The Regulations specify numerical standards for total and faecal coliforms, faecal streptococci and sulphite-reducing clostridia, and descriptive standards for total viable counts at 37°C and 22°C. Routine monitoring is not specified for faecal streptococci or sulphite-reducing clostridia. Examination for other organisms should be undertaken when it is considered on epidemiological or other grounds that they might be present and thereby be rendering the water unwholesome.

3.2 Definitions

Early water microbiologists recognised that faeces contain large numbers of bile salt-tolerant, facultatively anaerobic organisms capable of growing at 37°C and of fermenting lactose at this temperature, and so began to enumerate these organisms as 'indicators of faecal pollution'. The method generally employed was inoculation of MacConkey broth with incubation at 37°C for 48 hours, followed by subculture from cultures producing acid and gas to MacConkey agar to eliminate obligate anaerobes. The organisms isolated in this manner were referred to as "coliform organisms". As a consequence, the definition of coliform organism adopted was essentially that of *any* organism isolated by this method. Subsequent recognition of the existence of coliform organisms which were not always of faecal origin led to the introduction of differential tests to permit the separate characterisation of coliforms able to grow and ferment lactose at 44°C with the production of gas and to produce indole from tryptophan. These were considered to be exclusively of faecal origin and were called *Bacterium coli* Type 1, later to be renamed *Escherichia coli* (*E. coli*).

Definition of coliforms in terms of the method generally used for their detection was perfectly acceptable as long as methodology remained unchanged. When alternative methods began to emerge which do not rely on the production of acid and gas from lactose, the continued use of method-related definitions necessitated the adoption of confirmatory tests to verify gas production from lactose in liquid media.

Production of detectable volumes of gas from lactose within 48 hours at 37°C is not a characteristic which can in general be used to differentiate between species of the Family Enterobacteriaceae. Within most lactose-fermenting species strains occur, and may be common, which do not produce gas from lactose under these conditions. Indeed, some 5% of clinical isolates of *E. coli* from faeces have, in some studies, been anaerogenic at 37°C. There is no suggestion that the production of gas is in any way related to the sanitary significance of lactose-fermenting enterobacteria. However, if a coliform is to have been of faecal origin it must have been capable of growth at 37°C.

Within the Family Enterobacteriaceae, the fermentation of lactose invariably begins with the cleavage of lactose into glucose and galactose by the enzyme ß-galactosidase. Since the concept of the coliform is of strains of Enterobacteriaceae able to ferment lactose it follows that the most fundamental characteristic of a coliform must be the possession of a gene coding for the production of ß-galactosidase. The expression of this gene can be affected by many factors such as time, temperature and medium. Under different conditions the same organism may or may not ferment lactose sufficiently to register as a lactose-fermenter under the test conditions in use. The production of gas from lactose is a particularly variable characteristic. For these reasons new definitions of coliforms and *E. coli* are proposed (see section 7.7). These definitions should be regarded as practical working definitions for water examination purposes and not taxonomic definitions.

The new definition of coliform bacteria is based on the possession of the ß-galactosidase gene, and seeks to give a standard definition which is not method-related. It should facilitate the development of new operationally useful methods. For the methods described in this Report the presence of the ß-galactosidase gene is demonstrated by the production of acid from lactose. Alternative methods should give performance comparable to or better than that of the reference methods in this Report, and the production of acid from lactose should be the criterion against which alternative methods are to be assessed. It should be appreciated that different methods will demonstrate different populations of coliforms however they are validated. It should be noted that this definition no longer contains the requirement for the demonstration for the production of gas.

3.3 Microbiological Monitoring of Water Supplies

The water microbiologist is faced with the examination of water samples taken from different stages in the treatment process, from the initial water source to the point of use. Current practice assumes in large part that all requirements are equally well met by enumeration of total coliforms and *E. coli*, as simple indicators of faecal pollutio However, the waters to be examined differ widely, and include raw surface and grou waters for abstraction, treated water entering supply, water in distribution and wat within premises. In general, two types of indicator are required. These are a faec indicator which demonstrates the presence and extent of faecal contamination and quality indicator which can be used to measure the effectiveness of treatment and th integrity of distribution.

Whatever the organism used, monitoring relies on careful scrutiny of counts from sample collected over a period of time. There is no global equation for defining a 'significan single high count or a change in average count. Good knowledge of the water source, dat summaries which include graphs, and interpretation with common sense are importan

3.3.1 Raw waters

3.3.1.1 Surface waters and relatively polluted ground water

The water microbiologist has a clear requirement to use indicators, both of faecal pollution and water quality, when monitoring surface waters to be abstracted for potable supply. Of the traditionally used indicator organisms, *E. coli* is generally regarded as being a suitably specific faecal indicator and should continue to be used as such in this context.

When considering the bacterial load in relation to treatment, the ideal measure would be the total vegetative bacterial cell count, but since treatment does not reliably remove all bacterial spores the total viable count is of limited value. Some microbiologists (Bonde 1977, Mossel 1982) have advocated the use of total Enterobacteriaceae as indicators of process effectiveness and overall quality. However, to maintain historical continuity of data and comply with current legislation and practice, the use of the total coliform count is still recommended as a quality indicator.

3.3.1.2 Relatively unpolluted groundwaters

Many groundwaters are of historically good quality and show little or no evidence of a bacterial population. In such cases the total viable count at 37°C can be the most useful quality indicator, and can provide an early sign of more serious pollution. The total viable count at 22°C has limited public health significance but may perhaps provide useful information as a quality indicator. Additional valuable information can be provided by the examination for total coliforms and *E. coli*.

When total coliforms are detected but are found not to be *E. coli*, examination for faecal streptococci, which survive in water rather longer than coliforms, may help elucidate whether the coliforms were faecal in origin.

Clostridium perfringens spores are capable of surviving for considerable periods in water, and their presence in a groundwater in the absence of other faecal indicators may reveal a connection with surface water or an episode of pollution which had happened some time past. Examination for this organism is therefore worthwhile as part of the examination of a groundwater which has not been regularly monitored in the recent past.

3.3.2 Treated water entering supply

The water microbiologist examining treated water entering supply wishes to monitor treatment effectiveness using a quality indicator which is at least as resistant to the applied treatment as the most resistant pathogen of concern. Since it is known that certain enteroviruses and the cysts of *Giardia intestinalis* are more resistant to chlorine than *E. coli* and that oocysts of *Cryptosporidium* are almost completely resistant, the best quality indicator should be the one which is chlorine-resistant, but capable of being removed to a high degree by treatment before chlorination. Such properties appear to be shown by spores of *Clostridium perfringens* (Payment 1991a,b). Examination for these may be helpful when contamination of treated water with protozoal cysts or oocysts is suspected. This test is not normally in routine use by water microbiologists, and the monitoring for total coliforms is the most valuable test in current use in this context. In general, whether a coliform surviving treatment is of faecal origin or not makes no difference to its significance as an indication that treatment has been inadequate. However, it must be stressed that absence of coliforms cannot guarantee that viruses or protozoal pathogens are also absent.

Any finding of presumptive faecal coliforms must be viewed with concern and demands immediate attention. The implication is that there has been a breach of treatment integrity, with the risk that pathogens may be present.

3.3.3 Water in distribution

Information of interest includes;

(i) faecal ingress in distribution;

(ii) non-faecal ingress in distribution; and

(iii) bacterial growth within distribution.

Examination for a faecal indicator is essential if potentially or actually dangerous ingress has taken or is taking place. The faecal indicator of choice is *E. coli*.

Non-faecal ingress and growth in distribution are not always easily differentiated in practice, but similar information is required in both situations. Enumeration of total coliforms will provide useful information and is indeed required to satisfy the requirements of the Regulations.

The estimation of total viable counts at 37°C and 22°C may generate useful information. To be of value, samples need to be taken regularly from the same site. Random samples required by the Regulations for compliance monitoring provide total viable count information which is more difficult to correlate and interpret.

3.3.4 Water within premises

Once water enters consumers' premises changes in microbiological quality cease to be the responsibility of the water undertaker. Deterioration within premises is discussed in section 4.6.

3.3.5 Rationale for the use of indicator organisms

There is no absolute correlation between the number of indicator organisms and the actual presence or numbers of enteric pathogens, nor between the risk of illness occurring and the numbers of organisms present in a given sample. The finding of *E. coli* in a properly treated water indicates the presence of material of faecal origin and thus a potentially dangerous situation, the nature and extent of which is best determined by immediate 'on-site' and laboratory investigations.

The choice of tests in the detection and confirmation of coliform organisms, including *E. coli*, should be regarded as part of a continuous sequence, the extent for any particular sample depending partly on the nature of the water and partly on the reasons for the examination. Irrespective of their actual identity, all members of the coliform group of organisms as defined may be faecal in origin and an explanation of their presence must always be sought. If further investigation raises doubt as to the faecal nature of the pollution, examination for secondary indicator organisms such as faecal streptococci or *Clostridium perfringens* should be undertaken, since the presence of these can help resolve the uncertainty. Faecal streptococci occur normally in faeces, but in humans are usually greatly outnumbered by *E. coli*. If organisms in the coliform group, but not *E. coli*, are found in a water sample, the presence of faecal streptococci can afford evidence for their faecal origin. *Cl. perfringens* also occurs normally in faeces, though in much smaller numbers than *E. coli*. The spores of *Cl. perfringens* are capable of surviving in water for a much longer time than vegetative bacteria such as coliform organisms and faecal streptococci. They are also more resistant to chlorination. The isolation of *Cl. perfringens* from water thus suggests that faecal contamination has occurred in the more distant and in the absence of coliform organisms and faecal streptococci, that treatment ha been fully effective.

3.4 Other Possible Faecal Indicator Organisms

Coliforms, faecal streptococci and sporulating sulphite-reducing anaerobes are curre recommended for use as indicators of faecal pollution in water. Other micro-organi that have been proposed for this purpose include the *Bacteroides fragilis* gr *Bifidobacterium* species, *Candida albicans*, *Mycobacterium* species, *Rhodococ* *coprophilus* and coliphages.

These groups of micro-organisms are briefly described together with an indication of t value as indicators of faecal pollution. They do not appear to have been evaluated indicators of such pollution in treated waters. At present they are not considered to be any value in the routine examination of potable water, but may be useful in cert circumstances. See Appendix G for more details.

3.5 Indicators Distinguishing Human From Animal Faecal Pollution

The ability to distinguish between human and animal faecal pollution may be of value tracing the source of faecal pollution of a water supply and in assessment of the adequa of protection of a water supply, especially in rural areas.

In the past, two approaches have been suggested for distinguishing between human an animal faecal pollution. Firstly, an estimation of the ratio between one group of micr organisms and another (such as between faecal coliforms and faecal streptococci Secondly, the isolation of a specific indicator such as sorbitol-fermenting bifidobacteri (Appendix G), *Streptococcus bovis*, *Rhodococcus coprophilus* or *Enterococcus faecalis*

Because of the uncertainly associated with the interpretation of ratio estimates, the faecal coliform : faecal streptococcus ratio is no longer recommended for differentiating human from animal sources of pollution (APHA 1989).

Streptococcus bovis is the predominant faecal streptococcus in the gut of cattle and most farm animals while being relatively uncommon in the human gut (Mara and Oragui 1985). Oragui and Mara (1981) have described a selective medium for the enumeration of this micro-organism, but its usefulness as a specific indicator of animal faecal pollution is limited by its short survival time outside the gut. It could be used when found in conjunction with *Rhodococcus coprophilus*, to indicate the recent nature of faecal pollution from animals; its absence when *Rhodococcus coprophilus* is present would suggest more remote pollution.

Enterococcus faecalis has been used to indicate pollution of human origin as it is particularly associated with man (Mead 1964). However, *Ent. faecium* is considered by others to be more prevalent in human faeces (Guthof 1957, Buttiaux 1958). Care is therefore needed when interpreting results as the prevalence of *Ent. faecalis* depends on the source and its absence does not necessarily exclude human faecal pollution.

3.6 Other Bacteria

3.6.1 Colony counts

Other micro-organisms, such as those associated with soil and vegetation, also occur naturally in ground and surface waters. Many of these organisms are usually able to survive for long periods in the environment and in the warmer months may multiply considerably. Counts of aerobic organisms which grow as colonies on plates of a nutrient agar under defined conditions thus provide a useful means of assessing the performance of water treatment processes. Such colony or plate counts can also provide a general indication of the bacterial content and hence the hygienic quality of water supplies, although the counts themselves have little direct health significance. In practice, changes in the pattern of colony counts of samples from a given supply are usually much more significant than the actual numerical count of any particular sample. A sudden marked change in the colony count of water in a supply may give forewarning of more serious pollution, whereas deviations in the expected seasonal trend may indicate longer-term changes in the supply. Colony counts, if carried out regularly, are also of particular value when water is used for the large-scale preparation of food and drink. Some bacteria can multiply within the distribution network by using nutrients derived from fixtures and fittings or from assimilable or particulate organic carbon in the water itself. See section 4.3.

3.6.2 *Pseudomonas* group

Fluorescent pseudomonads are widespread in the environment and are able to multiply on a wide range of substrates. When these organisms gain access to treated water, they may proliferate in certain circumstances by utilising nutrients either present in the water or derived from unsuitable materials used in the construction of distribution systems or in domestic plumbing installations. They may also grow on membranes during routine coliform testing, though they do not form yellow colonies.

Pseudomonas aeruginosa, an important member of the group, may be derived from human or animal excrement, but its presence in faeces is not universal. Because of this and its ability to multiply in water containing suitable nutrients it cannot be used as an indicator of faecal pollution. Its presence in potable water is, however, undesirable as it can itself act as an opportunist pathogen; its subsequent growth can also be associated with considerable deterioration in microbiological quality of the water. This may affect the colour, turbidity, taste and odour of the water, and result in consumer complaints. Deterioration of this kind is particularly liable to occur, for example, where there is limited flow in part of the distribution system, and also a rise in the temperature of the water. Other fluorescent pseudomonads, especially *Ps. fluorescens* and *Ps. putida*, may also give rise to problems in treated waters by producing slimes during growth which often form the basis of consumer complaints. Since these organisms can grow in so many different situations it is impractical to give any guarantee about their absence from distributed water—however desirable this may be—although they should not normally be present in water for drinking when it leaves the treatment works. In the United Kingdom the enumeration of fluorescent pseudomonads, and *Ps. aeruginosa* in particular, is therefore **not** recommended as a routine procedure, although it may be of value in the investigation of consumer complaints and distribution problems. It may also be of value within certain industries, for example in the manufacture of food, drink or pharmaceutical products, where water of exceptional microbiological purity is often required. In hospitals and other places where immunocompromised persons are particularly prone to infection, *Ps. aeruginosa* may be of some importance as an opportunist pathogen and its presence in water may thus be of concern. In such situations, where water free from *Ps. aeruginosa* is desirable, special treatment facilities may be required on-site. For all these reasons, methods suitable for the detection and enumeration of *Ps. aeruginosa* in water are given in section 7.13, although it is emphasized that monitoring potable supplies for *Ps. aeruginosa* is not recommended as a routine procedure.

3.6.3 *Aeromonas* group

Aeromonas species are natural inhabitants of the fresh water environment and consequently are common in source water. They can infect wounds acquired in water and they are sometimes responsible for septicaemia particularly in patients with an impaired immune response. There is also growing circumstantial evidence that some strains may cause diarrhoeal disease. The study of aeromonads as a cause of infection is hindered by the difficulty in differentiating the genetically definable species by easy practicable chemical tests. In addition, some species appear on membranes during water treatment testing as small, lactose-fermenting colonies which can be easily confused with coliform bacteria. In simple terms it is useful to divide the species into the non-motile group, *A. salmonicida*, and the motile aeromonads. In the context of drinking water, the motile species are of more significance since they include the strains isolated from patients and are common in natural water where they sometimes form a large portion of the total heterotrophic bacterial flora. Motile aeromonads can be present in high numbers in fresh water both in the presence and absence of faecal pollution. High numbers are common in sewage effluent but they are of a type different from those found in pristine fresh water, although all types have been incriminated as possible enteric pathogens. The non-motile aeromonads are pathogens of fresh-water fish but are not as common in water as the motile species.

Aeromonas species are readily killed by chlorine and other commonly used water disinfection processes. However, any survivors of the initial treatment or any aeromonads entering the distribution system downstream through accidental damage, back flow or other causes may grow and multiply significantly. The amount of this growth depends on

the availability of nutrients in the water and on the temperature. Thus the
Aeromonas species in drinking water does not necessarily indicate faecal p
reflects inadequacies either in the treatment process or within the distribution sy
As with pseudomonads, because of their ubiquity there is no need to test ro
aeromonads. Other determinations such as residual chlorine, temperature an
organic carbon may indicate the potential for aeromonads to grow. However, ex
for aeromonads may be useful when investigating distribution problems. Becau
possible pathogenicity their detection in water may be required in pharm
manufacture, food and drink manufacture and hospitals. Accordingly, tentative
for their isolation are included in section 7.14.

3.6.4 *Mycobacterium* species

The mycobacteria include both obligate parasites and saprophytes. Some species,
M. kansasii, *M. xenopi* and *M. avium*, have been isolated from tapwater and
pathogenic for humans in certain circumstances (Collins, Grange and Yates
However, the routine examination of potable supplies for these micro-organism
recommended because of the prolonged incubation required, the difficulty in i
cation, and in the interpretation of the significance of any isolate.

3.6.5 Nuisance organisms

These organisms can cause objectionable taste, odour, colour and turbidity in wat
may interfere with treatment processes by blocking strainers and filters. They
morphologically and physiologically diverse group which includes fungi, actinomy
iron and sulphur bacteria, algae and protozoa. Most of them are controlled by the
water treatment processes, but occasionally may establish themselves in sedimen
slimes and on materials within the distribution system (Hutchinson and Ridgway 1
Routine examination for such organisms is not recommended because of their div
nature and unpredictable occurrence.

3.6.6 Cyanobacteria (Blue-green algae)

Cyanobacteria are a group of photosynthetic organisms with features of both algae a
bacteria. They occur naturally in many inland standing bodies of water, and can often
seen forming a surface scum or "bloom". A bloom is more likely to occur under stab
weather conditions, and is brought on more quickly as a result of increased temperatu
and light. The ability of many cyanobacteria to move through the water and to accumula
at the surface is due to their possession of gas-filled vesicles, which make them buoya
(Walsby 1975).

Problems of taste and odour have been associated with algal blooms. The ability o
cyanobacteria to produce toxins is well reported but there is no evidence that these pos
any significant risk to health via water supplies.

3.6.7 *Legionella pneumophila*

Legionellas are not normally infective when swallowed, and are therefore not a problem for potable water supplies as such. For this reason details of methods for their isolation are not included in this Report. However, legionellas can colonise domestic and other hot and cold potable water systems, and when aerosols generated from such colonised systems are inhaled infection can result. Attention is therefore drawn to the booklet by the Health and Safety Executive, 'The control of legionellosis including Legionnaires' disease' (HSE 1991) and the BSI methods for sampling (BSI 1992a) and for detection and enumeration (BSI 1992b) of *Legionella* organisms in water, where appropriate guidance can be found.

3.7 Enteric Viruses

The increasing recognition of water-borne enteric viral infections has focused attention on the need to detect viruses in potable water. However, there is little evidence that water suitably treated to comply with bacteriological drinking water standards will transmit viral infection. The Directive requires the absence of pathogens, including enteroviruses, in drinking water and WHO (1993) recommends that drinking water must essentially be free of human enteroviruses to ensure negligible risk of transmitting infection. The Regulations do not mention viruses specifically but require that water supplied for drinking, washing or cooking, or for use in food production, does not contain any organism at a concentration or value which would be detrimental to public health. At present, methods are available only for detecting enteroviruses and rotaviruses. They require large sample volumes, which should be collected as soon as a potential need is perceived, are technically demanding and have a variable efficiency of detection. The routine analysis of potable water for viruses is thus not recommended. The advantages of monitoring for enteroviruses stems from their environmental resistance. As they survive longer in water and are relatively more tolerant of chlorine disinfection than *E. coli* they have the potential to indicate faecal pollution over a longer timescale and at lower levels. Furthermore, methods most generally available are those for isolating certain human enteroviruses. The presence of such viruses in potable water will indicate faecal pollution, though they are not known to be responsible, *per se*, for symptomatic water-borne infection.

Consideration should be given to testing for viruses when there is evidence of post-treatment pollution of a potable water supply. Testing for viruses may also be carried out when there has been a problem with the treatment process, such as a partial failure of disinfection. Examination for viruses may also be done as an additional investigation when there is a suggestion of a possible outbreak of viral infection associated with a potable water supply.

Useful information on the efficacy of the treatment processes may be obtained by monitoring for the presence of enteroviruses in a surface water source and at stages through the treatment works. Increases in the viral content of a surface source water may be an indication for a modification to the level of treatment required.

Details of appropriate methods for detecting viruses in all kinds of water and related materials can be found in 'Methods for the isolation and identification of human enteric viruses from water and associated materials' (SCA 1994). It is likely that advances in technology will, before long, extend the range of available methods to include the detection of more water-borne viral pathogens.

3.8 *Giardia intestinalis, Cryptosporidium* and *Entamoeba histolytica*

Several protozoan parasites, including *Giardia intestinalis* (= *lamblia* = *duodenalis*) and a number of amoebae, can be transmitted in water and may give rise to infections in humans. The life cycle of each parasite is different, and the stage which is detectable in water is the cyst for *Giardia* and the oocyst for *Cryptosporidium*. Provisional methods for the isolation and identification of these and of some amoebae can be found in SCA (1989).

Cryptosporidium species were first recognised more than 80 years ago. They are able to infect a wide range of animal hosts including calves, lambs, piglets, poultry, rodents and dometstic pets, and are now recognised as a significant cause of human gastro-enteritis. Infection is transmitted by means of oocysts, the environmentally hardy stage of the parasite containing the infective stage (DoE/DH 1990).

Small numbers of cryptosporidial oocysts are likely to be present from time to time in most surface waters, particularly after heavy rainfall, and when certain livestock activities and slurry spreading occur. Oocysts can be present in discharges from sewage works and ground waters, which may become contaminated as a result of fractured or damaged sewage systems, and the uncontrolled discharge of septic tanks and cesspools. (See also section 4.1.6).

The cysts of *Entamoeba histolytica* may be found in waters contaminated with sewage. Techniques for the detection of this organism in water supplies have not been properly validated, but it is the general consensus that methods concentrating *Giardia* will be effective for *Entamoeba* species. The detection of cysts morphologically identical to those of *E. histolytica* does not have the same impact as the detection of *Giardia* or *Cryptosporidium* because species of *Entamoeba*, not infective for humans but with morphologically indistinguishable cysts, are found in wild, domestic and farm animals. Currently there is no commercially available antibody stain specific for *E. histolytica* cysts.

3.9 Animalcules in Mains Water

The presence of animals, either whole or in part, has been recognised as a cause for concern. Although their presence may indicate a water supply or water treatment problem, and their detection must always lead to an immediate assessment of microbiological

quality, there is no known health risk associated with animalcules commonly
mains water in the United Kingdom. The source of the water supply and the tre
receives generally affect the species present, their abundance and their ability to
the distribution system. A more detailed account of the presence and identific
animalcules in mains water is given in Appendix F.

3.10 Other Aesthetic Problems

An ideal potable water should be clear, colourless, odourless and acceptable to the
In practice, the aesthetic properties of a drinking water will depend to a large exte
source. Water obtained from deep bore-holes in sandstone or chalk will, in its un
state, generally be nearer the ideal than a water derived from an upland peaty sour
degree of treatment required to render a source water wholesome may also have an
on its organoleptic properties. In most instances, when a potable water excites a
comment regarding its appearance, taste or odour, the causes tend to be physi
chemical rather than microbiological. It is nevertheless advisable to examine a s
microbiologically as a check on the general quality of the water. The odour of hyd
sulphide may result from the bacterial reduction of sulphates. Musty, mouldy or e
tastes may be the result of growth of fungi or actinomycetes in the cold water pip
buildings where the temperature of the cold supply is undesirably high (Holden 1
Increased chlorination following, for example, repairs on the distribution syste
sometimes responsible for complaints regarding taste.

Chapter 4: Maintenance of Water Quality

4.1 Source Protection

4.1.1 Introduction

No source of water that is intended for human consumption can be assumed to be free from pollution. All sources have different microbiological qualities and may be subject to natural or man-made sources of pollution which may result in the deterioration of water quality to the point where treatment is no longer effective in removing the contamination. If this happens it may be necessary to use an alternative supply until the pollution is remedied.

Much can be done to limit pollution by regular inspection and monitoring of water sources, by encouraging the use of good agricultural practice and by controlling effluent discharge. Guidance on these matters is given in the Water Authorities' Association report (WAA 1988), the Code of Good Agricultural Practice (Ministry of Agriculture Fisheries and Food and Welsh Office Agriculture Department) (MAFF/WOAD 1985), and Policy and Practice for the Protection of Groundwater (National Rivers Authority) (NRA, 1992). This guidance should be followed by all those responsible for the protection of water sources.

4.1.2 Sources of pollution

4.1.2.1 Natural pollution

The quality of many source waters will depend upon geology, soil type, natural vegetation, climate and run-off characteristics. Disruption of natural geology and heavy rainfall can dramatically affect water quality. Wild animals and birds can also be natural sources of human pathogens, see section 2.1.1.

4.1.2.2 Agricultural pollution

All types of water sources may be subjected to contamination by agricultural activity. Free-range animals may deposit excreta into water and animals like cattle also have a habit of wading and may stir up sediments. Much can be done to reduce the risk of water contamination from slurry spillage, or the use of slurry on land followed by surface run-off, by considering controlling access to land, reaching agreements with land owners over agricultural practices and adopting aquifer protection policies.

4.1.2.3 Recreational activities

Recreational activity may cause pollution through direct contamination of water with faecal material or indirectly by faulty drainage or leakage from sewers and septic tanks provided as part of public access facilities. Proper control of recreational activities or treatment commensurate with the recreational use of water should provide adequate protection. Where the public has access to reservoirs, consideration should be given to the provision of toilets and handwashing facilities and where these are provided they should be well maintained and inspected regularly.

4.1.2.4 Effluent and waste disposal

The discharge of effluents from sewage treatment works, septic tanks and cesspools can dramatically increase the microbial content of surface waters. The installation of septic tanks and cesspools should be in accordance with the British Standard Code of Practice for the Design and Installation of Small Sewage Treatment Works and Cesspools, BS6297 (BSI 1983). The discharge of industrial effluents, particularly from abattoirs and cattle markets, may also contain large numbers of pathogenic micro-organisms which increase the risk of contamination. Slurries and solid material from sewage treatment and animal waste should be spread on land only with strict control, and water undert recommended to observe the Code of Practice for the Agricultural Use of Sewa (DoE 1989) in this matter. Due notice must be taken of any zones of protection effort made to prevent accidental spillage or heavy surface run-off following r

4.1.3 Water sources

4.1.3.1 Upland reservoirs

The microbiological quality of upland reservoirs, which depend for their su catchment areas and feeder streams, is usually very good. Plans should be a showing any installation which may cause pollution and such plans should be ke date. All catchment areas should be inspected regularly and agricultural and recr activities associated with reservoirs should be controlled to minimise excessive c nation by spillage, drainage or access of animals and people.

4.1.3.2 Rivers, lakes, lowland and pumped storage reservoirs

The microbiological quality of these source waters may be much poorer than upland reservoir waters necessitating adequate treatment regimes to be deve Occasionally, quality may deteriorate suddenly because of the spillage of efflue heavy rain causing direct run-off from land or the operation of storm overflows. such incidents occur, treatment may no longer be wholly adequate to protect the supply. Water abstracters should ensure that they are aware of potential sour pollution into rivers, and any pollution incident likely to affect water treatment sho notified to them as quickly as possible. The provision of bankside storage greatly re the impact of pollution events.

4.1.3.3 Springs, wells and boreholes

Groundwater forms an important part of water resources and provides up to 35% o potable water supplies in the United Kingdom. It is usually of much better quality surface water and often only requires chlorination before being put into supply. Aq contamination may be caused directly by the seepage of material or by the movemen groundwater of poor quality into areas of better water quality. Because aquifer pollu can exist for very long periods of time and may be impossible to remedy, it is preferabl take preventative measures to minimise pollution rather than to provide remedial actio develop alternative sources of water, which may be expensive.

Spring water should be collected in secure underground chambers and covers should raised clear of the ground and surrounding vegetation. Wells and boreholes should be li to a depth sufficient to prevent the entry of any surface pollution or polluted sub-soil wa There should be an effective seal between the lining and the ground. The head of a well borehole should be protected and the installation should be checked at regular intervals ensure that ingress does not occur. Up to date records of the percolation area must be ke showing any sewers, septic tanks, cesspools, waste disposal sites, soakaways or any oth sources of potential pollution. Water undertakers should be consulted if any new sites structures are proposed. There may be areas where the establishment of a protection zo might be considered to prevent contamination of the aquifer. Consideration should given to the geological nature of the aquifer and the presence or absence of any overlyi drift which may provide additional protection. The accumulation and spreading of huma and agricultural wastes might be prohibited or restricted in protection zones.

4.1.4 Monitoring source waters

Regular monitoring of source water is essential in order to provide information abou general water quality and to establish seasonal variations in water quality and changes i response to weather and other factors. Under circumstances where the microbiologica quality of the water deteriorates or where there is suspicion of microbial contamination water abstractors should initiate immediate investigations and take appropriate remedia action. Consideration should be given to the introduction of more detailed microbiologica monitoring including additional tests for bacteria, viruses and intestinal parasites. New water sources of which the microbiological quality is unknown should be subjected to intensive microbiological monitoring to establish the water quality and to ensure that proposed treatment regimes are adequate. The Regulations include specific requirements to monitor new sources.

4.1.5 Action following a pollution incident

It is essential for water undertakers to have plans to cope with pollution incidents and these should be rehearsed regularly. A comprehensive list of channels of communication should be available at all times and this should be kept up to date. Laboratory facilities for microbiological analysis should be adequately staffed and equipped to cope with emergencies.

4.1.6 *Cryptosporidium*

Following an outbreak of cryptosporidiosis in Swindon and Oxfordshire in 1989 a Government appointed Expert Group, under the chairmanship of Sir John Badenoch, was convened to advise upon the significance of *Cryptosporidium* in water supplies.

The Expert Group reported in 1990 (DoE/DH 1990) and its recommendations resulted in the establishment of a national collaborative programme of research which has been steered by the Drinking Water Inspectorate. The programme included the following studies: occurrence and distribution; removal and inactivation in water treatment; methods of anlysis; assessment of viability; and infectious dose. The Report of the Expert Group should be consulted for recommendations on means of reducing the risk of infection, preventing oocysts of *Cryptosporidium* from gaining access to water supplies, monitoring strategies, and investigation and management of outbreaks.

In July 1992, the Drinking Water Inspectorate published an interim report on the national research programme which included a review of progress worldwide (DWI 1992). It was apparent that there was a need for further work on more precise quantification of the level of risk and establishment of the degree of catchment protection and type of water treatment necessary to eliminate the risk, or to reduce the risk to an acceptable level. This programme of working is now drawing to a conclusion and the results will be published through the Water Research Centre and the Foundation for Water Research.

4.2 Water Treatment

4.2.1 Objectives of water treatment

The objective of water treatment is to produce a final water which is microbiologically and chemically safe for consumption, is not corrosive towards materials in contact with water and is aesthetically acceptable. The range of treatment processes includes clarification and sedimentation, filtration and disinfection. Depending on the source and nature of the water, one or more of these processes can be used, each further preparing the water physically and chemically for disinfection. Treatment to make water microbiologically safe to drink constitutes a complex and highly technical field and for further information the following should be consulted: Cox (1964), Skeat (1969), Holden (1970), Hutchinson and Ridgway (1977), the Standing Committee of Analysts (SCA 1980), White (1985), and Hall and Hyde (1992). Whilst each of the treatment processes is able to reduce the numbers of particular micro-organisms, no process can ever ensure their complete removal; in the UK, therefore, disinfection (usually by chlorination, although other techniques are becoming more popular) is the final essential safeguard against water-borne microbial disease.

When chlorine is used the dose should be so selected that the chemical demand of the water is satisfied and that an adequate contact time is achieved before water is distributed to any consumers (WHO 1993). An appropriate chlorine residual should be maintained throughout the distribution system and should preferably be present in water at consumers' taps, to reduce the risk of microbial regrowth and to provide an indication of the absence of post-treatment contamination (WHO 1993). It is essential therefore that the chlorine residuals are monitored regularly both at the works and in distribution. It is important to distinguish between the different forms of chlorine (free or combined) and to check the pH and temperature of the water. These and many other factors have a marked effect on the efficacy of chlorination (SCA 1980).

Although micro-organisms differ in their susceptibility to chlorine (in decreasing or resistance: protozoan cysts, bacterial spores, enteric viruses and enteric bacteri combination of chlorine concentration and contact time necessary for inactivati intestinal viruses and pathogenic bacteria can be readily achieved by a properly des and operated treatment works. It should be noted that certain incidents of water- disease in the United Kingdom and elsewhere have occurred as a result of inade chlorination or because no such facility was installed or in use (PHLS 1978, Galbrait 1987, Benton et al 1989).

Attention has also been drawn recently to the possible health effects of certain che compounds formed as by-products of chlorination. The World Health Organi (WHO) International Agency for Research on Cancer (IARC) concluded in 199 "there is inadequate evidence for the carcinogenicity of chlorinated drinking wa humans" (IARC 1991). Expert advice was obtained by the Department of Health in 1992. The committee on Carcinogenicity of Chemicals in Food, Consumer Product the Environment concluded that modification of chlorination processes or their re ment was not required on the available data on cancer epidemiology, animal carcin icity and mutagenicity in relation to chlorination by-products in drinking water 1993b). It is prudent to reduce the concentration of disinfection by-products if this c achieved without prejudicing the microbiological quality, and to continue to identif products and assess their potential for affecting health. It also continues to be the cas the microbiological safety of potable water supplies is of paramount importance (1993) and the benefits of chlorination are re-affirmed. However, it is also consi important to re-emphasise that when sources of surface water, or groundwater impact by surface water, are utilised then the installation of multiple barriers to the transmissi infection is strongly recommended as a series of safeguards against water-borne di (WHO 1993).

While the proper design, operation and maintenance of treatment works is of the ut importance, frequent microbiological monitoring is necessary for adequate assessme the hygienic quality and safety of drinking water. Chemical and biological tests— from those required for treatment control purposes—can be made less frequently. information derived from microbiological tests must however be assessed in the lig thorough practical and working knowledge of the conditions applying at the so throughout all the stages of treatment to which the water is subjected, and i distribution system itself.

It is particularly important that the microbiologist should consider the implications o sudden pollution of a previously satisfactory supply Failure or inadequacy of treat processes, particularly chlorination, can be very serious, but other hazards may c deterioration in microbiological quality. These include contamination via air-valves stop valves, infiltration into mains and service reservoirs, cross-connections, back and venturi effects. Sudden changes in the microbiological quality of ground waters occur through cesspool leakage, from accidental or illicit contamination of the gath grounds or by polluting material gaining access through faults or fissures in the stra through defects in the well or borehole lining. Heavy rains following prolonged dro may enhance the risk of pollution of a water source and service reservoirs if the structu unsound. Increased pumping from wells, perhaps as a result of prolonged drought, also lead to the pollution of previously satisfactory sources. Whenever these or environmental conditions occur the frequency of microbiological examination shoul increased; the points of sampling being carefully chosen so that any changes in qu may be identified quickly and appropriate action taken.

4.2.2 Point-of-use and point-of-entry devices

Public water supplies drawn directly from the mains do not on health grounds re further treatment. In some instances, however, consumers may object to the tast appearance of a mains water supply, or to certain of its constituents, and may wish to m use of a device to remedy these. This is acceptable provided that the device and its comply with the water supply bye-laws. The device may be fitted to the supply as it e the premises (point-of-entry device) or at a single tap (point-of-use device), usually i kitchen. Such a device may also provide a convenient means of improving the quality small private supply. If it is used to ensure that a private supply complies with legislative requirements it will be necessary to site it at the point of entry to the premises and it will need to be capable of fully treating the water. Details of treatment devices suitable for private water supplies are given in the Manual of Treatment for Private Water Supplies (DoE/WO/SO 1993).

4.2.2.1 *Disadvantages of point-of-use and point-of-entry devices*

Devices that incorporate some form of filter medium or ion-exchange resin will often allow bacteria to proliferate within the unit, so that in time, water leaving the device may yield increasing bacterial counts. Activated carbon filters in a warm environment provide an ideal growth medium for many bacteria and regular maintenance, especially regular renewal of the unit, is essential if the quality of the water leaving the filter is to remain acceptable (Geldreich et al 1985).

The use of these devices may also initiate adverse health effects. Ion-exchange resins may remove some desirable elements such as calcium from consumers' diet while simultaneously increasing the intake of sodium. Bacterial colonisation of reverse osmosis units has been linked to gastro-intestinal symptoms (Payment et al 1991), although the causal mechanisms remain to be explained.

4.3 Biofilms

In low-nutrient aqueous environments, micro-organisms preferentially colonise surfaces rather than grow in the planktonic phase. This gives them nutritional advantages and can protect them from adverse environmental influences. The organisms colonising surfaces become embedded in a matrix of extracellular polymeric substances which are excreted by the organisms themselves. This layer of growth is termed a biofilm and in water distribution systems is usually quite thin, not exceeding a few hundred microns. An appreciation of the properties and role of biofilms is imperative for an understanding of the microbiology of man-made water systems. In both the natural environment and water distribution systems biofilms are usually composed of complex consortia of micro-organisms including bacteria, fungi and protozoa. The metabolic by-products of one organism can provide nutrients for others. This enables organisms, that would otherwise be unable to grow by themselves, such as *Legionella pneumophila*, to proliferate. Biofilm distribution is patchy and can vary considerably even over distances of a few millimetres or less. Biofilms can also accumulate organic and inorganic debris from external sources by the adsorption of silt, sediments, inorganic precipitates and corrosion products. These materials can provide extra nutrients for microbial growth.

No material that comes in contact with water is immune to colonisation but some materials may support or promote more growth than others. To maintain water quality during distribution, construction materials should not promote growth. Non-metallic materials should comply with BS 6920, which includes a test for growth promotion. An equivalent standard does not exist for metals which, although they can become colonised with biofilms, cannot provide organic nutrients for growth.

Most of the growth that takes place in distribution systems probably occurs in biofilms and the majority of the planktonic organisms are derived from organisms leaving the biofilm or by the biofilm sloughing off. Organisms that have survived disinfection, including coliforms, can become attached to biofilms where they may subsequently grow. Biofilms are important because they contribute to many of the problems that can occur in water distribution systems. They may promote or cause corrosion of pipes, can be responsible for off-flavours, contribute to discoloured water, harbour pathogens such as *Legionella* species, increase the chlorine demand and provide a site for the regrowth of coliforms. Biofilms also protect organisms from disinfection. The contact time required to produce a particular degree of disinfection of organisms in the biofilm by chlorine may be hundreds or even thousands of times greater than that required to get an equivalent degree of death for the same organisms suspended in water (LeChevallier, Cawthon and Lee 1988). Thus it is possible for biofilms to continue to survive and grow even when the water contains residual chlorine at the concentrations used in drinking water. This reduction in disinfection efficiency is caused by the diffusion of the disinfectant being reduced by the biofilm and is less for monochloramine than chlorine. From the foregoing discussion it is clear that the efficient disinfection of a water system depends on the control of biofilms and disinfection failures may occur through failure to take this into consideration.

Measuring the degree of microbial contamination of water (planktonic phase) gives
estimate of the total microbial activity in a water system. Unfortunately it is diffi
measure the degree of biofilm formation routinely because of problems of coll
representative samples of biofilm. Other physical and chemical determinations s
total and assimilable organic carbon, dissolved oxygen and temperature could be m
areas where biofilms are considered to be a problem. It should always be remembere
the inability to detect micro-organisms in water samples does not mean biofilm
absent.

4.4 Microbiological Monitoring of Drinking Water

4.4.1 Routine monitoring—general considerations

The Regulations require water undertakers to define water supply zones in which not
than 50,000 people normally reside. Samples are required to be taken from consum
taps in these zones at specified frequencies related to the number of people residing i
zone. Samples are required to be taken of the water leaving treatment works at frequen
related to the volume of water or population supplied. Water in all service reserv
including water towers is required to be sampled once in each week the service reservoi
water tower is in use.

For each supply zone, the number and location of sampling points must be determined
ensure, as far as possible, that the data produced are representative of the quality of
water supplied in that zone. At least 50% of the sampling points for microbiological
residual disinfectant analyses must be selected at random.

"The Private Supplies Regulations" also specify numerical standards for identi
microbiological parameters. It is the duty of local authorities to take and analyse sampl
of water according to prescribed frequencies depending upon the classification of
private water supply.

4.4.2 Action when standards are infringed

Immediate action is essential whenever there is any indication that a microbiologica
standard has been infringed. At the least, this will require the examination of anothe
sample taken from the same and/or a closely related sampling point together wit
confirmation of the nature of the indicator organism found in the original sample. Furthe
action may be required and details are given in Chapter 7 of the Guidance Document and
in sections 2.1.2 and 4.6.2.2.

4.4.3 Reviews of the quality of a water supply

The microbiological quality of water supplies should be reviewed regularly. This may
provide evidence of seasonal variations in quality in a particular zone which may not
otherwise be apparent. Records of the results of all laboratory tests should therefore be
maintained to enable comparisons to be made. In addition, the Regulations require water
undertakers to provide local authorities, at least annually, with information on the quality
of the supplies in their area.

Total coliforms should always be absent from treated water in supply. In practice, this ideal
may not be consistently attainable and is recognised in the Regulations. Water shall be
regarded as satisfactory in respect of the requirement as long as 95% of all samples taken
during the previous year (or the last 50 samples, if fewer than 50 have been taken during
the year) have not contained total coliforms. The provision does not, of course, apply to
faecal coliforms (*E. coli*). Any intermittent and related low-level failures will require
investigation and remedial action.

Regular colony counts provide an indication of overall microbiological quality and each
supply zone will have its own particular 'normal' range. Any significant change in this
range, suddenly or as a trend over time, and especially of counts at 37°C, will require
investigation and, where necessary, remedial action. For colony counts, the Regulations
prescribe there should be no significant increase in levels over those normally observed.

4.5 Microbiological Sampling for Operational Evaluation

4.5.1 Raw water sampling for process evaluation

The Regulations require monitoring of a new source before it is put into supply to establish whether it is wholesome and what treatment is necessary to render it wholesome. In situations when raw water is prone to pollution there should be contingency plans for providing additional treatment, particularly chlorination, or to provide alternative supplies. In such circumstances there may be a need to consider automatic continuous monitoring of water quality and residual disinfection control systems. In any case a more intensive investigation should be undertaken when any unexplained deterioration in quality occurs.

4.5.1.1 Frequency of sampling

The Water Authorities' Association Report (WAA 1984) gives detailed information and frequencies for raw water monitoring, including comprehensive consideration of microbiological monitoring. Upland reservoirs will show seasonal variations in water quality. Catchment control is essential and guidance is given in the Water Authorities' Association Report (WAA 1988).

Underground fresh water supplies are expected to be free of pathogens. Experience has shown however that groundwater can become microbiologically contaminated (Short 1988) so regular examinations for bacterial indicators and colony counts are recommended for all borehole sources.

Samples of water should always be taken before boreholes, which have been pumped to waste or left standing, are put back into use. There may also be a need, in circumstances where pollution has occurred, to examine the water for bacterial, viral and protozoal pathogens.

4.6 Investigational Sampling

4.6.1 Water at the point of use

Compliance monitoring programmes based on periodic sampling do not provide absolute or continuous assurance of attainment of a satisfactory microbiological quality at all points where water is available for use by consumers. For this reason undertakers may receive valuable feedback from their consumers, indicating where a local deterioration in water quality may be occurring. Effective monitoring of consumer communications is important and can assist in the investigation of microbiological quality problems.

Many local authorities and water undertakers collect investigational samples for microbiological examination whenever they become aware of complaints of ill health that could possibly be related to drinking water. Many undertakers also collect microbiological samples in the course of investigations into aesthetic or other quality complaints. These investigations lead to considerable knowledge about water quality at the point of use and may reveal incidents of back-flow or other causes of water quality deterioration in distribution and plumbing systems. Formal procedures for investigating, recording and reporting all consumer complaints, will assist management of these complaints.

An immediate response should be made to all consumer complaints, especially if there is any suggestion of ill-health that may be related to drinking water. Sampling for coliforms, including *E. coli*, and where necessary, additional microbiological indicators such as faecal streptococci should ideally be carried out on the same day as receipt of such a complaint, together with any other chemical, biological and physical parameters deemed appropriate.

It is essential that those who deal with complaints from consumers are issued with clear guidelines describing the information to be obtained from complainants. The practice of collecting a microbiological sample wherever feasible in response to complaints concerning the quality of water supplies is commended as a means of providing further water quality data.

4.6.2 Sampling strategy for investigative purposes

4.6.2.1 Response to consumer complaints in building premises

Whilst routine sampling assesses the overall quality of the water being supplied consumers, investigational samples are aimed at establishing the quality of a partic supply at the point inside the premises where it is available to the consumer. It is import therefore to identify and sample the tap or fitting used for potable purposes. In so instances the tap will not be connected directly to the rising main but served via a stor cistern or other fitting. In these situations reference samples should be collected from a connected to the rising main, sited as close to the incoming point of supply as possible there is no such tap, or the circumstances suggest that contamination could be arising fr within consumers' installations, then samples should be collected from a standpipe set at the closest hydrant point upstream of the premises or from a tap in a neighbouri property on the upstream side. The use of these sample points will facilitate rap interpretation of the analytical results and site survey findings. The results should reported to the appropriate local authority and district health authority. Where the cause water quality deterioration is established, agreement should be reached on the mo appropriate remedial measures. Where the problem arises within consumers' installatio then the owner or appointed representative should be advised on how to remedy th problem and where appropriate, be advised of the consumer's liability under the wat bye-laws.

In large premises, considerable detail may be required in order to determine the numbe and location of appropriate sampling points. Ashworth and Colbourne (1987) report useful checklist which summarises the procedure for examining a wide range of qualit problems in buildings. A full inspection of the installation for compliance with wate supply bye-laws is useful when there is information to suggest a quality problem is linke in time to modification or extension of plumbing systems.

4.6.2.2 Response to routine sample 'failure' in distribution systems

When coliform bacteria are reported in any treated water sample it is necessary to investigate whether the result is indicative of a deterioration in the water in supply o merely an artifact of the sample or sampling point. Results of samples collected at th same time from other points within the distribution zone and associated treatment works should be examined. This may yield useful corroborating information, particularly if th samples have been collected as part of a systematic, as opposed to a random, sampling programme. Other information, including historical water quality data, reports on the physical condition of associated service reservoirs, operational data on the supplying works, remedial work on mains and prevailing weather conditions should also be sought and examined.

When coliform bacteria are detected in a sample, investigative samples should be collected as soon as possible. The investigative samples should include a repeat sample from the same sample point and where appropriate, additional associated samples. In the case of a presumptive coliform isolated from a service reservoir, additional samples may include samples from both the inlet and the outlet mains and from the distribution system fed by the reservoir. The distribution samples should preferably be collected from consumers' taps. If the presumptive coliform is isolated from a sample taken from a property or hydrant, repeat samples should be collected from the tap originally sampled, together with samples from consumers' taps at locations immediately upstream and downstream of the original sampling point.

4.6.2.3 Approach when faecal contamination is suspected

The immediate aim of the investigation is to establish whether the water in supply is contaminated with organisms indicative of faecal contamination. If the original unsatisfactory result indicates the presence of coliforms in the absence of *E. coli* then the investigative samples should be examined not only for coliforms and *E. coli* but also for additional indicator organisms such as faecal streptococci. If *E. coli* was present in the original sample then consideration should be given to the need to collect and preserve samples for examination for pathogens, particularly those which may be unaffected by the presence in the water of residual chlorine e.g. enteroviruses or protozoal cysts. Analysis of these samples need only to be performed if the investigational sampling and analysis confirm that the supply was subject to faecal contamination. The recommendation to obtain such samples at this early stage is based on experience from those instances where water supplies have been linked epidemiologically with water-borne disease. If such sampling is initiated only after notification of cases of disease, then the time delay makes it extremely difficult to obtain microbiological evidence to support the epidemiological findings.

4.6.2.4 *Approach when faecal contamination has been ruled out*

It is not uncommon for coliform organisms to be isolated from treated waters in the absence of *E. coli*. Environmental strains of coliforms are able to colonise the surfaces of pipes and survive in deposits in reservoirs where they will be protected from residual chlorine or survive other hostile conditions; however, their presence is undesirable given their primary role as indicators of the likelihood of more serious contamination. For this reason the site of colonisation and the source of nutrient must be sought by the water undertaker and priority given to implementing measures necessary to control the growth of these organisms. Investigative techniques that are useful for resolving such incidents include the collection and analysis of larger volume samples (1 litre), deposits and biofilms, the evaluation of construction materials by methods described in BS 6920 Part 2.4 (BSI 1988) and identification of isolates to species level.

Distribution systems are monitored at varying frequencies for counts of bacteria capable of growth at 37°C and 22°C. Where counts are considerably higher than previously reported, an investigation should be initiated. In the first instance this should comprise a review of bacterial counts from associated sample points and consumers' taps within the previous month. If this indicates that a sustained rise in bacterial counts has taken place in all or part of the distribution zone then arrangements should be made for colony counts to be performed on all microbiological samples collected from the affected area and its associated reservoirs and source works. In the absence of evidence of faecal contamination or a failure in treatment at the supplying works then elevated colony counts should not be viewed with concern in terms of the health of the population as a whole. However, the increased likelihood of aesthetic problems (for example, taste and odour) should be appreciated.

If elevated counts persist for longer than one month then an attempt should be made to characterise the predominant bacterial species, as these may be opportunist pathogens such as *Aeromonas* species and *Pseudomonas aeruginosa*. It is possible that other opportunist pathogens such as legionellas and mycobacteria may also be present but not detected, due to their inability to grow in the colony count medium. All these organisms may be present in low numbers in mains and reservoirs and are usually associated with pipe surfaces and deposits. Their appearance in large numbers in the water indicates that conditions in the distribution system have become suitable for growth as opposed to survival of these organisms. This may be as a result of changes in nutrient loading of the source water, an influx of material into the system, a change in environmental conditions (for example, a rise in temperature) or localised stimuli such as corrosion or use of an unsuitable construction material. If it can be established that the elevated colony counts are a persistent and not a transient problem in a distribution zone then attempts should be made to identify the cause and formulate appropriate remedial measures. Additional analysis for other chemical, physical and biological parameters is an important part of any such investigation.

4.6.3 Response to routine sample 'failure' in treatment works

The detection of any coliform organism or a significant increase in the colony count in a sample of fully treated water from a pumping station or treatment works requires immediate investigation. In addition to collecting a repeat sample of treated water, consideration should be given to the collection of water, at the same time, from water at each stage in the treatment process and the raw water. It is especially important to collect a sample of water from taps connected directly to points just before and after addition of chlorine to the water (contact tank).