and enterococci, to the destructive action of disinfectants. This is because it has the ability to form spore-like bodies called oocysts that make it less vulnerable to the disinfectant properties of chlorine and similar compounds. If disinfection is the sole treatment process used the numbers of *Cryptosporidium* oocysts will remain unchanged whereas the numbers of *E. coli* (and coliforms) may be reduced to undetectable levels.

The use of appropriate filtration (i.e.  $<1\mu\text{m}$ ) before disinfection is more effective because an appropriate physical treatment barrier will remove oocysts. In addition filtration will remove much of the particulate material present which could otherwise reduce the effectiveness of disinfection by creating an oxidant demand and/or shielding microbes from the effects of the disinfectant. This is a good example of why a multiple rather than a single barrier approach is preferred. In addition the use of multiple barriers will allow some protection to remain even if one process fails.

Despite the possible shortcomings in the use of bacterial indicators as a measure of the microbiological safety of a water supply, monitoring for coliforms and *E. coli* is still recommended and standards of quality are expressed in terms of these organisms. The reason for this is that monitoring for the pathogens themselves remains rather uncertain because methods of analysis are relatively insensitive and costly compared to those for indicator bacteria. Additionally the absence of one pathogen will not guarantee the absence of others.

Monitoring needs and treatment requirements should however be the subject of regular review and if a need is identified, through for instance, an outbreak due to a specific pathogen or a change noted in the risk assessment for a source, treatment strategies and monitoring requirements may need to be changed.

Growth of algae can be a problem in some surface water sources and in uncovered water storage reservoirs. Algae are naturally present in all inland waters and concentrations can increase and decrease rapidly depending on climatic factors and the availability of essential nutrients. Algae can cause taste and odour in water and some cyanobacteria (usually known as blue-green algae) release toxins that may prejudice the recreational use of water. Although algal toxins have not been identified in drinking water supplies at concentrations that would affect health, it would be prudent to avoid the use of water sources that exhibit high concentrations of such algae.

With the consent of the relevant environmental authorities, it may be possible in some circumstances to adopt measures to minimise the development of excessive algal blooms. The addition of iron salts to precipitate the nutrient phosphate is one measure, although it may not represent a long-term remedy to the problem. In the past, dosing of copper sulphate has been used to reduce growth of algae in reservoirs but its efficacy is questionable. The forced circulation of reservoirs to keep

water mixed is another measure. Blooms of algae occur mainly at the surface of reservoirs whereas water is abstracted at depth. Some forms of water treatment, including ozonation, activated carbon adsorption and addition of potassium permanganate can be effective in removing algal toxins. Algae are normally removed as particulate matter during water treatment but some algae can pass through screens and filters or reduce the efficiency of filtration or sedimentation systems.

## **2.3 Microorganisms associated with outbreaks and private supplies**

### **2.3.1 Review of outbreaks**

Being generally smaller, less well equipped than public supplies, and being subject to less stringent surveillance and regulatory requirements private supplies by their very nature are more likely to suffer water quality failures. A review was conducted, on behalf of the Inspectorate, into the number of outbreaks of gastrointestinal infections associated with private water supplies between 1970 and 2009. In the period between 1970 and 2000 there were 25 outbreaks associated with private water supplies. The strength of association between illness and drinking from a private supply was strong in 12 of these outbreaks. In 7 of the identified outbreaks, the strength of association was probable, whilst for the remaining 6 outbreaks the strength of the association was weaker and recorded only as possible. Over half of the identified outbreaks were caused by *Campylobacter* spp. (13/25, 52%). Other pathogens implicated in outbreaks included *Cryptosporidium* (4 outbreaks), *Streptobacillus moniliformis* (1 outbreak), *E. coli* 0157 (1 outbreak), *Giardia* (1 outbreak). These included one outbreak of mixed pathogens (*Cryptosporidium* and *Campylobacter*). From 2001 to 2009 there were twelve outbreaks. However, only one outbreak had strong evidence of an association with a private supply. For nine of the outbreaks, the strength of evidence for the role of the private supply was probable, and there was one outbreak scored as possible. Identified pathogens involved in the outbreaks included *Campylobacter* (7 outbreaks), *E.coli* 0157 (4 outbreaks), *Cryptosporidium* (3 outbreaks), *Salmonella* (1 outbreak) and norovirus (1 outbreak). These include 4 outbreaks where more than one outbreak pathogen was detected amongst cases within the outbreak. There were no identified outbreaks caused by unknown pathogens.

As is commonly seen with such private supplies the main pathogens present in these outbreaks would normally be removed by the conventional water treatment systems used for mains drinking water such as chlorination (for the bacteria and viruses) and flocculation, filtration and UV treatment (for these plus the chlorine resistant parasites, including *Cryptosporidium*). Outbreak investigations typically identified evidence of contamination by livestock, poor conditions surrounding the PWS and inadequate treatment practices. The control measures introduced for implicated

supply included interim advice to boil water, chlorination of water and flushing of water distribution systems<sup>1</sup>.

### **2.3.2 *Campylobacter***

The genus *Campylobacter* is common in the faeces of a wide variety of wild and domesticated animals. In the UK *Campylobacters* are the main causes of food-related gastroenteritis and although *Campylobacter* does not multiply readily outside its natural habitat, it can survive in water for some time. This organism is destroyed by disinfection with, for instance, chlorine, ozone or ultraviolet (UV) light and so any organisms passing through the earlier stages of water treatment should not remain viable in the treated water. However, the action of disinfectants can be hindered if the water has not been treated adequately by the removal of dissolved organic material and particulates. The latter can have a shielding effect particularly where UV disinfection is being used.

### **2.3.3 *Cryptosporidium***

Cryptosporidia are tiny parasitic animals. Some species cause the diarrhoeal disease cryptosporidiosis in humans. They produce robust spores, called oocysts, which endure for long periods in the environment, including in water. They are excreted by their host animals and therefore faeces of cattle, sheep and other animals, as well as human sewage are the main sources of *cryptosporidium* contamination in private water supplies.

Physical treatment processes (coagulation, sedimentation and filtration) can provide an effective barrier, preventing the parasite from being present in treated water. Membrane filters with sufficiently small pore sizes will also remove oocysts. Chlorination at the concentrations used in water supply does not inactivate oocysts and a combination of robust and effective catchment control measures, physical barriers and disinfection is required to ensure protection from *cryptosporidium*.

Private supplies derived from surface waters and from some springs will be vulnerable to contamination with *Cryptosporidium*, particularly in catchments where livestock farming is common. In these circumstances the use of a suitable filtration stage in treatment is advisable to physically remove *Cryptosporidium* oocysts as well as particulates, which could be shielding other microorganisms from disinfection. Filtration should be followed by disinfection using chlorine or another suitable and approved disinfectant, to destroy any remaining viruses and/or bacteria.

In reality UV is a more common method of microbiological treatment employed by owners of small private supplies. UV will deactivate *Cryptosporidium* oocysts but is

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<sup>1</sup> DWI Report WT1269 "Infectious diseases associated with private water supplies in England and Wales from 1970 to 2009"

only effective at when the UV light is of adequate intensity. Further to this the equipment must be operated and maintained according to the instructions for the particular model in use. Since turbidity greater than 1NTU may shield *Cryptosporidium* oocysts and other microorganisms from disinfection it is advisable to install a suitable filter prior to the UV unit.

#### **2.3.4 Giardia**

*Giardia* is a group of tiny parasitic animals which grow in the intestinal tracts of host animals. It causes a diarrhoeal disease in humans and can be transmitted by direct contact with infected animals and humans, or by consumption of water, food or beverages contaminated by the faeces of infected humans or animals. *Giardia* forms robust spores called cysts that are infectious and these survive well in water.

The cysts show greater resistance to UV, chlorine, and ozone than bacteria and viruses, but they are less resistant than *Cryptosporidium* oocysts. *Giardia* cysts are inactivated by boiling or pasteurisation.

Outbreaks associated with drinking water can occur where human or animal faeces contaminate the supply and the water is inadequately treated. Private supplies should be regarded as being a high microbiological risk if the catchment is prone to contamination by the faeces of animals, if there is a rapid route for recharge to reach the raw water intake and if there are inadequate treatment barriers.

#### **2.3.5 *Escherichia coli* serotype O157**

The bacterium *E. coli* O157 is a cause of severe disease in Britain. Although most outbreaks and individual illnesses have been due to contaminated food, the organism has been implicated in outbreaks associated with water supplies. In the UK this has been confined to private supplies and there has been a strong association with possible contamination from animal faeces.

Cattle and sheep, and so foods of animal origin, are amongst the most common vehicles of infection from *E. coli* O157. Large numbers are excreted in the faeces of infected animals even though the animal may be showing no symptoms of disease. A well maintained multiple barrier treatment strategy including a suitable adequate disinfection stage (chlorination or UV) therefore provide good protection against *E. coli* O157.

There are no specific standards for *E. coli* O157 in drinking water but, as mentioned above, the detection of any *E. coli* in water should be regarded as evidence that *E. coli* O157 could be present or that the supply is susceptible to breakthrough by this organism, or indeed other pathogens.

### **2.3.6 *Streptobacillus***

*Streptobacillus* is a bacterium which can be found in private water supplies. It is derived from animals and some types can cause Streptobacillary fever. However, it is a rare infection in the UK.

The small size of this bacterium may allow it to pass through water treatment filters, particularly if there has not been a coagulation stage. However, it is susceptible to disinfectants although it does have the ability to increase its tolerance of disinfection. Thus a well-maintained multiple barrier system would provide the best protection.

### **2.3.7 Enteric viruses**

There are several types of viruses which can be present in faeces and can cause viral enteritis. There have been several relatively large outbreaks (each of more than 100 cases) of viral enteritis associated with private water supplies derived from surface water. In each of these there was evidence of faecal contamination of the supply which had either been inadequately chlorinated, or not disinfected at all. Birds also carry viruses and can contaminate reservoirs and open cisterns.

Although filtration will remove viruses to some degree the primary treatment barrier is disinfection, either by chlorine or UV irradiation. For these to be most effective water must be conditioned by filtration (to remove particulates and aggregates of viruses) before disinfection. Where disinfection is the only treatment being employed, it must be maintained and its performance monitored regularly to optimise disinfectant activity for the prevailing water conditions.

### **2.3.8 *Salmonella paratyphi***

*Salmonella paratyphi* A and B cause the illness paratyphoid fever, which is usually food-borne, although cases of water-borne outbreaks due to *Salmonella paratyphi* B have been recorded in the UK.

Salmonellae would be expected to respond to water treatment processes in a similar way to coliform organisms and *E. coli* and would have a similar susceptibility to chlorination or other disinfection processes. A well-maintained multiple barrier system would therefore give good protection.

## **2.4 Chemical contaminants**

### **2.4.1 Aluminium**

Aluminium is a natural constituent of many raw waters, particularly acidic surface waters derived from upland catchments. Aluminium can deposit within the distribution system and give rise to aesthetic problems such as cloudiness and discolouration. The UK drinking water quality regulations include a national standard for aluminium of 200µg/l, which is based on avoiding aesthetic issues rather than being health based. Aluminium in raw water can be removed by coagulation and filtration. The use of aluminium sulphate as a coagulant in water treatment should normally result in a residual concentration of no more than 50 to 100µg/l. Aluminium in small water supplies can be removed by use of filtration or membrane techniques.

### **2.4.2 Ammonia**

Most natural waters contain traces of ammonia or ammonium compounds. The ammonia found in water may occur naturally or it may indicate that recent pollution has taken place. Certain anoxic groundwaters may contain elevated concentrations of ammonia (greater than 1mg/l as  $\text{NH}_4$ ) resulting from natural ammonification and denitrification processes. Ammonia may also be derived from the decay of organic material in the soil resulting in small concentrations in water. Unpolluted river waters rarely contain more than 0.05mg/l  $\text{NH}_4$ . The presence of ammonia could indicate contamination from human or animal sources and elevated concentrations in water should be investigated to ascertain the cause. The UK drinking water quality regulations set an indicator parameter value for ammonia of 0.5mg/l  $\text{NH}_4$ . However, the appearance of even small amounts of ammonia (e.g. above 0.05mg/l  $\text{NH}_4$ ) in a groundwater which is normally free from ammonia warrants further investigations.

Ammonia can be removed from water by aeration (after increasing the pH to 11), ion-exchange, biological denitrification and breakpoint chlorination. Of these, only chlorination is likely to be applicable to small supplies. Chlorination converts ammonia to chloramines (see Section 5.9.2) which are less potent disinfectants than chlorine itself and can give rise to taste and odour complaints. Therefore, when designing chlorination systems for ammonia containing waters, the chlorine capacity must be sufficient to produce a free chlorine residual and prevent the formation of taste and odour causing compounds.

### **2.4.3 Arsenic**

Arsenic is introduced into water through the dissolution of minerals and ores, from industrial effluents, and from atmospheric deposition. Concentrations in groundwater in some areas are sometimes elevated as a result of water-rock interaction in the aquifer. The most prevalent species of arsenic in water are inorganic. The

predominant form is either arsenic (V) (arsenate), which predominates in oxidising conditions, or arsenic (III) (arsenite), which is present in reducing conditions.

Inorganic arsenic is a documented human carcinogen. A relatively high incidence of skin cancer and possibly other cancers that increase with dose and age has been observed in populations ingesting water containing high concentrations of arsenic. The standard for arsenic in the UK is 10µg/l.

Arsenic (V) can be removed effectively by iron or aluminium coagulation. If present as Arsenic (III) then pre-oxidation (e.g. using chlorine) is required. Other potential removal techniques include ferric oxide, activated alumina, ion exchange and reverse osmosis.

#### **2.4.4 Iron and manganese**

Iron and manganese derived from minerals and sediments can be present in particulate or dissolved forms in groundwater and surface water. Iron and manganese concentrations in surface water are usually less than 1mg/l but much higher concentrations (up to 50mg/l Fe and 30mg/l Mn) can be encountered in groundwater. Iron can also arise from corrosion of ferrous pipework and chemicals used in treatment processes (coagulation).

Iron and manganese suspensions cause aesthetic problems including metallic taste and discoloration of water fittings and laundry. High dissolved iron and manganese concentrations can also increase chlorine demand and thus reduce the efficiency of chlorine disinfection and can interfere with the efficiency of UV disinfection by coating treatment units. The UK drinking water quality regulations include national standards for iron and manganese of 200µg/l and 50µg/l respectively. Iron and manganese can be removed by filtration although oxidation, coagulation and sedimentation may be required for high concentrations particularly if the metals are in dissolved form. An oxidation (aeration) process is invariably required when groundwater contain more than 1mg/l of dissolved iron or manganese.

#### **2.4.5 Lead**

The concentration of lead in raw water rarely exceeds 20µg/l but higher concentrations do occur in water drawn from strata containing galena or other lead ores. High concentrations of lead in drinking water are usually caused by the dissolution of lead (plumbosolvency) from lead pipework, tank linings or historic leaded alloys in water fittings. Traces of lead may also be derived from lead solder and from PVC pipes containing lead-based stabilisers. Lead based plumbing products are no longer approved for use in drinking water systems. The UK drinking water quality regulations specify a standard for lead of 10µg/l. For small water supply systems the best approach to reducing lead concentrations is the replacement of lead containing materials with non-leaded alternatives. However, treatment methods

are available to reduce plumbosolvency. Water that has been standing in lead pipes for long periods, for example overnight, should not be drunk. In these circumstances, the tap should be run to clear the pipes before taking water for drinking or cooking.

#### **2.4.6 Nitrate**

Nitrate ( $\text{NO}_3^-$ ) occurs naturally in water as a result of the oxidation of ammonia, which is released during mineralisation of organic nitrogen. In some areas agriculture is the major source of nitrate in surface water and groundwater. The discharge of nitrate containing effluents from sewage treatment works contributes to the concentration of nitrate in some surface water. The UK drinking water quality regulations specify a standard for nitrate of 50mg/l as  $\text{NO}_3$ , although in certain circumstances, where the concentration is less than 100mg/l a private household may not have to take action (see DWI Guidance Note: Nitrate and Private Water Supplies) . In addition the water must satisfy the following formula, where the square brackets signify the concentrations in mg/l of nitrate and nitrite:

$$\frac{[\text{nitrate}]}{50} + \frac{\text{nitrite}}{3} \leq 1$$

Ion-exchange, biological de-nitrification and certain membrane processes can reduce nitrate concentrations. Of these, only ion-exchange and membrane processes are likely to be practicable for small water supplies. It may be appropriate to consider controls over agricultural activities within catchment areas as a long term means of reducing the leaching of nitrate into water supplies, if these are the source.

#### **2.4.7 Pesticides**

The use of pesticides for agricultural and non-agricultural purposes is widespread and in the UK there are approximately 450 different active ingredients in pesticides licensed for use. In surveys of UK surface and groundwater sources, the most commonly reported pesticides are atrazine, simazine and dieldrin. Controls on agricultural uses and withdrawal of approvals for non-agricultural uses of these pesticides were introduced in the UK in 1992. Other pesticides commonly reported in water sources used for public supplies include isoproturon, mecoprop and chlorotoluron. Recently, metaldehyde has also emerged as a pesticide of concern due to the inability of conventional water treatment process to remove it.

The UK drinking water quality regulations specify standards of 0.1µg/l for individual pesticides and 0.5µg/l for total pesticides. These standards do not have any toxicological basis. Concentrations of individual pesticides found in typical surface waters can be reduced to less than 0.1µg/l by adsorption on granular activated carbon (GAC) with an empty bed contact time of typically 15 to 30 minutes,

depending on the pesticide, its concentration, GAC type and system design. Ozonation will also reduce pesticide concentrations to varying degrees. It is unlikely that treatment to remove pesticides from small supplies will be practicable and where significant concentrations are detected it will be necessary to consider provision of an alternative supply.

#### **2.4.8 Chlorinated solvents**

Contamination of groundwater by chlorinated solvents can result from accidental spillage of chemicals, leakage from underground storage tanks, leakage from disposal sites and deliberate discharges to soakaways. The rate of transport of the solvents through the aquifer is dependent on the properties of the aquifer. Rapid transport can occur if the overlying geological material is highly porous or fissured. Contaminated water can travel large distances, making it difficult to pinpoint the source of pollution.

The UK drinking water quality regulations specify standards of 3µg/l for 1,2-dichloroethane and 10µg/l for the sum of the detected concentrations of tetrachloroethene and trichloroethene. Solvent concentrations can be reduced by aeration or activated carbon adsorption. Activated carbon adsorption is likely to be the method of choice for small water supplies although provision of an alternative supply may be an economic consideration.

#### **2.4.9 Disinfection by-products**

##### **Trihalomethanes (THMs)**

There are a large number of chemical species which may form as a result of the disinfection process and result in taste and odour issues. When chlorine is used as the disinfectant the most common by-products are THMs and so these are of significance to private water supplies.

THMs are formed as a result of reactions between chlorine and some organic substances present in raw water. Highly coloured surface waters which contain humic and fulvic acids are particularly prone to THM formation. The UK drinking water quality regulations specify a standard for Total THMs of 100µg/l for the sum of the detected concentrations of four specified THMs (trichloromethane, dichlorobromomethane, dibromochloromethane and tribromomethane).

THM formation can be controlled by reduction of the organic content of the water before disinfection, modification of the disinfection practice or the use of disinfectants other than chlorine, such as ultraviolet radiation or ozone. However, ozone may cause other problems by reacting with organic matter. THMs precursors can be removed to some extent by adsorption on activated carbon.

## Bromate

Bromate is not present in source waters but is formed by oxidation of bromide if ozonation is used for water treatment. Elevated bromide concentrations occur where saline intrusion occurs into fresh aquifers in coastal areas, increasing the potential for bromate formation during ozonation. Bromate is also a potential impurity in sodium hypochlorite, a commonly-used disinfectant. The UK drinking water quality regulations specify a standard for bromate of 10µg/l.

The formation of bromate during ozonation depends on several factors including concentrations of bromide, ozone and the pH. It is not practicable to remove bromide from the raw water and it is difficult to remove bromate once formed, although granular activated carbon filtration has been reported to be effective under certain circumstances. Bromate formation can be minimised by using lower ozone dose, shorter contact time and a lower residual ozone concentration.

## 2.5 Physical and chemical properties of water

### 2.5.1 pH value

The pH value of water is a measure of its acidity or alkalinity. Pure water is very slightly ionised into positively charged hydrogen ions ( $H^+$ ) and negatively charged hydroxide ions ( $OH^-$ ). Water is neutral when the numbers of hydrogen ions and hydroxide ions are equal. When the concentration of hydrogen ions exceeds that of hydroxide ions, the water is acidic and has a pH value less than 7. Conversely, when the concentration of hydroxide ions exceeds that of hydrogen ions, the water is alkaline and has a pH value greater than 7. The pH scale is logarithmic, therefore a change in pH value of one unit represents a tenfold change in the concentrations of hydrogen or hydroxide ions.

Acidity in raw water can result from the dissolution of carbon dioxide to produce weak carbonic acid. Groundwater and surface water may also contain organic acids produced during the decomposition of vegetation. Surface water derived from a peaty moorland catchment may have a pH value as low as 4. Alkaline waters result almost entirely from the dissolution of the bicarbonate, carbonate and hydroxide salts of calcium, magnesium, sodium and potassium, for instance from limestone aquifers. Soft acidic waters can cause corrosion of pipework and the dissolution of metals such as copper, zinc and lead. Hard alkaline waters can cause scale formation and some hard waters may also be plumbosolvent.

The UK drinking water quality regulations include pH as an indicator parameter and specify a minimum pH of 6.5 and a maximum pH of 9.0. In water treatment, the pH value can be changed by aeration and alkali or acid dosing.

### 2.5.2 Hardness

Water hardness is caused by dissolved salts of calcium and magnesium. Total hardness consists of temporary and permanent hardness. Temporary hardness is caused almost entirely by the carbonates and bicarbonates of calcium and magnesium. Temporary hardness is precipitated by evaporation and boiling. Permanent hardness is caused almost entirely by the sulphates and chlorides of calcium and magnesium. Permanent hardness is not precipitated by boiling.

The hardness of waters, expressed in mg/l  $\text{CaCO}_3$  (calcium carbonate), can be classified as shown below:

**Table 1: Water Hardness**

| Water           | Hardness (mg/l $\text{CaCO}_3$ ) |
|-----------------|----------------------------------|
| soft            | up to 50                         |
| Moderately soft | 50 – 100                         |
| Slightly hard   | 100 – 150                        |
| Moderately hard | 150 – 200                        |
| Hard            | 200 – 300                        |
| Very hard       | over 300                         |

The Drinking Water Directive and the UK drinking water quality regulations do not specify standards for hardness, calcium or magnesium. Softening can be achieved by lime-soda softening, where the addition of lime ( $\text{Ca(OH)}_2$ ) and sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) to the water causes the hardness compounds to precipitate. An alternative method, common in domestic water softeners, is ion-exchange (base exchange), whereby the calcium and magnesium ions in the water are replaced by sodium ions. Where water is softened by base exchange softening it is important to provide an unsoftened outlet for potable purposes. Installation of a softener just before the hot water tank or boiler is a more economical method for preventing precipitation of hardness salts (limescale) than softening the whole supply.

### 2.5.3 Colour

Water can be coloured by humic and fulvic materials leaching from peat or other decaying vegetation and by naturally occurring salts of iron or manganese. Surface water derived from peaty moorland catchments may be strongly coloured. The characteristic brown colour of such water is variable and often shows a strong seasonal effect, with concentrations being greatest in late autumn and winter. Water

derived from lowland rivers can similarly show a seasonal increase in colour following autumn leaf fall.

Water may appear coloured because of material in suspension and true colour can only be determined after filtration. Colour is expressed in mg/l on the platinum-cobalt (Pt-Co) scale, which is equivalent to measurements expressed in Hazen units (°H). The removal of colour from water is necessary not only for aesthetic reasons but also because chlorination of highly coloured waters can give rise to high concentrations of trihalomethanes. High colour also reduces the efficiency of disinfection by UV irradiation, chlorination and ozonation and will also cause fouling of reverse osmosis membranes.

The Drinking Water Directive includes colour as an indicator parameter without a numeric standard but with the requirement “Acceptable to consumers and no abnormal change”. The UK water quality regulations specify a standard of 20mg/l Pt-Co. Filtration techniques may be applied to small supplies but the efficiency of colour removal is usually relatively poor.

#### **2.5.4 Turbidity**

Turbidity is caused principally by inorganic matter in suspension including mineral sediments (e.g. from chalk) and oxides of iron or manganese but organic matter including algae can also cause significant turbidity. Most surface waters show particularly high turbidity following periods of heavy rainfall, whilst groundwater generally shows low to very low turbidity. However, variations following heavy rainfall, for example, may indicate rapid recharge bringing in contaminants from the surface.

Turbidity measurement gives a quantitative indication of the clarity of water and analysis is carried out using a nephelometer. Nephelometers measure the intensity of light scattered in one particular direction, usually perpendicular to the incident light and are relatively unaffected by dissolved colour. Nephelometers are calibrated against turbidity standards prepared from a suspension of formazin. The standard unit of turbidity is the nephelometric turbidity unit or NTU.

Turbidity is removed because high turbidity can impair the efficiency of disinfection and for aesthetic reasons. The UK water quality regulations specify a standard of 4NTU at consumers' taps with an indicator parameter value of 1NTU in water leaving a treatment works.

Rapid sand filtration or microstraining can remove coarse turbidity and some species of algae. Fine turbidity and many species of algae that may penetrate rapid filters can be removed by slow sand filtration or by coagulation followed by sedimentation

or flotation and filtration. A variety of filtration techniques can be successfully applied to small supplies, however, cartridge filters are the most widely employed.

### **2.5.5 Taste and odour**

Sources of taste and odour in source water include decaying vegetation, algae, moulds and actinomycetes. Taste and odour are usually associated with the presence of specific organic compounds released by the source agent which give rise to “earthy” or “musty” taste or odour. Chlorine and the by-products of chlorination can also cause complaints of taste or odour. Relatively high concentrations of iron, manganese and some other metals can impart an unpleasant metallic taste. Domestic plumbing materials and arrangements and in some circumstances water mains may also impart a noticeable taste or odour.

The Drinking Water Directive includes taste and odour as indicator parameters without numeric standards but with the requirement “Acceptable to consumers and no abnormal change”. The intensity of odour and taste is expressed as a Dilution Number, which is the dilution of the sample with odour or taste free water at which the odour or taste is undetectable. The UK water quality regulations specify standards for both odour and taste of 3 dilution number at 25°C.

Taste and odour are removed principally for aesthetic reasons. Taste and odour can be reduced or removed by aeration, ozonation or adsorption on activated carbon or, where chlorination is the source of taste or odour, by control of the disinfection process.

## **2.6 Radioactivity**

All environmental water contains traces of naturally occurring radionuclides, the concentrations of which depend on the origin of the water. The natural radionuclides of most relevance to drinking water supplies are radon (Rn) and uranium (U). Radon is volatile and as a result it can be released from water as a gas. This is of concern if the release occurs within a confined space with insufficient ventilation.

Radon and uranium are only found in significant concentrations in groundwater in certain parts of the UK, depending on the type of geology from which the groundwater originates. Further advice is available from local authorities, the British Geological Survey and the Radiological Protection Services of Public Health England). These substances are not significant for any surface water sources in the UK.

The concentration of radioactive elements in water is expressed in terms of their activity, in Becquerels per litre (Bq/l). There is a European Commission Directive (2013/51/Euratom) which specifies a parametric value for radon in drinking water supplies of 100Bq/l and an action level of 1,000Bq/l, above which action should be

taken to protect public health. The requirements of this Directive have been transposed into the national drinking water quality regulations. There is no official recommended level for uranium and The World Health Organisation recommends a provisional guideline value for total Uranium of 30µg/l. However, there are separate guidance levels for individual uranium isotopes.

Treatment for radon cannot include point-of-use systems fitted to the tap because, being volatile, it is released into the atmosphere whenever water is used. Under-sink treatment using an activated carbon filter is also inadvisable because the filter would become radioactive. Radon removal treatment therefore has to be installed before entry of water into a building and aeration is the preferred treatment technique although other methods are feasible. Uranium removal is best achieved by point-of-use systems.