FINAL REPORT TO

guardians of drinking water quality
DRINKING WATER INSPECTORATE

Review of England and Wales Monitoring Data for Which a National or International Standard Has Been Set

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Final Report

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EXECUTIVE SUMMARY

The Drinking Water Regulations that incorporate the provisions of the European Union (EU) Drinking Water Directive into the law of England and Wales contain a list of substances for which there are numerical standards. However, there is also a requirement to consider other potential contaminants that might be present in drinking water. A number of authorities and jurisdictions outside the EU have produced guidelines or standards for substances that are not specifically listed in the EU Directive. There may, therefore, be legitimate questions from stakeholders on what is known about the presence of these substances in UK drinking waters. In addition, it is important to assess the information that is available should there be a suggestion that these additional substances be considered in revisions of the Directive.

Additional substances were identified in the World Health Organisation (WHO) Guidelines for Drinking Water Quality and in standards from the USA, Canada, Australia, New Zealand and Japan. Many of these were individual pesticides. These are fully covered by the pesticide parameters in the EU Directive, which refers to all pesticides and sets a precautionary maximum contaminant level. Searches of the peer reviewed and grey literature were performed for data on the concentrations of these substances in drinking water in all parts of the world, but particularly in the UK. Research on and monitoring of the chemicals of interest, commissioned or carried out by DWI, the Environment Agency or other UK authorities and agencies was also investigated for relevant data. Most of the larger water companies were approached to determine whether they had carried out investigations or monitoring for these substances. Not all companies were able to help but some provided a considerable amount of information. The data that were received usually reflected high risk sources.

Although there are no systematic data on the listed substances, the data that are available are helpful and indicate that the majority of substances, where they are present, occur at concentrations below the health-based guidelines from WHO. Occasional detections above the guideline values, but well below other health-based standards, appear to be associated with a very small number of naturally occurring inorganic substances in groundwaters.

In the third edition of its Guidelines, WHO introduced the concept of drinking water safety plans (DWSPs), which is an approach now generally accepted as best practice. This approach has been formally incorporated into the drinking water regulations for England and Wales and is based on hazard identification and risk assessment, followed by management procedures to mitigate those risks. The risks and mitigating procedures should also be prioritised to ensure that resources are directed where they will have the greatest impact. This approach provides a framework for managing risks from source to tap and helps to ensure that hazard identification occurs for substances that are potentially of concern for drinking water. This means that investigation of their presence in drinking water sources and in drinking water itself is targeted to where such substances are likely to be found and takes existing barriers into account. By doing this it is possible to demonstrate that the barriers are appropriate and functioning properly so that the need for extensive chemical analysis of specific substances is significantly

reduced. This approach is not only more efficient in directing resources where they will have most impact but it also means that water quality can be assured over a much wider range of *potential* contaminants than would otherwise be possible. Chemical monitoring of the final water merely informs us that there *is* a problem, while the DWSP approach is designed to ensure that controls are in place that will *prevent* a problem. Chemical monitoring is a final check on the presence and amount of chemicals; it does not control them.

Several of the listed substances are inorganic and most of these are present naturally as constituents of water, although there may also be anthropogenic sources that contribute to concentrations in water. Most of these have been assessed by the Environment Agency as part of their groundwater monitoring programme and are not of concern for drinking water. A DWI-commissioned in-depth study on uranium in drinking water identified a small number of samples, taken from private water supplies that exceeded the current WHO provisional guideline value, but not the USEPA standard. An early study, part of the Regional Heart Study, indicated that molybdenum concentrations may exceed the WHO guideline value in some areas. Since molybdenum is an essential element, it requires a different approach to risk assessment and DWI has therefore commissioned a study of molybdenum in drinking water in England and Wales.

A substantial number of the listed substances are volatile chlorinated organic molecules, most of which are used as solvents or result from the breakdown of solvents. Experience has shown that these do not occur at greater than trace concentrations in surface waters because they volatilise to atmosphere. However, if they are spilt or discharged to soil and are able to reach groundwater they may persist for a considerable time. Tri- and tetrachloroethene, and carbon tetrachloride, are incorporated into the regulations and, therefore, all waters are monitored for the presence of these substances. Because of chemical similarity it is possible that many other chlorinated organics would also be detected by the same analysis (if based on gas chromatographic separation with electron capture or full-scan mass spectrometric detection) and therefore action could be taken if detected concentrations were significant, i.e., close to health-based guideline values.

A small number of fuel related compounds are also included on the list. The odour threshold for all of these substances in water is very low and they are almost invariably unacceptable to consumers at considerably lower concentrations than the health-based values.

The additional non- or semi-volatile substances on the list include the cyanotoxin microcystin-LR, DEHP, DEHA, dioxins, EDTA and NTA. This is a diverse group of compounds but, within this group, dioxins have been shown not to occur in drinking water. This is because of their low water solubility and high potential to adsorb to particulate matter and sediment, which is readily removed during drinking water treatment. While cyanotoxins do occur in raw water, their potential presence can be readily identified by the fact that they are only present at significant concentrations in association with large blooms of cyanobacteria or blue-green algae. In addition, they are readily removed by a number of treatment processes. Monitoring for such substances is unhelpful and the guideline value primarily provides a benchmark for assessing the efficiency of treatment.

DEHP is widely used as a plasticizer and there is clear evidence that it does reach drinking water at low concentrations, which are well below the WHO guideline value.

EDTA and NTA are chelating agents that have been found at low concentrations, well below WHO guidelines, in many waters receiving treated wastewater. EDTA is a food additive and NTA is a detergent builder. Both appear to be removed by advanced water treatment and would not be expected to be present at concentrations of concern.

A number of disinfection by-products (DBPs) are included in the list. These are primarily included in the WHO Guidelines as a benchmark against which to assess the importance of such substances, which have received a great deal of research and media attention. European standards include a value for total trihalomethanes (TTHMs) while WHO sets guideline values for individual substances. Two other jurisdictions also include a total haloacetic acids value because these, with THMs, form the dominant chlorination DBPs. The most appropriate mechanism for controlling chlorination DBPs is the removal of natural organic matter (NOM) with which chlorine reacts. This will reduce all of the halogenated organic by-products while actually helping to maintain effective disinfection. It also means that there is no need to monitor a very wide range of by-products, the great majority of which always occur at concentrations below guideline values or health-based guidance concentrations. However, in some specific situations, for example chlorination at low pH haloacetic acids (HAAs) will increase even if THMs are reduced.

Several recommendations are made as a consequence of this study.

- Data on raw water sources of considerable interest with regard to drinking water quality is collected by the Environment Agency and DEFRA, either directly or through commissioned research. It is recommended that lines of communication be established to ensure that such data are made available to DWI to assist in judging the need for any action and to allow DWI to respond to any legitimate questions regarding contaminants/constituents of drinking water.

- The most important inorganic substances for which more data were required are uranium and molybdenum. However, DWI has commissioned work on both of these substances and the work on uranium has been completed. Consideration should be given to whether it is possible to carry out some specifically targeted investigations into the presence of thallium, taking into account natural and industrial sources.

- It would be appropriate to target monitoring for additional volatile chlorinated organic substances where tri-and tetrachloroethene and carbon tetrachloride have been identified in anaerobic groundwater, or where they have reached groundwater following passage through anaerobic conditions.

- Data show that the health risks for drinking water associated with microcystins from cyanobacteria in the UK are very low and most water companies successfully manage drinking water sources to minimise the numbers of cyanobacteria. However,

- The data on DEHP are relatively limited and it would be of value to have a better view of the range of concentrations in drinking water, which might be achievable by closer examination of water company GC-MS scans.

- Although the data that exist indicate that EDTA and NTA are present in raw and drinking water at concentrations well below the WHO guidelines, it would be useful to obtain some modern data on their occurrence in waters receiving significant inputs of wastewater. However, this is not considered to be a high priority.

- When water companies are introducing processes to achieve or assess reductions in THMs it would be appropriate also to consider whether concentrations of HAAs have been reduced.

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1 INTRODUCION

1.1 Background

Health concerns associated with chemical contamination of drinking-water arise primarily from the possibility of chemical compounds causing adverse health effects after prolonged periods of exposure. Single exposure to chemical constituents found in water rarely leads to health problems, except through massive accidental contamination of a drinking-water supply. Often, but not always, such incidents render the water undrinkable owing to unacceptable taste, odour and appearance, thus mitigating over-consumption. In order to protect consumers from potential health effects, standards are set by regulatory bodies for the maximum admissible concentrations of specific substances in drinking water. The Drinking Water Directive (98/83/EC) contains standards for a range of microbial and chemical parameters which were set based on the scientific data available at the time. However, the Directive also includes a requirement that the water is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health.

Standards and guidelines for drinking water have been developed by many national and international regulatory and advisory bodies, including the World Health Organisation (WHO), the United States Environmental Protection Agency (USEPA), and other national regulatory agencies such as Health Canada. Some of these standards and guidelines have been developed for substances that are not included in the minimum list of parameters in the Drinking Water Directive or UK Regulations, so there are legitimate questions on what is known about the presence of these substances in UK drinking waters.

There are a number of key issues that need to be considered when assessing the need for investigation of, or monitoring for, individual or groups of chemicals that might be present in drinking water. These include the likelihood of their occurrence in drinking water (e.g., whether they are used in the catchment of a particular supply), and the availability of appropriate analytical techniques. In addition, improvements in drinking water treatment mean that many more of the potential contaminants found in drinking water sources can be readily removed.

Not all of the drinking water parameters monitored in countries other than the UK will be relevant to the UK, but it is important to be aware of such developments, the need for such standards and the robustness of the scientific basis of standards set in other jurisdictions.

1.2 Project Objectives

The detailed objectives from the project tender for the research project identified by DWI were to:

1) identify all compounds for which drinking water standards have been set by other regulatory or advisory bodies, but which are not covered in the UK by routine regulatory monitoring, or monitoring is not adequate. As a minimum the project was required to cover guidelines or standards from WHO, USEPA, Health Canada and the Australian national authorities.

2) identify relevant studies and data, in the published and grey literature, including water company data, that establish concentrations of the identified compounds in drinking water or water sources in England and Wales;

3) assess broadly the quality of the data and studies identified, in terms of the scope of the study and the performance of the analytical methods used and conclude on the likely levels found;

4) for any of the identified compounds where no data or inadequate data exist assess the likelihood of these compound being present in drinking water in England and Wales;

5) recommend whether monitoring is required, in the short-term, for any of the identified compounds, or whether there is a likelihood that future monitoring will be needed.

Many of the parameters set for drinking water quality cover microbial parameters, but these were specifically excluded from the research carried out for this report.

2 DERIVATION OF DRINKING WATER STANDARDS

Sections 2 and 3 of this report identify the drinking water standards set by WHO, USEPA, Australia, Canada, New Zealand and Japan for parameters (chemical and algal toxins) which are not monitored as part of current regulatory requirements in the UK. Section 2 describes how each regulatory or advisory body sets and prioritises selection of these parameters and identifies how recently they were set. Section 3 lists the numeric standards for the identified parameters by substance type, highlighting any significant differences in the parametric values.

Drinking Water Standards applied in the UK are largely derived from the European Directive on the quality of water for human consumption (98/83/EC), published in 1998. In the UK the EU directive is transposed into legislation through the Water Supply (Water Quality) Regulations 2000 (WSWQ) as amended and the equivalent statutory instruments for Scotland and Northern Ireland. The Directive contains mandatory standards for microbiological quality and several mandatory standards for chemical contaminants. It also contains some indicator parameters that are mostly associated with acceptability by end users. The EU Directive includes strict requirements for monitoring to demonstrate compliance with the standards.

Within the EU, Member States can include additional requirements for further substances that are relevant within their territory, or they can set tighter standards, but Member States are not allowed to set less stringent standards. Thus there will be differences within the EU in the specific standards set and in some of the individual parameters. For example, the limit values for trihalomethanes vary considerably across the EU. The Directive set the parametric values for total trihalomethanes (TTHMs) at 100 µg l^{-1} (sum of concentrations of chloroform, bromoform, dibromochloromethane and bromodichloromethane), with an interim value of 150 µg l^{-1}. Austria, Belgium and Italy adopted a value of 30 µg l^{-1}; Germany, Luxembourg and Sweden a value of 50 µg l^{-1}; and Ireland, Spain and the UK a value of 100 µg l^{-1}, forgoing the option of applying the interim value. Another example is the adoption of a national standard of 3 µg l^{-1} for tetrachloromethane in the UK.

2.1 World Health Organization (WHO)

The WHO guidelines do not have any legal force, but are used as the scientific point of departure for setting national standards. They also provide a means of determining the implications for health of a substance that is identified at a concentration above the standard. The WHO Guidelines for Drinking Water Quality are probably the most influential source of information available for establishing drinking water quality.

The guidelines are intended to provide the basis for developing national standards but this also requires that local needs (e.g., occurrence) and constraints, including technical resources, and social and economic circumstances, are taken into account. Consequently, they are the benchmark for drinking water standards in most parts of the world, including Europe. WHO only produces guideline values for substances that are of health significance and does not establish guideline values on any other basis, e.g., consumer acceptability. WHO guideline values normally represent the concentration of a substance that does not result in any significant risk to health over a lifetime of consumption, although guideline values for some substances are based on shorter-term exposure, particularly those based on childhood exposure.

Some of the guideline values are designated as provisional, and may be greater than the calculated health-based value. This is because there are practical considerations relating to difficulties in treating the substance to reduce its concentration in drinking water, or because it cannot be measured in drinking water at the health-based value. Such substances are regularly reviewed because technical developments can lead to the situation changing. Some guideline values that are health-based are also designated provisional if there is significant uncertainty about the toxicological and epidemiological data on which the guideline value is based and reflects the need to keep this under continuous review. In cases in which the provisional guideline value is higher than the calculated health-based value, such as those based around achievability, the guideline is still set at a level at which there is no significant increase in risk to consumers, although there may be a small reduction in the theoretical margin of safety, which is generally large.

WHO's Guidelines are regularly updated by a process of 'rolling revision'. WHO emphasise that the Guideline values should not just be adopted as they stand, but that it is important that due consideration is given to which substances are important for a particular country, taking into account both occurrence and concentration data. It is considered important not to include unnecessary parameters that result in a need for monitoring, since monitoring requires the use of often scarce resources. In addition WHO emphasises the need to consider local circumstances and to modify guideline values as appropriate taking into account costs and benefits as well as the possible risks to health.

The EU Drinking Water Directive includes a statement that WHO Guidelines will normally be the point of departure for European standards and it is considered to be the first point of reference for substances for which the EU has not set specific standards.

WHO emphasises that guideline values should not be included in national standards unless there is an adequate reason and encourages member states not simply to incorporate all of the guideline values into national standards.

2.2 Australia

The latest edition of the Australian Drinking Water Guide (ADWG) was released in December 2004. An updated version of the ADWG was released in late 2006 with the addition of a chapter on Drinking Water Treatment Chemicals. Following the publication of the previous major edition of the ADWG in 1996, the National Health and Medical Research Council (NHMRC) instituted a rolling revision process for future updates to the document, to allow sections to be updated at variable intervals as warranted by information from new research. This contrasts with previous practice where the Guidelines remained fixed for several years, then underwent a major review. The most recent round of rolling revisions commenced in early 2007. Also in early 2007 the NHMRC formed the Water Quality Advisory committee, a panel of experts in the water and environmental field, to provide advice on a broad range of health-related water quality issues, and to oversee a new round of rolling revisions to the ADWG. A targeted consultation process was carried out with key bodies involved in management of drinking water quality and public health, e.g., the Australian Pesticides and Veterinary Medicines Authority and the Office of Chemical Safety.

The ADWG are not mandatory but they are framed within a process that should also consider economic, political and cultural issues, including customer expectations and willingness and ability to pay. There are two types of ADWG. The first is a health-related guideline value which, like the WHO Guidelines, is aimed at ensuring no significant adverse effects over a lifetime of exposure. The second type relates to the aesthetic qualities of drinking water and is concerned with appearance, taste and colour. Importantly, exceedance of any of these values is a prompt for further investigation.

Many of the ADWGs are based on WHO recommendations and Priority Setting 'expert groups' are also used to select drinking water parameters that are additional to those considered by WHO.

Values for pesticides are presented as two values – guideline values, often set at the current analytical limit of detection (LoD) which may prompt further investigation but do not indicate a hazard, and health values which are calculated from acceptable daily intakes (ADIs) or derived from mathematical models that are used to extrapolate the risk of genotoxic carcinogens from animal studies at high doses to low environmental concentrations. These heath-based values are developed so that they are relatively conservative in nature in view of the uncertainties in the extrapolation process.

The ADWGs may differ from WHO guideline values because of the assumption that average adult weight is 70 kg, rather than the WHO value of 60 kg. Furthermore, differences may arise in values for substances that have been considered using a mathematical model to extrapolate risk since WHO uses the concentration associated with an additional theoretical risk of one additional cancer case in 100,000 population drinking 2 litres of water containing the substance at that value for a lifetime. The Australian guidelines use a risk of one additional cancer in a population of 1,000,000. In some cases a traditional ADI approach with an additional safety factor is applied to account for carcinogenicity.

Compliance is assessed as the 95th percentile of the concentrations determined by monitoring over the previous 12 months.

2.3 Canada

The Guidelines for Canadian Drinking Water Quality are prepared by the Federal-Provincial-Territorial Committee on Drinking Water and are used as the basis for

Provincial standards. The guidelines cover 165 microbiological, physical, chemical and radiological contaminants in drinking water that may be of concern for public health if present at high concentrations. In Canada, responsibility for assuring the quality of drinking water falls under the jurisdiction of the Provinces and Territories. Health Canada's role is to provide scientific and technical expertise to the Federal-Provincial-Territorial Committee on Drinking Water (CDW) and to prepare appropriate background documents and proposals for consideration by the committee.

CDW identifies new and existing risks to water quality in a number of ways:

1) Members bring forward information about substances of concern in their jurisdictions.
2) Health Canada reviews scientific studies published in journals and sits on national and international committees that deal with drinking water issues. These activities provide Health Canada with information on new and emerging risks to human health, which it monitors and shares with the CDW.
3) Health Canada and the CDW also monitor health risk assessments that may be developed internationally, including those developed by WHO and the USEPA. As a Pan American Health Organisation/WHO Collaborating Centre for Water Quality, Health Canada participates in the development of guidelines by WHO and timelines may be influenced by this process. However, guideline development is based primarily on needs identified in Canada.

Priorities for developing or updating specific guidelines are based on several key considerations and vary with the type of contaminant. In general, the highest priority guidelines are those dealing with microbiological contaminants, such as bacteria, protozoa and viruses. The second level of priority is for disinfection by-products, followed by other chemical contaminants and, finally, radiological contaminants. There may also be other priorities assigned to different substances or organisms within each category. Microbiological contaminants are the highest priority because of the acute risks they pose to health and are subject to a rolling revision, whereby the Secretariat regularly identifies new and relevant sources of information through a comprehensive review of the literature and active participation in internal groups, as well as in external national and international groups.

Disinfection by-products (DBPs) are the second priority because disinfection with oxidative disinfectants is almost universally applied to public drinking water. There is a high awareness of DBPs in Canada and because they result from the treatment process they are seen as different to raw water contaminants, although it is acknowledged that there must be a balance between theoretical risks from DBPs and measurable risks from pathogens.

The third priority for guideline development is the presence of chemical contaminants in Canadian source waters 'at levels known or suspected to cause adverse health effects'. Because of the large number of chemicals that fit this description, priorities within this category are established by the CDW using a tool called the Draft October 3, 2006 'priority ratings table'. This table, which incorporates Provincial and Territorial data, is updated once per year with information about the latest research on health effects, the frequency and levels at which Canadians are exposed to each chemical via drinking water (when these data are available), and the availability of analytical and treatment technologies to identify and then reduce or eliminate the contaminant from drinking water supplies.

Once the data have been entered into the table and a list of possible priorities generated, the CDW members review the proposed list to ensure it reflects both the priorities of their own jurisdiction and national concerns. Ideally, substances of highest priority for guideline development are those which have the potential to affect a significant number of people and which pose a high risk to human health. Substances which affect few people or pose a less significant health risk are moved lower in the priority ranking.

The priorities for radiological guidelines are determined by the Federal-Provincial-Territorial Radiation Protection Committee (RPC). However, because the health effects of radiological contaminants are due to overall radiation levels rather than to the presence of a specific radiological contaminant, these guidelines are established as a single parameter. Guidelines are derived to conform to international radiation protection methodologies, and are updated on a regular basis. New or revised radiological guidelines are approved by both RPC and CDW and are included in the Guidelines for Canadian Drinking Water Quality. Identified priorities are included in the CDW's work plan, updated annually. (D Green, Health Canada, pers. comm.)

2.4 Japan

Drinking Water Quality Standards (DWQS) set in Japan cover 50 parameters. The current standards came into effect on April 1, 2004. Standards are established based on two fundamental principles:

1) standards are set for all parameters that have a possibility of having an adverse effect on the protection of health and/or the livelihood of people, depending on the locality, type of untreated water, or purification method, even when the detection level of the substance is low on a national basis; and
2) water suppliers are obliged to carry out drinking water quality analysis only for the basic items and may exempt some of the non-basic items from analysis according to the situation. Where a decision is taken not to analyse for substances this decision must be appropriate and transparent. In 2004 the DWQSs were changed to embody the principle of setting a legal standard for all items that may cause a problem even if they are detected only locally. Thus this flexibility was given to water companies to implement analysis that better suits the regional situations. Each water supplier has to justify their decisions through a water quality analysis plan which is published annually.

Drinking Water Quality Standards were established under a policy to include as many items as possible even if they are associated only with regional or site-specific issues. Specifically it was decided that the DWQSs would include 'items that are detected or can possibly be detected in treated water at a level of 10% or higher of the assessment level (excluding items that happen to show a high level due to a singular value)'. The 'items not listed in the DWQSs, but that can possibly be detected in treated water at the level of 10% or higher of the standard value in some cases' are now categorized as "Complementary items to set the targets for water Quality Management". Also the 'items on which necessary information and knowledge should be collected' are now categorized as "Items for further studies".

There are 27 parameters set under the complementary targets. Items in this category do not need to be included in the standards because of low detection levels or provisional evidence of toxicity. This category includes items normally detected in the natural environment and items that have the potential to be detected in drinking water because of their use in large quantities. Although inclusion in this category does not necessitate a water quality analysis, analysis is recommended in line with the DWQSs for the sake of data collection and accumulation of knowledge.

There are a further 40 items listed in the items for further study. These items were excluded from the previous two categories either because toxicities have not yet been determined or concentrations in drinking water are not clear. Further studies are necessary to accumulate information and knowledge on these items.

No specific pesticide is listed in the DWQS, but they are included in the complementary set under the general heading 'pesticides' and are evaluated by the total pesticide level. In evaluating the total pesticide level, 101 substances were listed as 'pesticides' based on their detection and consumption levels in Japan. Water suppliers must monitor the total pesticide level with due consideration given to the usage period and the conditions in the area around the water source. The Total Pesticide Level is calculated as follows:

The target level is set for each of the 101 pesticides. The sum of the ratio for the measurement value (DV_i) to the target value (GV_i), where i is a specific pesticide, should not be greater than 1.

$$DI = \sum_i \frac{DV_i}{GV_i} \leq 1$$

DI: value of measurement standard
DV_i: measurement value of pesticide i
GV_i: target value of pesticide i

The Ministry of Health, Labour and Welfare has adopted the rolling revision system as used by WHO and has established a committee of experts to review drinking water quality standards.

2.5 New Zealand

The current drinking water standards came into effect on 31 December 2005. The overall focus has been away from 'quality control' to a broader approach of 'quality assurance'. Underpinning the new quality assurance approach will be a requirement for drinking water suppliers to develop a Public Health Risk Management Plan. The Ministry of Health developed the Drinking Water Standards for New Zealand (DWSNZ) with the assistance of the Expert Committee on Drinking Water Quality. Extensive use was made of:

1) Guidelines for Drinking Water Quality 2004 (WHO 2004)
2) Previous DWSNZ
3) Australian Drinking Water Guidelines 1996
4) National Primary Drinking Water Regulations: Long term 2 Enhanced Surface Water Treatment Rule: Proposed rule (USEPA 2003).

The DWSNZ specifies the Maximum Acceptable Values (MAVs) for more than 140 determinands. To minimise the number of determinands that have to be monitored routinely in any specific drinking-water supply, but still maintain adequate safeguards to public health, the DWSNZ has grouped the determinands into four priority classes. The highest priority is given to potential indicators of disease-causing organisms since these are considered to be (almost always) of greater concern than the presence of chemical contaminants, which are considered to be usually associated with chronic effects.

Priority 2 applies to determinands, in a specific supply or distribution zone, where there is good reason to believe that the substance is present in concentrations which present a potential public health risk (usually greater than 50% MAV). This covers determinands that could be introduced into the drinking water supply by treatment chemicals or where determinands have been demonstrated to be in the drinking-water supply, e.g., arsenic and boron in geothermal areas. The designation of a Priority 2 determinand for a given supply is based on monitoring and knowledge of the sources of health-significant determinands in the catchment, treatment processes and distribution system. The Drinking Water Assessor responsible for assessing the supply notifies the water supplier of the designation after consulting the supplier and reviewing any contrary evidence.

Priority 3 applies to determinands not likely to be present in the supply to the extent where they could present a risk to public health, i.e., substances known not to exceed 50% MAV. The water supplier does not have to monitor priority 3 determinands. The Ministry of Health will carry out investigations on water supplies from time to time to assess whether Priority 3 determinands should be elevated to Priority 2 until such time as the drinking water supplier's water supply risk assessment procedures are adequate for the supplier to do such investigations themselves. Priority 4 applies to determinands not likely to be present in New Zealand drinking-waters, e.g., pesticides not registered in, and not yet introduced into, New Zealand. They are included in the tables to ensure that MAVs are available should those pesticides be used in the future.

The DWSNZ 2005 has two principal components:

1) the water quality standard, which defines the MAVs at which the risk of disease from drinking water is negligible. A new concept, operating requirements based on the water safety plan approach, has been introduced where monitoring of a MAV is impracticable.
2) The compliance specifications, which define the checks (and their frequencies) that are to be taken to demonstrate compliance with the DWSNZ.

2.6 USEPA

National Primary Drinking Water Regulations are legally enforceable standards that apply to public water systems. The EPA (Environmental Protection Agency) sets the standards but, in most cases, EPA delegates the responsibility for implementing them to States and Tribes. There are two categories of drinking water standards:

1) A National Primary Drinking Water Regulation (NPDWR or primary standard) is a legally enforceable standard that applies to public water systems. Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water. They take the form of Maximum Contaminant Levels or Treatment Techniques, since levels are often based on achievability. However, in accordance with USEPA policy, almost all substances that are considered to possess carcinogenic properties have a maximum contaminant level goal of zero.
2) A National Secondary Drinking Water Regulation (NSDWR or secondary standard) is a non-enforceable guideline regarding contaminants that may cause cosmetic effects (e.g., skin or tooth discolouration) or aesthetic effects (e.g., taste, odour or colour) in drinking water. EPA recommends secondary standards for water systems but does not require systems to comply. However, States may choose to adopt them as enforceable standards.

The EPA considers input from many individuals and groups throughout the standard setting process. One of the formal means by which EPA solicits the assistance of its stakeholders is the national Drinking Water Advisory Council (NDWAC). The 15-member committee was created by the Safe Drinking Water Act. It comprises five members of the general public, five representatives of state and local agencies concerned with water hygiene and public water supply, and five representatives of private organizations and groups demonstrating an active interest in water hygiene and public water supply, including two members who are associated with small rural public water systems. NDWAC advises the EPA Administrator on all of the agency’s activities relating to drinking water. In addition to the NDWAC, representatives from water utilities, environmental groups, public interest groups, States, tribes and the general public are encouraged to take an active role in shaping regulations by participating in public meetings and commenting on proposed rules. Special meetings are also held to obtain input from minority and low-income communities, as well as representatives of small businesses.

The Safe Drinking Water Act Amendments of 1996 require the US Environmental Protection Agency to publish every five years a list of chemical and microbial contaminants that are known or anticipated to occur in public water systems, that may have adverse health effects, and that, at the time of publication, are not subject to any proposed or promulgated National Primary Drinking Water Standards. The first national

Drinking Water Contaminant Candidate List (CCL) was published in March 1998 and was categorized based on four priority areas in drinking water research (occurrence, health effects, treatment, and analytical methods). The CCL is the primary source of priority contaminants for evaluation by EPA's drinking water programme. Contaminants on the CCL are not currently subject to any proposed or promulgated national primary drinking water regulation, but are known or anticipated to occur in public water systems and may require regulation under the SDWA. The first list contained 50 chemical and 10 microbial contaminants/groups. On a staggered, second five-year cycle (three-and–a half years after a CCL is required), EPA is required to evaluate this research together with any information that is already available and make a determination for at least five contaminants on whether or not to proceed with the regulatory development process. EPA completed its first regulatory determination process in July 2003, when it recognised the need for a more robust and transparent process for identifying and prioritising potential contaminants for future CCLs.

In February 2005, EPA published the second CCL of 51 contaminants and has announced preliminary determinations for 11 of them (EPA 2007).

In August 2005, the USEPA proposed the second of two Unregulated Contaminant Monitoring Rules (UCMR2; EPA 2005), which will require monitoring for a list of 26 chemical contaminants suspected of being present in drinking water. The purpose of the UCMR2 is to develop data on the occurrence of these contaminants in drinking water, the size of the population exposed to these contaminants, and exposure levels. This information will be used along with health effects information to determine whether or not drinking water standards should be established for these contaminants. The monitoring was scheduled to begin in 2007. The UCMR includes contaminants that are considered to be potential DBPs and for which monitoring will be conducted in the distribution system.

3 COMPOUNDS FOR WHICH STANDARDS HAVE BEEN SET BY OTHER REGULATORY OR ADVISORY BODIES

The compounds listed in this section are those for which drinking water standards or guidelines are set by one or more of the WHO, USA, Australia, Canada, New Zealand or Japan, but for which drinking water standards are not currently set in the UK.

3.1 Inorganic substances

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for inorganic substances is set out in Table 3.1.

Asbestos
Research has indicated that most waters contain some asbestos fibres, whether or not they are distributed through asbestos cement pipes. This is because asbestos is widely found in the environment as a consequence of natural dissolution of asbestos-containing minerals. The use of asbestos cement pipes in distribution systems can give rise to an increase in the numbers of asbestos fibres in drinking water, particularly immediately after installation. However, a review of the possible health risks (DWI 2002) associated with asbestos cement drinking water pipes concluded that there appears to be no concern for health of consumers receiving water through such pipes. All of the regulatory authorities considered during this review have assessed asbestos at some time but only the USA has set a drinking water standard for asbestos, with a value of 7 million fibres per litre.

Barium
Barium is present as a trace element in both igneous and sedimentary rocks. It occurs most commonly as barium sulphate (barite). All of the jurisdictions reviewed, except Japan, set standards for barium, with values ranging from 0.7 to 2 mg l^{-1}.

Beryllium
Beryllium (Be) is a divalent metal that can occur both naturally or as a result of industrial discharge, particularly from the use of specialized alloys such as in armaments and weapons manufacture. Beryllium hydrolyses easily due to its small atomic size and high surface charge density. Under pH conditions on the alkaline side of neutral, Be precipitates/co-precipitates as oxide/hydroxide phases (especially with aluminium) resulting in dissolved Be concentrations in the range of a few ng l^{-1} to a few µg l^{-1}. Beryllium is mobilised under acidic conditions and consequently it is under such conditions that environmental concerns are normally the greatest (Neal 2003).

Both the USA and New Zealand have set drinking water standards for beryllium at 4 µg l^{-1} and WHO is currently considering beryllium under its rolling revision programme.

Hydrogen sulphide

WHO consider that it is unlikely that a person could consume a harmful dose of hydrogen sulphide from drinking water ingestion and therefore have not proposed a guideline value. In particular, hydrogen sulphide can be detected by odour at concentrations which are below those that could be of concern for health. The only jurisdiction that sets a standard for this substance is Australia, which has set an aesthetic/operational value of 50 µg l^{-1}.

Iodide/Iodine

Iodine, which is an essential element, occurs naturally in water in the form of iodide. Traces of iodine are produced by oxidation of naturally occurring iodide during water treatment. Since iodine is not currently recommended for long-term disinfection, WHO have not set a guideline value. However, a number of WHO regions have asked for guidance and iodine is included in the plan of work of the rolling revision of the WHO Guidelines with the focus on its use as a disinfectant both for emergency and routine use. Of the jurisdictions considered only Australia sets a standard at 0.1 mg l^{-1}. This is a relatively high value and is above the concentrations that might be expected in the great majority of UK waters. WHO has also considered iodine and iodide through the Programme on Chemical Safety and this will provide one of the documents for consideration by the Guidelines Expert Group.

Molybdenum

Molybdenum is found naturally in soil and is used in various industrial processes. Of the jurisdictions considered, USA and Canada do not set standards for molybdenum, and Japan and New Zealand set a standard of 0.07 mg l^{-1}, the same as the WHO guideline value. Australia has set a standard of 0.05 mg l^{-1}. WHO is reviewing the guideline for molybdenum in the context of it being an essential element and the contribution of drinking water to overall intake.

Silver

Silver occurs naturally mainly in the form of insoluble and immobile oxides, sulphides and some salts. However, silver ions are used increasingly as bacteriostats in a range of circumstances in which drinking water may be affected. The USA, Australia and New Zealand have set standards at 0.1 mg l^{-1}. However, this standard is based on very old data that do not meet modern standards. Silver will be considered by WHO as part of the rolling revision in the context of its use in disinfection.

Thallium

Of the jurisdictions considered only the USA set a standard for thallium, at 2 µg l^{-1}. It remains uncertain why the US set a standard but there seems to be little indication of problems in drinking water except where there are other metals associated with sedimentary rocks, e.g., arsenic.

Uranium

Uranium is widespread in nature, occurring in granite and various other mineral deposits. WHO has set a provisional guideline of 0.015 mg l^{-1} based on toxicology but the provisional designation is because of outstanding uncertainties about the toxicology and epidemiology of uranium as well as difficulties concerning technical achievability in smaller supplies. Australia and Canada have set standards at 0.02 mg l^{-1} and New Zealand has a provisional standard set at the same value. Japan has set a complementary target standard at the much lower level of 0.002 mg l^{-1}. The USA has set a standard of 30 µg l^{-1}. WHO will consider emerging data on the human health effects of uranium consumption in drinking water. These data are indicating that uranium may not be of as great a concern for humans as previously thought.

Zinc

Zinc is an essential trace element found in nearly all potable water in the form of salts or organic complexes. WHO consider that a guideline value is not required, but it advises that drinking water containing zinc at levels above 3 mg l^{-1} may not be acceptable to consumers. All the jurisdictions considered set standards, which vary from 1 mg l^{-1} in Japan to 5 mg l^{-1} in Canada and the USA.

Table 3.1 Summary of Standards set in other jurisdictions – Inorganic substances

Substances for which drinking water standards are set by others, but not UK	WHO Guideline Value (mg l^{-1})	USA MCL (mg l^{-1})	Australia MAC (mg l^{-1})	Canada MAC (mg l^{-1})	New Zealand (MAV) (mg l^{-1})	Japan (mg l^{-1})
Asbestos (fibres per litre)	n.a.[1]	7000000				
Barium	0.7	2	0.7	1	0.7	
Beryllium	Under consideration	0.004			0.004	
Hydrogen sulphide	n.a.[1]		0.05 [§]			
Iodide (see Iodine)						
Iodine	To be considered by WHO as a disinfectant		0.1			
Molybdenum	0.07[2]		0.05		0.07	0.07 [**]
Silver	To be considered	0.1[*]	0.1		0.1 (P)	
Thallium		0.002				
Uranium	0.015 (P)[2]	0.030	0.02	0.02	0.02 (P)	0.002 [***]
Zinc	n.a.[1]	5 [*]	3	≤5.0	1.5	1

(P) = Provisional

[1] Considered not applicable, i.e., occurs in drinking water at concentrations well below those at which toxic effects may occur

[2] Will be reviewed by WHO

[§] Aesthetic or operational value

[*] Secondary MCL

[**] Designated for further study, target value

[***] Complementary target standard

3.2 Volatile Organic Compounds (VOCs)

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for VOCs is set out in Table 3.2.

3.2.1 Halogenated hydrocarbons

Halogenated, particularly chlorinated, hydrocarbons are used extensively by industry throughout the world. They are particularly used as solvents but some, such as 1,2-dichlorobenzene, are used as deodorisers and others as chemical intermediates and pesticides. These substances are dense non-aqueous phase liquids (DNAPLs) able to penetrate deep below the water table in drinking water aquifers where they slowly dissolve to form plumes over decades. Plumes may attain km-scale lengths due to their low sorption, limited chemical reaction and varied, but often low, biodegradation potential (Ellis and Rivett 2007).

Due to concerns that 1,1,1-trichlorethane was a significant contributor to ozone depletion, its use was phased out in 1995.

Where drinking water values are set by several organisations for a particular halogenated hydrocarbon, the standards may vary considerably. For example, the standards set for 1,1,1-trichloroethane, 1,4-dichlorobenzene and dichloromethane vary over at least an order of magnitude. The EU Directive has a combined value of 10 µg l^{-1} for trichloroethene and tetrachloroethene and this is based on a negotiated compromise. Some member states include other halogenated hydrocarbon solvents such as 1,1,1-trichloroethene in this parameter as incorporated into their national standards.

3.2.2 BTEX and fuel related compounds

BTEX

BTEX is the acronym used for the group of petroleum-derived substances comprising benzene, toluene, ethylbenzene and xylenes. These compounds are found in petroleum products, most notably gasoline and kerosene. The UK already sets a drinking water standard of 0.001 mg l^{-1} for benzene. All jurisdictions have set standards for the other BTEX compounds except Japan which has no standard for ethylbenzene. The health guidelines are higher than concentrations which may affect the appearance, taste or odour of the water, and which would be expected to lead to consumer complaints. This is reflected in the Canadian standards which are based on consumer acceptability and are considerably lower than the health-based standards set by the other countries.

Styrene

Styrene or vinyl benzene is widely used both as a solvent and as a starting material for production of polystyrene. It is also used in the manufacture of glass-reinforced plastic and when such material of an unsuitable standard is used in water supply it can give rise to contamination by styrene. Styrene may also be found in petroleum. The WHO guideline value is 0.02 mg l^{-1} and Australia and New Zealand have set standards at 0.03 mg l^{-1}. The USA standard is 0.1 mg l^{-1}. However, styrene is highly likely to cause detectable taste and/or odour at concentrations below these health-based standards.

Methyl tertiary-butyl ether (MTBE)

MTBE is an additive in unleaded gasoline used as an oxygenate to raise the octane number. It should be noted that concentrations of MTBE added to gasoline in the USA and UK vary widely—typically USA fuels contain 10–15% by weight whilst UK fuels contain 0–5% by weight (EA 2000). Concerns about MTBE arise from the fact that its properties differ significantly from other gasoline constituents such as benzene, toluene, ethyl benzene and xylene (BTEX) compounds. These properties (e.g., high solubility, low biodegradation potential and low sorption) mean that MTBE dissolves rapidly on contact with groundwater and the resulting MTBE plumes migrate rapidly, thereby threatening potential receptors down gradient. The toxicity of MTBE is low, but its low taste and odour threshold makes it an undesirable contaminant in water used for potable water production (Chisala et al. 2007). Generally, problems with MTBE only occur in groundwater and not surface water.

There is no NPDWR in the US for MTBE, but the Office of Water has placed MTBE on the drinking water CCL for further evaluation. In addition, MTBE has been included in the final UCMR. In 1997 USEPA issued an advisory recommending control levels that prevent adverse taste and odour effects of 20 – 40 µg l^{-1}. This level is considered to provide protection against any potential adverse effects with a very large margin of safety. Despite the fact that the USEPA has not set a PDW standard, 11 US states have set values ranging from 10 µg l^{-1} to 70 µg l^{-1} with one state (Mississippi) having a value of 240 µg l^{-1}. In California, where MTBE has been a major concern, a controversial primary MCL of 13 µg l^{-1} was established in 2000 that addresses health concerns and a secondary MCL of 5 µg l^{-1} was established which addresses taste and odour concerns.

3.2.3 Other

Dioxane, 1,4-

1,4-Dioxane is used as a solvent and stabilizer in industrial chemicals. WHO have proposed a guideline value of 0.05 mg l^{-1}. However, of the jurisdictions considered only Japan has set a standard for drinking water which is at the same level as the WHO guideline.

Table 3.2 Summary of Standards set in other jurisdictions - Volatile Organics

Substances for which drinking water standards are set by others, but not UK	**WHO Guideline Value (mg l^{-1})**	**USA MCL (mg l^{-1})**	**Australia MAC (mg l^{-1})**	**Canada MAC (mg l^{-1})**	**New Zealand (MAV) (mg l^{-1})**	**Japan (mg l^{-1})**
Chlorinated hydrocarbons						
1,1,1-trichloroethane	n.a.[1]	0.2			2 (P)	0.3 ****
1,1,2-Trichloroethane		0.005				0.006 ****
1,1-dichloroethane		CCL				
1,1-dichloroethene	n.a.[1]	0.007	0.03	0.014	0.03	
1,2-Dichlorobenzene	1 §	0.6	1.5	0.2	1.5	
1,2-dichloroethene	0.05		0.06		0.06**	
trans-1,2-dichloroethene		0.1				
cis-1,2-Dichloroethene (dichloroethylene)		0.07				0.04
1,2-Dichloropropane (1,2-DCP)	0.04 (P)	0.005			0.05***	
1,4-Dichlorobenzene	0.3 §	0.075	0.04	0.005	0.4	
Chlorobenzene (mono)	n.a.[1]	0.1	0.3	0.08	0.3	
Dichloromethane	0.02	0.005	0.004	0.05	0.02	0.02
Hexachlorocyclopentadiene		0.05				
BTEX and fuel related compounds						
Ethylbenzene §	0.3	0.7	0.3	≤0.0024 *	0.3	
Styrene §	0.02	0.1	0.03		0.03	
Toluene §	0.7	1	0.8	≤0.0024 *	0.8	0.2 ****
Xylenes (total) §	0.5	10	0.6	≤0.3 *	0.6	0.4 *****
Methyl tertiary-butyl ether (MTBE)	n.a.[1]	CCL		0.015 *		0.02 ****
Others						
Dioxane, 1,4-	0.05					0.05

[1] Considered not applicable, i.e., occurs in drinking water at concentrations well below those at which toxic effects may occur

§ Concentrations of the substance at or below the health based guideline value may affect the appearance, taste or odour of the water, leading to consumer complaints

* Aesthetic or operational guideline

** Total of cis and trans isomers

*** Provisional MAV pesticide

**** Complementary target standard

***** Designated for further study, target value

3.3 Semi-Volatile Organics

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for semi-volatile organic substances is set out in Table 3.3.

Di(2-ethylhexyl)adipate (DEHA)
DEHA is used primarily as a plasticizer. WHO does not consider it necessary to derive a health-based guideline value since it considers that DEHA occurs at concentrations well below those at which toxic effects are observed. New Zealand has set a provisional MAV at 0.1 mg l^{-1} and the USA has set a MCL at 0.4 mg l^{-1}.

Di(2-ethylhexyl)phthalate (DEHP)
DEHP is also widely used primarily as a plasticizer. Of the jurisdictions considered, only Canada and Japan do not set standards for DEHP. USA, Australia and New Zealand have all set similar standards which are of the same magnitude as the WHO guideline value of 0.008 mg l^{-1}.

Dioxin (2,3,7,8-TCDD)
2,3,7,8-TCDD is a chlorinated dioxin and can be formed as an impurity in the manufacture of other chemicals such as chlorinated phenols and as a consequence of combustion processes. Only the USA has set a standard for this substance at the very low level of 3×10^{-8} mg l^{-1}.

Table 3.3 Summary of Standards set in other jurisdictions – Semi-volatile Organics

Substances for which drinking water standards are set by others, but not UK	WHO Guideline Value (mg l^{-1})	USA MCL (mg l^{-1})	Australia MAC (mg l^{-1})	Canada MAC (mg l^{-1})	New Zealand (MAV) (mg l^{-1})	Japan (mg l^{-1})
Di(2-ethylhexyl) adipate (DEHA; a Plasticiser)	n.a.[1]	0.4			0.1 (P)	
Di(2-ethylhexyl) phthalate (DEHP; a Plasticiser)	0.008	0.006	0.01		0.009	
Dioxin (2,3,7,8-TCDD)		3×10^{-8}				

(P) = Provisional

[1] Considered to be not applicable, i.e., it occurs in drinking water at concentrations well below those at which toxic effects may occur

3.4 Disinfection By-Products (DBPs)

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for DBPs is set out in Table 3.5.

Disinfectants, in addition to removing pathogens from drinking water, also serve as oxidants in water treatment for removal of a range of chemical contaminants, including natural organic matter or NOM, in combination with other treatments. Chlorine and chloramines are also used to provide a residual in distribution in order to help maintain hygienic conditions.

Chlorination is the most widely used technique for disinfection of drinking water but ozone is increasingly used as part of the treatment process and chloramines are used to provide a residual disinfectant for distribution. These oxidants react to varying extents and in varying ways with contaminants in the raw water to form unwanted by-products (DBPs). The formation of DBPs primarily results from the reaction of disinfectants with naturally occurring organic materials (NOM), i.e., humic and fulvic acids and inorganic ions, particularly bromide. A wide range of halogenated DBPs can be formed during chlorination and those present in the highest concentration are trihalomethanes (THMs) and halogenated acetic acids (HAAs), with a range of other compounds present at lower concentrations, including halogenated ketones and haloacetonitriles. When bromide and, to a lesser extent, iodide are also present in the raw water they can take part in the reaction to give rise to brominated substances and much lower concentrations of iodinated substances. When ozone is used the major by-product is bromate but there is a wide range of organic molecules that are formed from the oxidation of NOM. Table 3.4 summarises the dominant DBPs arising from use of different disinfectants.

Table 3.4 Disinfectant by-products arising from use of different disinfectants

Disinfectant	Disinfectant residual in water distribution system	Dominant precursors for DBP formation	Dominant DBPs of regulatory concern
Ozone	No	Bromide, NOM	Bromate (BrO_3^-), aldehydes
Free chlorine $HOCl/OCl^-$	Yes	Bromide, NOM	THMs, HAAs
Monochloroamine (NH_2Cl)	Yes	Organic nitrogen	NDMA, cyanogen chloride
Chlorine dioxide (ClO_2)	No	Decay of ClO_2	Chlorite, chlorate
UV irradiation	No	None	None at present

Chlorine was at one time primarily applied in the form of chlorine gas, which dissolves to form hypochlorous acid (HOCl), known as free chlorine, in the water. However, sodium hypochlorite, which also forms HOCl in water, is becoming the more frequent form of chlorine donor because of the handling, storage, environmental, health and safety issues associated with chlorine gas (http://www.veoliawater.co.uk/en/corp-responsibility/business/quality/). Both HOCl and hypochlorite ion (OCl^-) act as disinfectants but HOCl is almost two orders of magnitude more effective. The chemistry is complex and is influenced by temperature, pH and a number of other potential contaminants such as ammonia, which reacts rapidly with free chlorine to form chloramines. The reactions with NOM are also complex and similarly influenced. Free chlorine also oxidizes bromide (Br^-) present in the water, to form HOBr which then becomes involved in the reactions by which halogenated DBPs are formed. Some DBPs, such as THMs, also continue to form in distribution, depending on temperature, while some will degrade in distribution. WHO has provided guideline values for a number of DBPs but does not consider that it is necessary or appropriate for all of these to be incorporated into national standards. As a consequence most jurisdictions establish standards for total trihalomethanes (TTHMs) and/or total haloacetic acids (HAAs) but few establish standards for other chlorination by-products. While many have applied a value of 100 µg l^{-1}, this will depend on the way in which compliance is measured, so compliance with a TTHM standard of 80 µg l^{-1} based on a three monthly average (USEPA) will be roughly equivalent to an absolute maximum of 100 µg l^{-1}. In Europe, the eventual standard for TTHMs will be 100 µg l^{-1} following an interim standard of 150 µg l^{-1}. However, a number of member states have set more stringent TTHM standards. It is worth noting that the USEPA has set a standard for total HAAs of 60 μg l^{-1} that includes a group of five HAAs (mono-, di- and tri-chloroacetic acids and mono- and di-bromoacetic acids). Other jurisdictions such as Canada have also set standards for HAAs along with THMs to give a broader coverage of chlorination by-products.

Chloroamines

Mono-, di- and trichloroamines are by-products of drinking water chlorination and are formed when ammonia is added to chlorinated water. Monochloroamine is also used as a residual disinfectant in distribution. The use of monochloroamine instead of chlorine for disinfection reduces the formation of THMs. However, depending on the conditions under which chloramine is formed, other by-products, such as cyanogen chloride and nitrosodimethylamine (NDMA) may be formed. Currently only WHO has proposed a guideline for NDMA but cyanogen chloride breaks down to form cyanide and the guideline value is based on cyanide, which is already included in most national standards.

Ozone

Ozone is increasingly used as both an oxidant and a disinfectant. As with other disinfectants the use of ozone can lead to by-product formation, although as with the other disinfectants the extent of formation will depend on what is in raw water and the conditions of use. The by-product of greatest concern is bromate, which forms in the presence of bromide ion. Aldehydes may also be formed but these are not normally considered to be of concern since the yield is relatively low compared to health-based values. Only WHO has considered one of these aldehydes, formaldehyde, but the first addendum of the third edition of the Guidelines concluded that it was not considered necessary to set a formal guideline value.

Chlorine Dioxide

Chlorine dioxide is used to a lesser extent than other disinfectants. It does not form as many by-products but it does break down to leave chlorite and chlorate, both of which have been considered by WHO, while USEPA has set a standard for chlorine dioxide and its breakdown products. Within the EU, Italy introduced a standard of 0.8 µg l^{-1} for chlorite which was applied from December 2003, and subsequently lowered to 0.2 µg l^{-1} with effect from December 2006. This caused a number of difficulties for drinking water treatment plants and the Italian Ministry of Health set a temporary limit for chlorite of 1.3 mg l^{-1}, or under particular conditions of 1.8 mg l^{-1} (Roccaro et al. 2005).

Bromate can also be formed in the electrolytic generation of hypochlorite from brine containing elevated concentrations of bromide. Chlorate also forms in hypochlorite solution over time if this is not stored correctly.

WHO and other regulatory authorities emphasise that disinfection efficiency should not be compromised in trying to meet guidelines or standards for DBPs.

Table 3.5 Summary of Standards set in other jurisdictions – Disinfectant By-Products (DBPs)

Substances for which drinking water standards are set by others, but not UK	WHO Guideline Value (mg l^{-1})	USA MCL (mg l^{-1})	Australia MAC (mg l^{-1})	Canada MAC (mg l^{-1})	New Zealand (MAV) (mg l^{-1})	Japan (mg l^{-1})
Haloacetic acids		0.06		0.08 *		
Chloroacetic acid (monochloroacetate)	0.02		0.15			0.02
Dichloroacetic acid (DCA)	0.05 (P)		0.1		0.05 (P)	0.04
Trichloroacetic acid (TCA)	0.2		0.1		0.2	0.02
Chlorophenols						
2,4,6-trichlorophenol	0.2	CCL	0.02			
2,4-dichlorophenol		CCL	0.2	0.9	0.0003 §	
2-chlorophenol	n.a.[1]		0.3			
2,3,4,6-Tetrachlorophenol				0.1		
Others						
Chloramines—total		4**				
Chlorate	0.7 (P)				0.8 (P)	0.6 ***
Chlorinated furanones	n.a.[1]					
Chlorite	0.7 (P)	1 (DBP)			0.8 (P)	0.6 ***
Chloropicrin	n.a.[1]					
Cyanogen chloride	0.07 (asCN)		0.08		0.08	
Formaldehyde	n.a.[1]		0.5		1	0.08
N-nitrosodimethylamine (NDMA)	0.0001					
Monochloramine	3		3		3	
Trichloroacetaldehyde (chloral hydrate)	n.a.[1]		0.02		0.01 (P)	
Haloacetronitriles						
Bromochloroacetonitrile						
Dibromoacetonitrile	0.07				0.08	0.06 ****
Dichloroacetonitrile	0.02 (P)				0.02 (P)	0.04 ***
Trichloroacetonitrile	n.a.[1]					

§ Taste threshold (0.04 mg l^{-1} = odour threshold)

[1] Considered to be not applicable, i.e., occurs in drinking water at concentrations well below those at which toxic effects may occur
* Proposed
** MRDL
*** Complementary target standard
**** Designated for further study – target value
(DBP) set under Disinfectants DBP Rule
(P) = Provisional

Table 3.6 Summary of Standards set in other jurisdictions – Algal toxins

Substances for which drinking water standards are set by others, but not UK	WHO Guideline Value (mg l^{-1})	USA MCL (mg l^{-1})	Australia MAC (mg l^{-1})	Canada MAC (mg l^{-1})	New Zealand (MAV) (mg l^{-1})	Japan (mg l^{-1})
Microcystin-LR (Cyanobacterial Toxin)	0.001 (P)			0.0015	0.001 (P)	0.0008 *

(P) = Provisional
* Designated for further study – target value

Table 3.7 Summary of Standards set in other jurisdictions – Others

Substances for which drinking water standards are set by others, but not UK	WHO Guideline Value (mg l^{-1})	USA MCL (mg l^{-1})	Australia MAC (mg l^{-1})	Canada MAC (mg l^{-1})	New Zealand (MAV) (mg l^{-1})	Japan (mg l^{-1})
Dialkytins (organotins)	n.a.[1]					
EDTA (Ethylenediamine tetraacetic acid)	0.6		0.25		0.7	0.5 *
Nitrilotriacetic acid (NTA)	0.2		0.2	0.4	0.2	
Tributyltin oxide (Organotin) - Biocide	n.a.[1]		0.001		0.002 (P)	

[1] Considered to be not applicable, i.e., occurs in drinking water at concentrations well below those at which toxic effects may occur, normally controlled by product specification.
* Designated for further study – target value

3.5 Algal Toxins

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for algal toxins is set out in Table 3.6.

Cyanobacteria occur widely in lakes, reservoirs, ponds and slow-flowing rivers and are capable of sudden explosive growth to form blooms, which are detectable visually. Many species are known to produce toxins and, although not all blooms of such species produce toxin at all times, there is a reasonably high probability that they will be toxic. Several of the toxins are a potential concern for public health as a consequence of the presence of blooms of toxin producing cyanobacteria in recreational waters, but there is also the potential for toxin to enter drinking water when reservoirs and lakes used for potable water abstraction are affected. Frequently these incidents are managed by a combination of techniques, such as early treatment of the blooms and by moving the intake to a deeper level in order to avoid the blooms. The cyanotoxins occurring most frequently appear to be the microcystins. Microcystin-LR is one of the most common and the most toxic of more than 70 structural variants of microcystin and therefore a guideline value for microcystin-LR can be used as a surrogate for assessment and for setting targets as a worst-case estimate. Very few cyanotoxins have been studied comprehensively for their toxicity but microcystin-LR is the most studied. The definitive UK studies that provided data on which guidelines and standards are based was funded by the Department of the Environment in partnership with the UK Water Industry (Fawell et al. 1999). WHO has indicated that the preferred option for managing the risks of cyanotoxins in drinking water is prevention of the blooms in the first instance.

Blooms of cyanobacteria and other algae in reservoirs and in river waters may also give rise to geosmin, 2-methyl isoborneol and other chemicals, which have very low taste thresholds in drinking water. Of the jurisdictions considered in this report only Japan has set standards for these by-products at 0.01 µg l^{-1}.

3.6 Pesticides

The EU Drinking Water Directive specifies a precautionary or political standard of 0.1 µg l^{-1} for any pesticide (lower values are specified for several older organochlorine insecticides which are no longer approved for use in the UK) and a value of 0.5 µg l^{-1} for total pesticides. WHO and other jurisdictions set guidelines/standards for individual pesticides. It should be noted that these guidelines and standards for specific pesticides, other than those named in the EU Directive (aldrin, dieldin, heptachlor and heptachlor epoxide), are all higher, and most are significantly higher, than 0.1 µg l^{-1}. The European approach requires that water suppliers assess which pesticides are used within the catchment area of each water source and develop monitoring programmes as appropriate. Because of the precautionary standard it is not necessary to consider pesticides further in this report.

3.7 Others

A summary of the standards set by WHO, USA, Australia, Canada, New Zealand and Japan for these substances is set out in Table 3.7.

3.8 Substances Under Consideration

Some substances are emerging as potential issues for drinking water in specific circumstances and are therefore considered here. These are not necessarily present in all water sources but may arise as a consequence of particular circumstances of use or discharge. Some have been identified as potentially being present in drinking water and as a consequence guidance has been developed or is being considered by some jurisdictions. The USEPA candidate contaminant list (CCL) is an important activity and is an appropriate, evidence-based approach for identifying the need for advice or standards. Table 3.8 lists the chemical substances that are on the USEPA CCL with the exception of pesticides.

Perfluorooctanesulfonate (PFOS) and Perfluorooctanoic acid (PFOA)
Perfluorooctanesulfonate is currently being considered by WHO under its rolling revision programme and is of increasing interest in the USA, Europe and the UK in particular following the Buncefield fire in which large quantities of fire-fighting foam were used containing fluorinated additives that break down to PFOS and PFOA. DWI has provided advice to water companies on actions to be taken in the case of these substances being present in drinking water, with appropriate trigger concentrations.

Table 3.8 USEPA Chemical Contaminant Candidate Substances

Chemical Contaminant	CAS RN
1,1,2,2-tetrachloroethane	79-34-5
1,2,4-trimethylbenzene	95-63-6
1,1-dichloroethane	75-34-3
1,1-dichloropropene	563-58-6
1,2-diphenylhydrazine	122-66-7
1,3-dichloropropane	142-28-9
1,3-dichloropropene	542-75-6
2,4,6-trichlorophenol	88-06-2
2,2-dichloropropane	594-20-7
2,4-dichlorophenol	120-83-2
2,4-dinitrophenol	51-28-5
2,4-dinitrotoluene	121-14-2
2,6-dinitrotoluene	606-20-2
2-methyl-Phenol (o-cresol)	95-48-7
Aluminium (a new look at the data)	7429-90-5
Boron (WHO GV under revision)	7440-42-8

Chemical Contaminant	CAS RN
Bromobenzene	108-86-1
DCPA mono-acid degradate	887-54-7
DCPA di-acid degradate	2136-79-0
p-Isopropyltoluene (p-cymene)	99-87-6
Methyl bromide	74-83-9
Methyl-t-butyl ether (MTBE)	1634-04-4
Nitrobenzene	98-95-3
Organotins (largely from materials)	N/A
Perchlorate	14797-73-0
RDX	121-82-4
Vanadium	7440-62-2

Table 3.9 lists additional substances that have been incorporated into national standards of other European States but for which there are no standards set in the UK. Many of these substances are those that have already been identified in the sections above.

Table 3.9 Additional substances incorporated in national standards of other European States

Additional substances incorporated in national standards of other European States
Alkylbenzenes
Barium
Beryllium
Bromodichloromethane
Cis 1,2-dichloromethene
Chlorate
Chlorite
Chloramines
Chlorophenols (various)
Dichloromethane
EDTA
Formaldehyde
Hydrogen sulphide
Methane
Microcystin
Molybdenum
MTBE
Napthalene
NTA
Polychlorinated biphenyls/terphenyls (PCB/PCT)

Additional substances incorporated in national standards of other European States
Potassium
Radon
Silver
Styrene
Tin
Trichloroacetaldehyde
Trichlorobenzene
Trichloromethane
Vanadium
Xylene
Zinc

The European Parliament has proposed thirty new substances for addition to the list of Water Framework Directive Priority Substances proposed by the European Commission in COM(2006)397 final. Many of the substances proposed by the European Parliament have been prioritised by them because they may be issue for drinking water treatment. It is indeed one of the aims of the Water Framework Directive to reduce the amount of water treatment required. However, to date the emphasis of the Commission in deriving Environmental Quality Standards (EQS), and of the current Expert Group on standards in developing standardised methodologies, has been on environmental effects and not on drinking water treatment. This means that although substances may be prioritised by the Parliament on the basis of human health concerns, no methods have yet been developed by the Commission to develop EQS for these when the route of exposure is via drinking water.

Of these thirty substances six of them are pesticides and therefore already covered under the EU Drinking Water Directive. Of the others, only free cyanides are currently subject to a drinking water standard in the UK. Of the remaining substances only MTBE and EDTA have drinking water standards set in other jurisdictions. Perfluorooctanesulfonate is currently being considered by WHO under its rolling revision programme and is of increasing interest in the USA, Europe and the UK in particular following the Buncefield fire in which large quantities of fire-fighting foam were used containing fluorinated additives that break down to PFOS and PFOA. DWI has provided advice to water companies on actions to be taken in the case of these substances being present in drinking water, with appropriate trigger concentrations. The proposed substances are listed in Table 3.10.

We were unable to obtain information on concentrations of the proposed substances in UK waters, however, the Environment Agency confirmed that their Water Information Management System database does contain detects for the following substances: bisphenol A, free cyanides, dioxins, PCBs, bentazon, glyphosate, mecoprop, 4-methylbenzilidene camphor, perfluorooctanoic acid, EDTA and tetrabromobisphenol A.

Table 3.10 New Priority Substances Proposed under the EU Water Framework Directive

EU Proposed Substances	Comment
4 – Methylbenzilidene camphor	
4, 4' – Biphenol	
Amidotrizoate	Pharmaceutical
AMPA	Pesticide (metabolite of glyphosate)
Bentazone	Pesticide
Bisphenol A	
Carbamazepine	Pharmaceutical
Clotrimazole	Pharmaceutical
Dibutylphthalate (DBP)	Plasticiser
Diclofenac	Pharmaceutical
Dicofol	Pesticide, not approved for use in the UK
Diethylene triamine pentaacetic acid (DTPA)	Chelating Agent
Dioxins	
EDTA	Drinking Water Standards set by other jurisdictions
Ethyl tert-butyl ether (ETBE)	Fuel additive
Free cyanides	Drinking Water Standard = 50 ug l^{-1}
Glyphosate	Pesticide
HHCB	Musk compound
Iopamidol	Pharmaceutical
Mecoprop (MCCP)	Pesticide
MTBE	Drinking Water Standards set by other jurisdictions
Musk ketone	Musk compound
Musk xylene	Musk compound
Naphthalene-1,5-Disulphonate	
Octyl-methoxycinnamate	Pharmaceutical
Perfluorooctane sulphonic acid (PFOS)	
Perfluorooctanoic acid (PFOA)	
PCBs	
Quinoxyfen	Pesticide
Tetrabromobisphenol A (TBBP-A)	Flame retardant
Tonalid (AHTN)	Musk compound

4 OCCURRENCE OF NON-REGULATORY PARAMETERS IN UK DRINKING WATER

A search of the open scientific and grey literature was carried out to determine what information has been published on the occurrence and concentrations of the identified 'non-regulatory' parameters in England and Wales, and also in Scotland and Northern Ireland. This search yielded little information, but Table 4.1 summarises the findings from the studies that were located. Substantially more information was available for the occurrence of the compounds in other countries and a summary of that information is provided in Annex 1 to this report. While these data relate to occurrence in other countries, they can be of value in assessing the circumstances in which they may occur in UK waters. In addition data on raw waters also provides information on the potential for substances to reach drinking water.

Table 4.1 Summary of studies carried out in the UK on 'non-regulatory' parameters

Parameter	Groundwater μg l^{-1}	Surface Water μg l^{-1}	Drinking Water μg l^{-1}	Ref
Inorganics				
Barium	5 - 426			Taylor et al 2006
		15.3 - 36.8		Neal et al. 2000
	1.5 - 146			Edmunds et al. 2003
	23 - 625			Ford and Tellam 1994
Beryllium	0.06 - 1.56 0.14 (mean)	0.09 (mean) 1.14 (max)		Neal 2003a
		0 - 0.1		Neal et al. 2000
Iodine	3 - 54			Edmunds et al. 2003
Molybdenum	< 7			Edmunds et al. 2003
		0 – 70.3		Neal 2003b
		2.1 – 40.2		Neal et al. 2000
Uranium	0.01 – 1.7			Edmunds et al. 2003
		0.5 – 1.3		Neal et al. 2000
	<0.02 - 48			DWI 2006
Zinc	7 - 157			Taylor et al 2006
		6.7 – 12.6		Neal et al. 2000
Volatile organics				

Parameter	**Groundwater $\mu g\ l^{-1}$**	**Surface Water $\mu g\ l^{-1}$**	**Drinking Water $\mu g\ l^{-1}$**	**Ref**
Chlorinated hydrocarbon solvents				
1,1,1-trichloroethane	> 0.1 < 10 (means) 100 (max)	< 1.0		Shepherd et al. 2006
1,1-dichloroethane	> 0.1 ≤ 1.0			Shepherd et al. 2006
1,1-dichloroethene	> 0.1 < 1.0			Shepherd et al. 2006
1,4-Dichlorobenzene	>0.1 < 1.0			Shepherd et al. 2006
cis-1,2-Dichloroethene (dichloroethylene)	< 1.0 ≤ 10 (mean) 24 (max)	> 1.0 < 5.0		Shepherd et al. 2006
trans-1,2-Dichloroethene (dichloroethylene)	>0.1 < 1.0			Shepherd et al. 2006
BTEX and fuel related compounds				
Methyl tertiary-butyl ether (MTBE)	>0.1 < 1.0			Shepherd et al. 2006
Disinfection by-products (DBPs)				
Haloacetic acids (HAAs)				
Dichloroacetic acid (DCA)			116 (max) 6.6 – 21.1(means)	Malliarou et al. 2005
Trichloroacetic acid (TCAA)			95 (max) 7 – 15.7 (means)	Malliarou et al. 2005
Other				
EDTA		< 2 - 129		FWR 1992
NTA		< 2 - 43		FWR 1992

Detailed assessment of the quality of the data reported in the open scientific literature is difficult since the full details of analytical methods are often not provided in the paper reporting the monitoring data, and sometimes the source references, for example PhD theses, are not readily available. In addition, scientific papers rarely state the full details of method validation and on-going Quality Assurance and Control procedures that were implemented. However, the reported data have appeared in peer reviewed scientific journals and would be expected to be of reasonable quality even if the methods have not been as rigorously validated or as tightly controlled as those used by the Environment Agency and the drinking water companies to produce the data reported in a later section of this report.

4.1 Inorganic Substances

The presence of barium derived from natural sources at relatively high concentrations (up to 625 µg l^{-1}) in the Birmingham aquifer was reported by Ford and Tellam (1994). The high concentrations were due to barium leached from the rock strata comprising the aquifer and the high levels were possible due to the very low sulphate concentration in the groundwater. Higher concentrations of sulphate, such as are present in many surface waters, would have reduced the barium concentrations significantly due to the very low solubility product of barium sulphate.

Neal et al. (2000) report the presence of several inorganics (barium, beryllium, molybdenum and zinc) in the River Ouse from a one-year (1997/8) detailed water quality study. The Great Ouse represents one of the major UK river basins draining approximately 7% of the surface area of England. Due to the complex nature of the Great Ouse water courses, sampling was undertaken on a uniform stretch of the river near the village of Great Paxton (grid reference TL 204634). Both unfiltered and filtered samples were taken in the field for chemical analysis. The collection was made at a hydrologically active point well away from the more quiescent edges of the river. None of the concentrations reported exceed the drinking water standards set in other jurisdictions.

Taylor et al. (2006) carried out depth-specific sampling of urban groundwater using bundled multilevel piezometers installed in dedicated boreholes drilled to depths ranging from 50 to 91 mbgl[1] at two locations in each of Birmingham and Nottingham. Criteria for site selection included contrasting hydrogeological conditions (e.g., unconfined versus confined) and proximity to (but not located on) industrial premises. Hydrochemical sampling was conducted over three intervals from June 2000 to March 2001. The authors reported concentrations for barium and zinc, none of which exceeded the drinking water standards set in other jurisdictions.

Edmunds et al. (2003) analysed chemical data from 65 boreholes in Berkshire and the Chilterns area from studies carried out by the British Geological Survey and the Environment Agency during the 1990s. Concentrations for barium, iodine, molybdenum and uranium were reported, none of which exceeded the drinking water standards set in other jurisdictions.

Neal (2003a) investigated a major hydrochemical beryllium dataset for the lowland UK collected as part of a major community research programme, the Land Ocean Interaction Study (LOIS). An anomalous and short-lived increase in beryllium concentration (up to 29 µg l^{-1}) was observed in October/November 1995, possibly linked to drought conditions and sewage/industrially related discharges. The beryllium concentration data reported in this paper came from a wide range of studies carried out at the Centre for Ecology and Hydrology catchment research sites at Plynlimon in mid-Wales: the headwater catchments of the River Severn, with three main tributaries, the

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[1] mbgl = maximum depth below ground level encountered at the exact location of the investigation

Afon Hafren, the Afon Hore and the Nant Tanllwyth (8.7 km^2 area in total) and encompassed monitoring results up to 1998. These values were considered to be very similar to other rural and upland areas of the UK where beryllium rich bedrock and industrial/urban sources are absent. For eastern UK rivers, the summary statistics given were as follows: dissolved Be concentrations mean 0.02 $\mu g\ l^{-1}$ across the region with individual means for the different rivers in the range of 0.02, 0.05 and 0.09 $\mu g\ l^{-1}$ for the Wear, Great Ouse and Thames respectively.

Also as part of LOIS, various contaminants were monitored over an extensive period between September 1993 and February 1997 across a major part of the UK. The study area included rural, industrial and urban impacted catchments. Molybdenum levels across the eastern UK rivers ranged from 0 to 70.3 $\mu g\ l^{-1}$. This maximum level was recorded in the River Aire, with a mean value of 23 $\mu g\ l^{-1}$ (Neal 2003b). The maximum level is equal to the WHO guideline value.

A comprehensive study (DWI 2006) was undertaken in 2005 to measure the quantity of uranium present in samples of raw groundwater taken from operational boreholes and springs across England and Wales. Results from the 101 groundwater sources analysed indicate a range in uranium concentrations of <0.02 to 48 $\mu g\ l^{-1}$ (median 0.39 $\mu g\ l^{-1}$). Only two samples exceeded the WHO provisional guideline value of 15 $\mu g\ l^{-1}$, both of which were from private supplies. The authors also compared these results with those from the BGS groundwater-chemistry database. The range of 1556 groundwater samples from Great Britain was < 0.01 to 67.2 $\mu g\ l^{-1}$ (median 0.29 $\mu g\ l^{-1}$). Of these 11 samples were > 15 $\mu g\ l^{-1}$, 7 samples > 20 $\mu g\ l^{-1}$ and 4 samples > 30 $\mu g\ l^{-1}$. A large majority of the samples, 78%, had concentrations less than 1 $\mu g\ l^{-1}$.

Between 1977 and 1980, the Water Research Centre (WRc) collected water samples from 1000 homes in 25 towns in Great Britain in conjunction with the Regional Heart Study (Powell et al. 1987). These samples were analysed for a number of inorganic constituents by plasma-emission spectrometry. These included several substances that are among the unregulated substances for which other jurisdictions have set guidelines or standards, including barium, beryllium, molybdenum, vanadium and zinc. The results of this study were as follows: barium: mean 71.4 $\mu g\ l^{-1}$, 50th percentile 49.5 $\mu g\ l^{-1}$, 90th percentile 152.5 $\mu g\ l^{-1}$, beryllium: mean 0.11 $\mu g\ l^{-1}$, 50th percentile 0.1 $\mu g\ l^{-1}$, 90th percentile 0.14 $\mu g\ l^{-1}$, molybdenum: mean 60.4 $\mu g\ l^{-1}$, 50th percentile 29.7 $\mu g\ l^{-1}$, 90th percentile 118.5 $\mu g\ l^{-1}$, vanadium: mean 9.3 $\mu g\ l^{-1}$, 50th percentile 6.2 $\mu g\ l^{-1}$, 90th percentile 22.4 $\mu g\ l^{-1}$, zinc: mean 15.6 $\mu g\ l^{-1}$, 50th percentile 9.5 $\mu g\ l^{-1}$, 90th percentile 32.7 $\mu g\ l^{-1}$.

4.2 Volatile Organic Compounds

Shepherd et al. (2006) report groundwater quality data from samples collected from 14 deep abstraction wells and 20 shallow monitoring wells in the Tame Valley area. They also report data from 96 riverbed piezometers and 128 surface water samples. By cross reference to other publications (Ellis and Rivett 2007) it is believed that the samples were taken in 2001.

Only 21 of the 52 VOCs analysed were detected, with eight of these VOCs being detected in just one sample. Occurrence was dominated by chlorinated VOCs (18 of the 21 VOCs detected) with trichloroethene (TCE) predominant across the various media. Other non-chlorinated VOC detections were for the hydrocarbons benzene and toluene and the fuel oxygenate MTBE. Other VOCs including ethylbenzene and xylenes, chlorinated VOCs infrequently used by industry, and brominated VOCs (with one exception) were below detection limits. Comparison across the various media indicated that the greatest range of VOCs, maxima and means were generally detected in the abstraction wells, with the lowest values detected in the surface waters. The latter finding was considered to be as a result of rapid loss from surface waters due to water–air (Henry's Law) partitioning. Greatest contaminant occurrence and breaching of water quality standards occurred in abstraction wells despite samples being representative of a depth-integrated (i.e., likely diluted) sample of aquifer quality. This was ascribed to: (i) their proximity to sources; (ii) increased probability of capture (sampling) of source-area contamination; and, (iii) chlorinated VOC nature, in particular their DNAPL (dense non-aqueous phase liquid) property. Although parent chlorinated VOCs such as trichloroethene and perchloroethene (PCE) are widespread, there was some evidence of natural attenuation due to biodegradation and abiotic chemical reactions in the Birmingham system. This was due to the formation of lesser chlorinated organics that are rarely, if at all, used by the majority of resident industry. For example, the biodegradation products cis-1,2-dichloroethene (cDCE) (trans 1,2-dichloroethene (tDCE) was also less frequently detected and at lower concentrations) and vinyl chloride (VC) were detected and ascribed to dechlorination of TCE and PCE under highly reducing, methanogenic and sulphate-reducing, conditions. 1,1-dichloroethane (1,1-DCA), most likely formed by biotic de-chlorination of the parent 1,1,1-TCA solvent under highly reducing, e.g., methanogenic, conditions was also found. 1,2-DCA was more rarely found and potentially formed from, for example, successive de-chlorination of 1,1,2,2-tetrachloroethane. Abiotic reaction products that were detected included 1,1-DCE, which also potentially derived from the solvent 1,1,1-TCA. Evidence in support of these reactions was primarily through groundwater sample co-occurrence of both parent and daughter products.

VOC concentrations in riverbed piezometers were in the range 0.1–100 μg l^{-1} with regulatory limits occasionally exceeded by an order of magnitude. Although anaerobic biodegradation products such as cis-dichloroethene (cDCE) were widespread, they were unlikely to have formed in the generally aerobic riverbed. The lack of anaerobic conditions was ascribed to insufficient accumulation of low permeability, organic-carbon rich riverbed sediments in this medium–high energy river. For riverbed samples, only 13 of the 52 VOCs analyzed for were detected, with TCE most frequently detected in 71% of samples, followed by cDCE in 54%. Chlorinated aliphatic VOCs were dominant, comprising nine of the 13 VOCs detected, and MTBE was the only non-halogenated VOC detected. Aromatic hydrocarbon VOCs were not detected (~0.1 μg l^{-1} detection limits). Maximum concentrations were 1,1,1-TCA 110 μg l^{-1}, TCE 62 μg l^{-1}, DCA 25 μg l^{-1} and cDCE 24 μg l^{-1} with five of the thirteen detected VOC maxima <1 μg l^{-1}. Mean concentrations were typically at least an order of magnitude lower (Ellis and Rivett 2007). The general absence of aromatic hydrocarbon VOCs (although widely used in the city) in aquifer groundwater abstractions (Shepherd et al. 2006) and riverbed piezometers was ascribed to their being readily attenuated by biodegradation in the vicinity of source areas. Although parent compounds were clearly able to reach the riverbed, suggesting attenuation in the aquifer beforehand was limited, occurrence of degradation products such as cDCE was significant. cDCE is rarely used by industry, but is the predominant isomer formed by anaerobic dechlorination of TCE under sulphate-reducing or methanogenic conditions. The expected degradation products of the other main locally-used parent solvent 1,1,1-TCA were also found. 1,1,1-TCA detections co-occurred with 1,1-DCA. The latter occurred in ~30% of samples with cDCE co-occurring in the majority, thus endorsing the hypothesis of biotic activity. 1,1- DCA is most likely ascribed to the biotic dechlorination of 1,1,1-TCA under reducing (methanogenic) conditions. Two of the three transects contaminated by 1,1-DCE contained elevated 1,1,1-TCA.

In 2000, the Environment Agency and Institute of Petroleum jointly carried out a review of the occurrence of MTBE in groundwater in England and Wales. The review showed that 12.5% and 1.2% of the 255 public water supply (PWS) boreholes examined had detectable (0.1 µg l^{-1}) and tasteable (5 µg l^{-1}) MTBE concentrations respectively. They concluded that the concentrations found in groundwater were unlikely to pose a risk to human health but were a potential taste and odour problem in drinking water (EA 2000).

4.3 Disinfection By-Products

Malliarou et al. (2005) used US EPA Method 552.2 (1995) for the determination of HAAs. in samples of tap water. Water samples were collected in 2003 from three different regions in the UK to assess the correlation between total THMs and HAAs in order to determine whether THMs are a good surrogate parameter for the concentration of HAAs. Temperature, pH and free and total chlorine were also measured to see if these parameters influenced the outcomes. Malliarou et al. found that in two out of the three regions (A and B) there was a high correlation between total THMs and total HAAs, but whereas the HAA and THM levels in one of the regions were approximately equal, in the other region HAA levels were 3-4 times higher than the THM levels. In the third region (C) there was no correlation at all between total THMs and total HAAs even though the average levels were approximately equal. The ratio of total THM and total HAAs levels was significantly correlated with temperature, pH, free and total chlorine. The overall conclusion of Malliarou et al. was that total THM levels were not a good indicator of HAA levels in the UK tap water samples analysed. The results are shown in Table 4.2.

In a survey of UK drinking water the maximum concentrations of DCA and TCA were found to be 60 µg l^{-1} and 100 µg l^{-1}, respectively (P Jackson, WRc-NSF, pers. comm). However, continuous efforts have been made to reduce the precursors of DBPs and this will result in a continuing decline in concentrations.

Table 4.2 Individual and total haloacetic acid and total trihalomethane levels (µg l^{-1}) in three water regions in the UK (Malliarou et al. 2005)

	Region (no. of samples)	TCAA	DCAA	BCAA	DBAA	BDCAA	MBAA	THAA	TTHM
Geometric Mean (std dev)	A (n=31)	7.0 (4.5)	6.6 (2.9)	2.1 (2.7)	3.8 (2.5)	1.4 (2.6)	1.7 (3.3)	31.3 (1.6)	46.2 (1.6)
	B (n=29)	10.3 (7.0)	21.1 (3.9)	4.5 (4.1)	2.2 (4.6)	3.5 (3.6)	1.4 (5.2)	58.9 (3.2)	14.9 (4.5)
	C (n=27)	15.7 (2.8)	19.0 (2.0)	1.4 (2.8)	0.3 (3.9)	1.2 (2.0)	1.1 (2.8)	46.2 (1.7)	44.7 (1.6)
Maximum	A	34	23	9	17	8	8	82	76
	B	95	116	30	24	21	17	244	72
	C	51	58	23	21	8	5	91	75

TCAA = trichloroacetic acid, DCAA = dichloroacetic acid, BCAA = bromochloroacetic acid, BDCAA = bromodichloroacetic acid, MBAA = monobromoacetic acid, THAA = total haloacetic acid, TTHM = total trihalomethanes

4.4 Other Substances

Many of the data that have been generated on a range of substances of interest are not readily accessible and are often contained in unpublished technical reports. One study that is published is a consideration of oestrogens and oestrogenic activity in raw and treated water in the Severn Trent Water area (Fawell et al. 2001). This study looked at several substances including diethyl hexyl phthalate (DEHP). This was present in raw water at concentrations of between 2.2 and 4.9 µg l^{-1} while concentrations in final waters were lower, with a reduction by about half as a result of treatment. It is interesting to note that bankside storage also resulted in a reduction in concentration of almost half.

Other data are available on a range of organic substances, but this is dispersed across a range of reports and much is very old and probably no longer relevant. For example, WRc carried out a study in which 14 drinking waters (derived from different quality surface waters and some groundwaters) were surveyed for organic contaminants using GC-MS. This study was published in 1981 (Fielding et al. 1981) and many of the substances in the list were potentially detectable occasionally. However, none were found at concentrations of more than about 1 µg l^{-1}.

A Department of the Environment commissioned survey (FWR 1992) of 25 UK river sites and 10 sewage treatment works carried out in 1992 found concentrations of NTA in river water ranging from < 2 µg l^{-1} (LoD) to 43 µg l^{-1}. The mean and median concentrations in the cleanest rivers were < 2 µg l^{-1}, whereas the mean concentration in polluted rivers was 16 µg l^{-1} with a median concentration of 10 µg l^{-1}. This same survey also measured concentrations of EDTA. The range of values reported was from < 2 µg l^{-1} (LoD) to 129 µg l^{-1}. In the most pristine rivers the mean concentration was between 6 and 7 µg l^{-1} with a median < 2 µg l^{-1}. In the most polluted rivers the mean concentration was 57 µg l^{-1} with a median of 47 µg l^{-1}. In sewage effluent the concentrations of both NTA and EDTA were much greater than those in rivers, with ranges of < 2 µg l^{-1} to 740 µg l^{-1} for NTA and 60 µg l^{-1} to 1640 µg l^{-1} for EDTA. The levels found in rivers are well below guideline values. The much higher levels found in sewage effluent are less likely to occur today due to the improvements made in industrial and sewage wastewater treatment.

5 UK MONITORING OF NON-REGULATORY PARAMETERS

5.1 Groundwater monitoring carried out by Environment Agency

The Environment Agency of England and Wales (EA) carries out an extensive programme of groundwater quality monitoring using analytical methods that have been thoroughly validated and are applied with associated internal and external Quality Assurance and Quality Control procedures. Table 5.1 summarises the data collected for non-regulatory parameters that are routinely monitored in England and Wales. The data relate to the national monitoring network of ~3400 sites. Not all of these are drinking water sources and the data relates to raw water before treatment. The EA has adopted a risk-based approach to determinand selection and as a consequence not all determinands will be measured in every source. The data cover the period 1 January1996 to 31 October 2007.

WHO Guideline values are also shown in the far right column of Table 5.1 to provide some context for the concentrations reported. With the exception of the xylenes, the mean concentrations found were all well below the appropriate WHO guideline values. The very high values relate to sources not used for drinking water.

Table 5.1 Monitoring results for UK groundwaters

Parameter	Number of sites	Number of samples	Sampling period	Number of results below LoD	Min All (including values <LoD) µg l^{-1}	Max Detect (excluding values < LoD) µg l^{-1}	Mean (setting all <LoD values to half LoD) µg l^{-1}	WHO Guideline Value µg l^{-1}
INORGANICS								
Barium	3043	21954	Jan 96 Oct 07	3102	2.4	25400	95.31	700
Beryllium	2707	16163	Jan 96 Oct 07	15987	<0.08	67.2	0.597	Under consideration
Iodide	774	2113	Mar 02 Oct 07	1897	<2.5	4350	48.1	
Silver	2929	19402	Jan 96 Oct 07	19290	<0.04	79.6	0.457	To be considered
Thallium	2413	7451	Nov 98 Oct 07	7365	<1	24.2	0.672	
Uranium	2484	8062	Nov 98 Oct 07	5284	<0.1	71.1	1.44	15 (P)
Zinc	3166	28976	Jan 96 Oct 07	7849	1.27	155070	110.1	n.a.
VOLATILE ORGANICS								
Chlorinated hydrocarbon solvents								
1,1,1-trichloroethane	2769	13168	Jan-96 Oct 07	11979	0.02	126	0.377	n.a.
1,1,2-Trichloroethane	2597	8366	Jan 96 Oct 07	8299	<0.05	17	0.077	
1,1-dichloroethane	2322	5336	Jan 96 Oct 07	5256	<0.06	18.7	0.230	

Parameter	**Number of sites**	**Number of samples**	**Sampling period**	**Number of results below LoD**	**Min All (including values <LoD)** **µg l^{-1}**	**Max Detect (excluding values < LoD)** **µg l^{-1}**	**Mean** **(setting all <LoD values to half LoD)** **µg l^{-1}**	**WHO Guideline** **Value** **µg l^{-1}**
1,1-dichloroethene	2322	5818	Jan 96 Oct 07	5754	<0.005	21.6	0.249	n.a.
cis-1,2-Dichloroethene (dichloroethylene)	2442	5999	Jan 96 Oct 07	5853	<0.1	1100	0.588	50
trans-1,2-Dichloroethene (dichloroethylene)	2442	5993	Jan 96 Oct 07	5951	<0.1	12	0.245	50
BTEX and other fuel related compounds								
Ethylbenzene	2634	9057	Jan 96 Oct 07	8820	<0.05	27.5	0.612	300
Toluene	2728	10979	Jan 96 Oct 07	10271	<0.001	57.6	0.599	700
1,2-Xylene	2620	8615	Jan 96 Oct 07	8307	<0.05	32.7	0.951	0.5 (total xylenes)
1,3-Xylene or 1,4-Xylene	2621	8672	Jan 96 Oct 07	8284	<0.0002	125	1.542	0.5 (total xylenes)
Styrene	2540	7326	Jan 96 Oct 07	7317	<0.05	2.07	-	20
Methyl tertiary-butyl ether (MTBE)	2616	8834	Jan 96 Oct 07	8684	<0.0001	67	0.865	n.a.
DISINFECTION BY-PRODUCTS								
Chlorophenols								

Parameter	**Number of sites**	**Number of samples**	**Sampling period**	**Number of results below LoD**	**Min All (including values <LoD)** $\mu g\ l^{-1}$	**Max Detect (excluding values < LoD)** $\mu g\ l^{-1}$	**Mean (setting all <LoD values to half LoD)** $\mu g\ l^{-1}$	**WHO Guideline Value** $\mu g\ l^{-1}$
2,4,6-trichlorophenol	1635	4863	Jan 96 Oct 07	4846	<0.005	1.92	0.037	200
2,4-dichlorophenol	1450	3209	Jan 96 Oct 07	3196	<0.00002	0.825	0.036	
2-chlorophenol	1641	4822	Jan 96 Oct 07	4790	<0.005	1.87	0.035	n.a.

n.a. means that levels generally reported in drinking waters are considered by WHO to be well below health-based values

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5.2 Monitoring carried out by Water Companies

The Water Companies in England and Wales carry out a wide range of regulatory monitoring using methods of analysis that have been thoroughly validated and are applied with associated internal and external Quality Assurance and Quality Control procedures. In addition, they monitor some parameters for which there is currently no regulatory requirement but which are in the list of parameters identified by the current study.

Water Companies will carry out additional monitoring when risk assessment of a particular source indicates that there may be a particular threat, or in response to research findings on the occurrence of particular substances. This may take the form of an investigation and if significant concentrations are found then this may lead to monitoring. Fourteen of the largest water companies were approached to ask if they had specific data on the substances that were listed as being included in WHO Guidelines or in the standards of the jurisdictions indicated above. Contact by e-mail was followed up by telephone discussions. Of the fourteen companies, responses were received from twelve, with one of these unable to provide assistance because of other commitments. No response was received from two companies even after direct approaches by telephone. One of the twelve currently did no monitoring or investigation for additional parameters, although this will change with the introduction of drinking water safety plans, which require a risk assessment in the catchment. Where data were available water companies were pleased to assist and the quality of the data provided is known to be high because of the accreditation, auditing and inspection requirements for water company laboratories.

Barium, silver and zinc had prescribed values under the 1989 Water Supply (Water Quality) Regulations and as a consequence it would appear that many water companies continue to monitor for these parameters. The former PCVs were as follows: silver 10 μg l^{-1} (unless silver was used in a water treatment process, i.e., in point of use devices and in buildings for Legionella control, in which case this was raised to 80 μg l^{-1}), zinc 5 mg l^{-1} and barium 1 mg l^{-1}.

Table 5.2 provides an overview of the monitoring of the additional parameters that were identified by this review that has already been carried out in England by the drinking water producers. The subsequent tables provide the numerical values for the concentrations of the parameters reported and the types of water they were measured in.

Table 5.2 Summary of monitoring activity by UK drinking water companies

Water Company	**A**			**B**			**C**			**D**			**E**			**F**			**G**			**H**			**I**			**J**		
Water type¹	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**D**	**S**	**G**	**D**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**D**
Inorganics																														
Barium	**X**	**X**	**X**			**X**				**X**	**X**	**X**	**X**	**X**	**X**	**M**			**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Beryllium			**X**													**M**											**X**			**X**
Molybdenum										**X**	**X**	**X**	**X**			**M**			**X**									**X**		**X**
Silver	**X**	**X**	**X**			**X**				**X**	**X**	**X**			**X**	**M**			**X**		**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	
Tin																**M**						**X**	**X**	**X**			**X**			
Uranium		**X**	**X**			**X**				**X**	**X**	**X**																**X**		**X**
Zinc	**X**	**X**	**X**			**X**				**X**	**X**	**X**	**X**	**X**	**X**				**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Volatile organics																														
Chlorinated hydrocarbon solvents																														
1,1,1-trichloroethane		**X**	**X**								**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**	**X**	**X**			**X**	**X**	**X**	**X**
1,1,2-Trichloroethane																											**X**			
Chlorobenzene																									**X**		**X**			
cis-1,2-Dichloroethene											**X**																			
Dichloromethane																											**X**			
BTEX/other fuel compounds																														
Ethylbenzene										**X**	**X**	**X**				**PM**						**X**	**X**	**X**						
Styrene																									**X**		**X**			
Toluene		**X**									**X**	**X**				**PM**						**X**	**X**	**X**			**X**			
Xylenes (total)											**X**	**X**				**PM**						**X**	**X**	**X**						
MTBE		**X**	**X**								**X**	**X**							**X**	**X**		**X**	**X**	**X**						
Disinfection By-products																														
Haloacetic acids																														
Trichloroacetic acid											**X**								**X**	**X**										
Chlorophenols																														
2,4,6-										**X**		**X**										**X**	**X**	**X**						

Water Company	**A**			**B**			**C**			**D**			**E**			**F**			**G**			**H**			**I**			**J**		
Water type[1]	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**D**	**S**	**G**	**D**	**S**	**G**	**F**	**S**	**G**	**F**	**S**	**G**	**D**
trichlorophenol																														
2,4-dichlorophenol										**X**	**X**	**X**																		
2-chlorophenol		**X**								**X**		**X**																		
Others																														
Chlorate	**X**		**X**								**X**	**X**												**X**						
Chlorite											**X**	**X**												**X**						
Algal toxins																														
Microcystin-LR																												**X**		
Geosmin										**X**		**X**																		**X**
Others																														
Iodine																											**X**			

[1] S = surface water; G = groundwater; F = finished water; D = distribution system (customer tap)

M= monitored but no quantitative data supplied

PM= developing a suite of analytical techniques to enable monitoring to take place

Table 5.3 Monitoring results from several Water Companies in England – inorganics

Period	Jan 2005 Oct 2007			Jan 2000 – Oct 2007				Unknown			Unknown			2007		
Water Company	A			D				H			I			J		
	Surface raw	Ground raw	Final	Surface Raw	Surface Final	Ground Raw	Ground Final	Surface Raw	Ground Raw	Final	Surface	Ground	Final	Surface	Ground	C Taps
Barium[2] – WHO GV 700 µg l^{-1}																
Min–Max* µg l^{-1} (mean)	66.3 (42.8)	96.3 (63.4)	99.4 (48.9)	2.5 – 84	2.6 – 135	2.4 – 964	2.4 – 840	300	100	70	8.7 - 624 (81)	10 -109 (27)	0 – 775 (49)	70	590	185
No of det	97	271	657	379	408	2025	1017	1400			18	33	6605	166	38	613
No of sites				18	17	129	95	100			12	3	795	9	8	114
No of det < LOD	0	2	1													
Beryllium – WHO GV under consideration																
Min–Max* µg l^{-1} (mean)			<LOD										0.001 (0.001)			2
No of det			1										3			9
No of sites													1			6
No of det < LOD			1													
Molybdenum – WHO GV 70 µg l^{-1}																
Min–Max* µg l^{-1} (mean)				1 –6.3	1 – 6.1	1 – 40	1 – 7.5							5400		5
No of det				378	338	1757	880							70		9
No of sites				18	17	127	95							1		7
No of det < LOD																
Silver – WHO GV to be considered																
Min–Max* µg l^{-1} (mean)	2.83 (0.9)	0.84 (0.84)	2.24 (0.85)	0 – 0.3	0.3 - 0.7	0.08 - 0.3	0.1 - 0.3	0.1	0.5	0.5	0.1- 20 (1.8)	0.2 - 0.8 (0.6)	0 - 25 (0.6)		1	1
No of det	49	4	634	25	70	73	12	1000			14	33	6306		4	66

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[2] Barium was a regulated parameter at consumers' taps under the 1989 drinking water regulations. The standard was 1000 µg l^{-1} 12 month average. The 1989 Regulations were superseded by the 2000 Regulations, which removed the requirement to sample for barium from 01 Jan 2004, although most water companies continue to do so.

Period	**Jan 2005 Oct 2007**			**Jan 2000 – Oct 2007**				**Unknown**			**Unknown**			**2007**		
Water Company	**A**			**D**				**H**			**I**			**J**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface Raw**	**Ground Raw**	**Final**	**Surface**	**Ground**	**Final**	**Surface**	**Ground**	**C Taps**
No of sites				3	2	18	1	100			9	3	772		1	6
No of det < LOD	47	4	619													
Tin (Considered by WHO but no need for a guideline value)																
Min–Max* µg l^{-1} (mean)								ND	9	4			ND			
No of det								50					1			
No of sites								20					1			
No of det < LOD																
Uranium – WHO GV 15 µg l^{-1} (P)																
Min–Max* µg l^{-1} (mean)		3.52 (0.6)	3.7 (0.65)	0.1 - 2.6	0.1 - 0.5	0.1 - 30	0 - 25							<LoD		<LoD
No of det		63	326	458	474	2462	1429							7		1
No of sites				19	18	128	128							2		1
No of det < LOD		13	63													
Zinc – WHO GV n.a,																
Min–Max* µg l^{-1} (mean)	200 (26.1)	180 (25.7)	650 (21.4)	1 - 7050	3.6-78	3.6 - 36400	3.6 - 1890	3550	2440	55	2 – 640 (143)	4.4 - 2210 (425)	0 - 118 (63)	670000	540	2530
No of det	75	272	665	1076	1058	3946	1938	1500			103	56	104529	1517	1660	4996
No of sites				20	19	134	105	100			12	3	1541	70	108	221
No of det < LOD	69	226	648													

*- value on its own denotes maximum.

- LoD – limit of detection

Period	**Jan 2005 Oct 2007**	**Jan 2000 – Oct 2007**		**Unknown**	
Water Company	**B**	**E**		**G**	
	Final	**Untreated**	**Final**	**Surface**	**Ground**
Barium - WHO GV 700 µg l^{-1}					
Min–Max* µg l^{-1} (mean)	<10 – 87	8 - 182		1.6 - 153	4 - 107
No of det	188	22		457	132
No of sites	8	17		12	4
No of det < LOD	7				
Beryllium - WHO GV under consideration					
Min–Max* µg l^{-1} (mean)					
No of det					
No of sites					
No of det < LOD					
Molybdenum - WHO GV 70 µg l^{-1}					
Min–Max* µg l^{-1} (mean)		96		<4	
No of det		1		1	
No of sites		1		1	
No of det < LOD					
Silver - WHO GV to be considered					
Min–Max* µg l^{-1} (mean)	<0.2 <0.5	<0.1 - 6.3		<0.04 - 2.2	<0.04 - 0.6
No of det	91	7		454	130
No of sites	8	6		12	4

Period	**Jan 2005 Oct 2007**	**Jan 2000 – Oct 2007**		**Unknown**	
Water Company	**B**	**E**		**G**	
	Final	**Untreated**	**Final**	**Surface**	**Ground**
No of det < LOD	91				
Uranium - WHO GV 15 µg l^{-1} (P)					
Min–Max* µg l^{-1} (mean)	<0.01 – 10.7				
No of det	55				
No of sites	1				
No of det < LOD	4				
Zinc - WHO GV n.a,					
Min–Max* µg l^{-1} (mean)	<10 - 295	<1 - 480	3.1 - 23.4	<3 - 5270	<3 - 147
No of det	382	131	7	946	145
No of sites	8	64	7	12	4
No of det < LOD	264				

* - value on its own denotes maximum

Table 5.4 Monitoring results from several Water Companies in England – volatile organics

Period	**Jan 2005 Oct 2007**		**Jan 1998 Oct 2007**	**unknown**			**Jan 2000 Oct 2007**			**Jan 1995 Oct 2007**		**Unknown**		**2007**		
Water Company	**A**		**B**	**C**			**D**			**G**		**I**		**J**		
	Ground raw	**Final**	**Final**	**Surface**	**Ground**	**Final**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface**	**Ground**	**Surface**	**Final**	**Surface**	**Ground**	**C Taps**
Chlorobenzene - WHO GV n.a.																
Min–Max* $\mu g\ l^{-1}$ (mean)												46	46			
No of det												1	1			
No of sites												1	1			
cis-1,2-dichloroethene - WHO GV 50 $\mu g\ l^{-1}$																
Min–Max* $\mu g\ l^{-1}$ (mean)								1 – 5								
No of det								2								
No of sites								1								
Dichloromethane - WHO GV 20 $\mu g\ l^{-1}$																
Min–Max* $\mu g\ l^{-1}$ (mean)													34 (34)			
No of det													3			
No of sites													1			
1,1,2-trichloroethane																
Min–Max* $\mu g\ l^{-1}$ (mean)													0			
No of det													1			
No of sites													1			

Period	Jan 2005 Oct 2007		Jan 2000 Oct 2007			Jan 2004 Nov 2007		2006	Jan 1995 Oct 2007		Unknown			Unknown	2007		
Water Company	**A**		**D**			**E**		**F**	**G**		**H**			**I**	**J**		
	Groun d raw	**Final**	**Surface Final**	**Ground Raw**	**Ground Final**	**Raw**	**Final**	**Raw & Final**	**Surface**	**Ground**	**Surface Raw**	**Ground Raw**	**Final**	**Final**	**Surface**	**Ground**	**C Taps**
1,1,1-trichloroethane - WHO GV n.a.																	
Min–Max* µg l^{-1} (mean)	4.7 (0.6)	0.1 (0.1)	0.08 – 0.16	0.08 – 1.3	0.08 – 0.88	<0.3 – 71.41	<0.3 – 19.85	0.1	0.5 – 1.3	<0.5 – 0.6	ND	0.038	0.2	0.01 (0.01)	0.721	0.1	0.436
No of det	362	211	23	375	161	1532	2110	524	19	54	6000			6	119	30	472
No of sites			2	14	9	50	41	212	4	3	100			1	6	4	110
No of det < LOD	118	211															

* - value on its own denotes maximum

Period	Jan 2005 Oct 2007			Jan 2000 – Oct 2007				Unknown			Unknown		
Water Company	**A**			**D**				**H**			**I**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface Raw**	**Ground Raw**	**Final**	**Surface Raw**	**Ground Raw**	**Final**
Ethyl benzene - WHO GV 300 µg l^{-1}													
Min–Max* µg l^{-1} (mean)				1 –1	0.07 – 0.07	0.07 – 1	0.07 – 0.07	ND	1	0.6			
No of det				1	12	49	17	3000					
No of sites				1	1	7	4	100					
Toluene - WHO GV 700 µg l^{-1}													
Min–Max* µg l^{-1} (mean)		4.75 (0.23)			0.1-0.1	0.06 – 1	0.06 – 1	ND	2	1			<1 - <1 <1
No of det		252			12	65	32	3500					3
No of sites					1	7	5	100					1
No of det < LOD		239											
Xylene - WHO GV 500 µg l^{-1} (for total xylenes)													
Min–Max* µg l^{-1} (mean)					0 – 0	0 – 1.2	0 – 1	ND	1	0.6			

Period	**Jan 2005 Oct 2007**			**Jan 2000 – Oct 2007**				**Unknown**			**Unknown**		
Water Company	**A**			**D**				**H**			**I**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface Raw**	**Ground Raw**	**Final**	**Surface Raw**	**Ground Raw**	**Final**
No of det					12	55	21	3500					
No of sites					1	8	4	100					
Styrene- WHO GV 20 µg l^{-1}													
Min–Max* µg l^{-1} (mean)											73		73
No of det											1		1
No of sites											1		1

* - value on its own denotes maximum

Period	**Jan 2005 Oct 2007**			**Jan 2000 – Oct 2007**				**Jan 1995 Oct 2007**		**Unknown**		
Water Company	**A**			**D**				**G**		**H**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface**	**Ground**	**Surface Raw**	**Ground Raw**	**Final**
MTBE - WHO GV n.a.												
Min–Max* µg l^{-1} (mean)		9.95 (4.5)	0.11 (0.11)		0.09 – 0.1	0.09 – 1	0.09- 0.7	<0.1	<0.06 – 100	0.001	0.012	0.01
No of det		1067	211		12	296	44	2	27	3500		
No of sites					1	40	5	2	2	100		
No of det < LOD		622	210									

* - value on its own denotes maximum

Table 5.5 Monitoring results from several Water Companies in England - Disinfectant by-products

Period	**Jan 2005 Oct 2007**			**Jan 2000 – Oct 2007**				**Unknown**		
Water Company	**A**			**D**				**H**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface Raw**	**Ground Raw**	**Final**
2,4,6-trichlorophenol - - WHO GV 200 µg l^{-1}										
Min–Max* µg l^{-1} (mean)				0.001-0.007	0.001-0.32		0.001 – 0.001	ND	0.001	ND
No of det				7	20		9	175		
No of sites				3	5		3	20		
2,4-dichlorophenol										
Min–Max* µg l^{-1} (mean)				0.001 – 0.2	0.001-0.001		0.001-0.001			
No of det				27	20		9			
No of sites				4	5		3			
No of det < LOD										
2-chlorophenol - - WHO GV n.a.										
Min–Max* µg l^{-1} (mean)		0.05 (0.05)		0 – 0.001	0 – 0.001		0.001-0.001			
No of det		3		7	20		9			
No of sites				3	5		3			
No of det < LOD		3								

* - value on its own denotes maximum

Period	**Jan 2005 Oct 2007**			**Jan 2000 – Oct 2007**				**Jan 1995 Oct 2007**		**Unknown**		
Water Company	**A**			**D**				**G**		**H**		
	Surface raw	**Ground raw**	**Final**	**Surface Raw**	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface**	**Ground**	**Surface Raw**	**Ground Raw**	**Final**
Trichloroacetic acid - WHO GV 200 μg l^{-1}												
Min–Max* μg l^{-1} (mean)						0.04		<0.016-5.5	<0.016-< 0.2			
No of det						1		932	136			
No of sites						1		12	4			
Chlorate - WHO GV 700 μg l^{-1} (P)												
Min–Max* μg l^{-1} (mean)	1		91 (43.4)		60 – 272	0.7 - 2						(0.73)
No of det	1		3		12	14						500
No of sites	1				3	2						100
No of det < LOD	1		0									
Chlorite - WHO GV 700 μg l^{-1} (P)												
Min–Max* μg l^{-1} (mean)					0.7 – 50	0.7- 0.9						(0.01)
No of det					12	14						500
No of sites					3	2						100

* - value on its own denotes maximum

Table 5.6 Monitoring results from several Water Companies in England - Algal Toxins and related compounds

Period	**Jan 2000 – Oct 2007**				**2007**		
Water Company	**D**				**J**		
	Surface Raw	**Surface Final**	**Ground Raw**	**Ground Final**	**Surface Raw**	**Final**	**C Taps**
Microcystin-LR WHO GV 1 µg l^{-1}							
Min–Max* µg l^{-1} (mean)					0.07 – 861	0.05	
No of det					115	1	
No of sites					19	1	
Geosmin							
Min–Max* µg l^{-1} (mean)	0.001-0.006	0.001-0.008		0.001-0.001			0.002 – 0.007
No of det	7	20		9			9
No of sites	3	5		3			4

* - value on its own denotes maximum

Examination of the available data shows that, in general, the mean values (and in most cases the maximum values) reported for determinands that have been monitored in several samples are lower than any related WHO guideline value that has been set for drinking water. The only exceptions of note are for barium and uranium where the levels in a very small number of specific finished drinking waters can exceed the guideline values set by WHO under some circumstances. The WHO guideline values are set on the basis of long-term (lifetime) exposure and average concentrations, for any individual consumer, have more relevance in determining the implications of the presence of the substances concerned. However, the maximum concentrations are below those set as health-based standards by other jurisdictions and are, therefore, not of concern for health. It should also be noted that WHO is currently reconsidering these substances with the potential for raising the guideline value in the light of new data.

Some water companies carry out survey analysis of drinking water for organic substances using GC-MS. Although this will not necessarily identify or accurately quantify all of the additional parameters reviewed in this report, because much will depend on the nature of the substance and the extraction techniques used, many of the substances listed would be expected to be detected. Should these have been present in significant concentrations they would have been reported and, if close to the WHO guideline values, they would have been investigated further. Although it is difficult to prove a negative, this provides some reassurance regarding many of the organic substances and their occurrence and concentrations in drinking water.

It is recognised that water companies will have carried out investigative monitoring over a long period of time and much of the early data, although very useful, pre-dates current electronic storage systems and is not readily accessible. For example, some companies with eutrophic reservoirs commissioned analysis for microcystin-LR in the 1980s before privatisation and in the very early 1990s just after privatisation. This was also true for several other substances, including the chlorinated solvents in groundwater sources which were examined to determine whether there was contamination.

The monitoring data available are not comprehensive or systematic. This is to be expected since these substances are not currently included in the regulations and there is no specific requirement for monitoring. However, water companies generally are aware of the need to consider a wider range of potential constituents and contaminants that may be an issue for, or threat to, drinking water. Most of the investigation and monitoring is risk-based or is based around monitoring substances that were in previous standards in order to follow trends over time. The introduction of drinking water safety plans (DWSPs) in the amended regulations means that water companies need to carry out an assessment of the hazards and risks for each water supply. This will result in the identification of whether many of the substances included in this study are used or present in the catchment for each water source. All public drinking water in the United Kingdom receives treatment and in many cases this will result in the removal of such potential threats. DWSPs also require that water suppliers establish appropriate means of managing the risks identified and can provide assurance that the means of mitigating the risks are operating properly. This may be achieved by showing that the barriers, such as, but not exclusively, drinking water treatment, are working efficiently at all times. Under such circumstances there is not a requirement for extensive routine monitoring for a specific substance. There is, therefore, likely to be an increase in the data available as a consequence of hazard and risk assessment and from investigation of the hazards identified.

In spite of the fact that there is no formal requirement for monitoring drinking water for the substances listed, a substantial amount of data has been obtained by water companies. These data are likely to reflect circumstances in which substances of interest are expected to be present at higher concentrations.

6 POTENTIAL REQUIREMENTS FOR ADDITIONAL MONITORING/INVESTIGATIONOF CHEMICALS IN UK DRINKING WATER

6.1 Introduction

There is a move in the UK towards a more holistic approach to ensure the safety and quality of drinking water supplies through the use of Drinking Water Safety Plans (DWSPs). This concept of risk assessment and risk management during the production and distribution of drinking water was introduced by WHO in the 2004 Guidelines for Drinking Water Quality. Under such a regime the quality monitoring of drinking water shifts from drinking water at the tap towards quality management through the entire production and distribution cycle from source to consumers' taps. This reflects the fact that monitoring of the final product, where the parameter does not change in distribution, or water at the tap where the parameter is influenced by distribution, is actually only a final check on whether the mitigation measures have worked, or to prove that the standards have been met. There is a resource requirement associated with chemical monitoring and WHO has emphasised the need to assess just how much benefit will be obtained from setting standards for particular substances and chemical monitoring for those substances in treated water.

6.1.1 Hazard and Risk Assessment

The introduction of DWSPs will require that water suppliers assess the hazards and the potential risks associated with these hazards from source to tap. Chemical constituents and contaminants form one group of hazards and their identification in the catchment for each water supply will mean that there should be an increase in data, although not necessarily analytical and monitoring data, on the potential of many of these substances to be present in source waters. The assessment of risk will include whether treatment is adequate to remove identified hazardous substances to levels of no concern and so the result will be that analytical effort will be properly targeted and will provide data where it is most important. WHO has produced a guide, "Chemical Safety of Drinking-water: Assessing priorities for risk management" (Thompson et al. 2007), which provides a considerable amount of information that will aid in identifying hazards and assessing risks for a range of substances.

There are a number of indicators that might lead to the need for more detailed investigation. The presence of chlorinated solvents as industrial contaminants in anaerobic aquifers may be as a consequence of industrial activity at the surface and results from poor handling and spills of these substances. The situation has been improving over time as pollution control becomes more effective and companies using such substances become more aware of risks. However, some of these compounds may, under some circumstances, break down to give rise to other substances that may be more toxic and so their identification should lead to a more thorough investigation to ensure that other compounds are not also present.

The potential sources of the substances reviewed in this report are given briefly in table 6.1. It is important to understand that monitoring does not control the concentration of a substance, it only provides information on whether that substance is present, what its concentration is and, potentially, whether it has been controlled it or not.

Table 6.1 Potential sources of contaminants

Substances for which drinking water standards are set elsewhere, but not in the UK	**Potential primary sources that could affect drinking water**
Inorganics	
Asbestos (fibres per litre)	Naturally occurring, asbestos cement pipes in water systems
Barium	Naturally occurring, , spent coal
Beryllium	Naturally occurring, electrical, aerospace, defence industries
Hydrogen sulphide	Naturally occurring in some anaerobic groundwater. Occasionally found in stagnant DW in the distribution system as a result of O_2 depletion and the subsequent reduction of sulphate by bacterial activity
Iodide (see Iodine)	
Iodine	Naturally occurring plus used as emergency disinfectant
Molybdenum	Naturally occurring, alloy for various metals; compounds used as lubricant additives
Silver	Naturally occurring, used as bacteriostat
Thallium	Primarily a consequence of presence in some ores and use in specialized, electronics, glass and alloys.
Uranium	Naturally occurring
Zinc	Contaminant from pipes and fittings, present in some raw waters
Volatile organics	
Chlorinated hydrocarbon solvents	
1,1,1-trichloroethane	Adhesives, aerosols, textiles, paint, inks, metal degreasers
1,1,2-Trichloroethane	Solvent in rubber, other organic products, chemical production wastes
1,1-dichloroethane	Solvent and chemical intermediate
1,1-dichloroethene	Monomer in polyvinylidene co-polymer production and chemical intermediate
1,2-Dichlorobenzene	Used in industry and as a domestic odour masking agent
1,2-dichloroethene	Intermediate in chemical synthesis and PVC production
1,2-Dichloropropane (1,2-DCP)	Chemical intermediate, soil fumigant, waste industrial solvents
1,3-Dichlorobenzene	Rarely found in drinking water

Substances for which drinking water standards are set elsewhere, but not in the UK	**Potential primary sources that could affect drinking water**
1,4-Dichlorobenzene	
Chlorobenzene (mono)	Metal degreasing and chemical intermediate
cis-1,2-Dichloroethene (dichloroethylene)	Intermediate in manufacture of chlorinated compounds and solvent.
Dibromoethane, 1,2-	Solvent and chemical intermediate
Dichloromethane	Paint stripper, metal degreaser
Hexachlorocyclopentadiene	Pesticide intermediate
trans-1,2-Dichloroethene (dichloroethylene)	Waste solvents
BTEX and fuel related compounds	
Ethylbenzene	Gasoline, organic solvent, chemical manufacturing
Styrene	Plastics, rubber, resin, leachate from landfill
Toluene	Gasoline additive and solvent
Xylenes (total)	Gasoline and solvent in paints, inks,
Methyl tertiary-butyl ether (MTBE)	Fuel additive unleaded petrol
Others	
Dioxane, 1,4-	Stabilizing chemical in industrial solvents
Semi-volatile organics	
Di(2-ethylhexyl) adipate (DEHA; a Plasticiser)	Plasticiser in synthetic rubber, food packaging, cosmetics
Di(2-ethylhexyl) phthalate (DEHP; a Plasticiser)	Widely used plasticiser
Dioxin (2,3,7,8-TCDD)	Contaminant in past processes involving chlorinated substances, from combustion
Disinfection by-products	
Haloacetic acids (HAAs)	
Chloroacetic acid	Formed when disinfectants are used in water treatment
dibromoacetic acid	
Dichloroacetic acid (DCA)	
monobromoacetic acid	
Trichloroacetic acid (TCA)	
Chlorophenols	
2,4,6-trichlorophenol	Chlorophenols present in DW as a result of chlorination of phenols, as by-products of the reaction of chlorine with phenolic acids. Also used as biocides or found as degradation products of phenoxy herbicides. The first 3 most likely to occur as by- products of chlorination
2,4-dichlorophenol	
2-chlorophenol	
2,3,4,6-Tetrachlorophenol	
Others	
Higher Chloramines	As a consequence of high ammonia in wastewater with improperly controlled chlorination – give rise taste
Chlorate	Breakdown product of ClO_2 and improperly stored hypochlorite,
Chlorinated furanones	

Substances for which drinking water standards are set elsewhere, but not in the UK	**Potential primary sources that could affect drinking water**
Chlorite	Breakdown product of ClO_2
Chloropicrin	Primarily as a DBP
Cyanogen chloride	Cyanide in raw waters is converted to cyanogen chloride by chlorination, may also be formed during production of chloroamines in situ a residual disinfectant
Formaldehyde	By-product of ozonation+ manufacture of chemicals, including resins & adhesives
N-nitrosodimethylamine (NDMA)	Primarily a by-product in chloramination but also present in some wastewater effluents
Monochloramine	Disinfectant
Trichloroacetaldehyde (chloral hydrate)	Chlorination DBP
Haloacetronitriles	
Bromochloroacetonitrile	Clorination DBPs
Dibromoacetonitrile	
Dichloroacetonitrile	
Trichloroacetonitrile	
Algal toxins	
Microcystin-LR (Cyanobacterial Toxin)	Naturally occurring in still or slow-flowing eutrophic surface waters.
Others	
Dialkytins	Stabilisers in PVC pipes and fittings
EDTA (Ethylenediamine tetraacetic acid)	Chelating agent and food additive found widely in wastewater
Nitrilotriacetic acid (NTA)	Chelating agent and laundry detergent builder found in wastewater.

6.2 Suggested Additional Parameters for Monitoring in Drinking Water

6.2.1 Disinfection By-Products

Chlorination is an important disinfection process and is the most widely used around the world. It is a good disinfectant that provides a residual in distribution that helps to maintain hygiene and acts as a marker for any ingress of contamination. There are significant benefits associated with its use and WHO and the EU emphasise that disinfection should never be compromised in order to meet guidelines or standards for DBPs. Nevertheless it is appropriate to strive to minimize DBPs and this can be done without compromising disinfection efficiency. The most appropriate means of controlling chlorination by-products is to remove the organic precursors, which are largely of natural origin.

The natural organic matter (NOM) in raw waters can be partially removed using conventional treatment processes (coagulation, flocculation, sedimentation and filtration) or by combining/replacing these processes with more efficient removal processes such as granular or particulate activated carbon (GAC/PAC) filtration, enhanced coagulation and membrane filtration. An integrated approach to treatment is therefore required that provides better control of all process operational factors (e.g., control of pH, point of disinfection and minimizing the amount of chlorine) used in order to manage DBP formation.

The two dominant groups of chlorination by-products are THMs and HAAs. While TTHMs are already monitored in response to the requirements of the regulations they may not be a good surrogate for the HAAs. This is particularly so when chlorination is practiced at low pH which will tend to favour the formation of HAAs compared to THMs. There is, therefore, an argument for considering HAAs when establishing management of water treatment to minimise DBP formation.

In general, maintaining a neutral pH while reducing precursors is likely to result in a reduction in all chlorination DBPs. Concentrating on minimising these two groups of chlorination DBPs is likely to result in minimising all chlorination DBPs and few authorities recommend monitoring for any others. Where THMs have also been shown to be a reasonable marker for HAAs then the measurement of THMs would suffice. Although HAAs do not normally increase in distribution, unlike THMs, booster chlorination in distribution may result in some increase if the DBP potential of the natural organic matter has not been fully realised.

Of those remaining DBPs, not already included in current standards, that would warrant further investigation/monitoring the most appropriate would be chlorate if stored hypochlorite is the primary chlorine donor, since chlorate can form during storage of hypochlorite. In this case examination of the hypochlorite may be the most appropriate means of ensuring that chlorate formation does not result in elevated concentrations in drinking water. Regulatory controls are already in place in respect of chlorate in on-site electrolytically generated hypochlorite.

Chloramination is increasingly being used to maintain a residual disinfectant in distribution. Although there are potential DBPs that can arise as a consequence of chloramination under some circumstances, the possible formation of these by-products is still a research issue. Research to investigate the formation of chloramination by-products in the UK, by Cranfield University for the Scottish Government, is in progress with expectation of the results within two years. The results of this research will determine the need for further investigation and even monitoring at a future point in time.

6.2.2 Other Parameters for which Additional Monitoring/Investigation might be Appropriate

The introduction of DWSPs will lead to the identification of circumstances in which most of the substances listed above could reach drinking water. Investigation and monitoring will, therefore, be a function of hazard identification and risk assessment.

However, there are other substances for which it would be useful to obtain more comprehensive data. In particular, the data on some of the inorganic constituents are more limited, although some companies have looked for some of the listed substances at least in supplies where they are suspected of occurring. DWI has already commissioned research on uranium (discussed above) and molybdenum (in progress) and these are the most important substances for which more information was required. Existing studies on beryllium confirm that it is present only at sub-microgram per litre concentrations and, unless there is a specific risk from a discharge that should be identified under DWSPs, there is no requirement for further studies.

WHO has not considered thallium and only the USA has developed a standard. Thallium is a highly toxic metal and there appear to be few data on its occurrence in the UK. This may be because it is unlikely to occur or it may simply be that the question has not been asked. However, in view of the fact that the occurrence would be very limited it would not be appropriate to seek data unless this could be properly targeted. The British Geological Survey (BGS) may have data that indicate the probability of its natural occurrence and the other sources could be readily identified in relation to its potential presence in wastewater discharges.

One member state in the EU has included a standard for vanadium but, at present, there is only a limited basis on which to set a health-based value. The data from the early Regional Heart study provides a reasonable base for any future movement on a health-based value and the only investigation of value would be to check one or two sites from that time to assess if there have been any changes.

Questions have been raised as to the formation of iodinated and some other brominated DBPs from studies in the USA. It might be of value to have a better knowledge of the concentrations of iodide and bromide in raw waters. While obtaining such data is not a high priority, it may be that BGS has data that are not readily available outside that organisation.

The organic substances that are listed are largely volatile chlorinated organic substances that are only of concern for groundwater. While the amount of monitoring data from the water companies is very limited, companies are well aware of the risk to groundwater. Trichloroethene, tetrachloroethene and tetrachloromethane (carbon tetrachloride) are the most important of these substances and are included in existing regulations. There is, therefore, extensive knowledge of which groundwaters are vulnerable to contamination and which are contaminated. It would be appropriate to target monitoring for additional substances where tri- and tetrachloroethene have been found in anaerobic groundwater or where they have reached groundwater following passage through anaerobic conditions that favour the breakdown of these substances.

Cyanotoxins arise in drinking water sources as a consequence of blooms of cyanobacteria. There is a relatively high potential (>50%) for such blooms to produce toxins, but microcystin-LR is not the only toxin that is produced, even though it is probably the most common. Monitoring is not, therefore, particularly helpful although some data would be useful to demonstrate the effectiveness of any treatment. When there are no blooms then there will be no toxins. Prevention of blooms by nutrient reduction and by reservoir management is the most appropriate way forward and provides reassurance with regard to all toxins. Microcystins and most other known toxins are not persistent in water bodies and are metabolised by freshwater microorganisms. In addition, many forms of treatment will also remove or break down the toxins, including, to some extent, chlorine, while ozone is particularly effective (Fawell et al. 1993, Lahti et al. 2001). Two European member states (France and Spain) have included the cyanotoxin, microcystin LR, in their regulations. However, the utility of routine monitoring is very doubtful, while investigative monitoring during a bloom may provide some information on the effectiveness of control mechanisms for microcystins, if these are reliant on drinking water treatment.

BTEX compounds are associated with taste and odour and in some cases arise as a consequence of ingress of contamination through plastic water mains and service connections. Routine monitoring is of doubtful value and targeted investigation is commonly applied at present where there is evidence of potential contamination.

Previous studies in other parts of the world have shown that dioxin is not a real issue for drinking water. The chemical characteristics of the dioxins mean that the strong tendency is for these substances to adsorb preferentially to sediment and particulate matter in the aquatic environment. Indeed that is most probably how they reach the aquatic environment. Water treatment is very good at removing particulate matter from raw water and as the best practice with regard to turbidity removal improves, then removal of particulate-associated contaminants also improves.

DEHA was included as guideline value by WHO but its environmental occurrence appears to be low in view of the way it is used. By contrast DEHP does occur widely in the environment and there are some limited data on its occurrence in drinking water and on its removal in treatment. DEHP is targeted as a potential endocrine disrupting substance although, if this actually the case, it is an extremely weak endocrine disruptor. On this basis it would be of value to have a better view of the range of concentrations in drinking water. It is possible that this could be achieved by examination of water company GC-MS scans, although the ubiquitous nature of its presence in articles means that it is difficult to achieve low background levels unless targeted analysis is used.

There is only historical data on EDTA or NTA in drinking water in the UK. Although EDTA will probably be found in river water receiving treated wastewater, the concentrations found elsewhere appear to be low in relation to the WHO guideline value. Although these substances would not be a high priority for investigation or monitoring it would be valuable to have some modern data on the occurrence in source and drinking waters targeted on waters receiving treated wastewater.

In view of the great deal of research and media attention given to DBPs, particularly chlorination DBPs, sometimes as a consequence of misunderstanding, this group of substances often takes on an inflated significance. Although a range of chlorination DBPs are included in the WHO Guidelines a more comprehensive list was provided as a benchmark against which to assess the importance of such substances, rather than with the intention that they should be incorporated into national standards. European standards include a value for total trihalomethanes or TTHMs while WHO sets guideline values for individual substances. The standard of 100 µg l^{-1} as a maximum is broadly equivalent to the USEPA standard of 80 µg l^{-1} measured as an average and is well within the WHO guideline values for the individual substances. Two jurisdictions include a total haloacetic acids value or values for di- and trichloroacetic acid because these are the other dominant chlorination DBPs along with THMs. The most appropriate mechanism for controlling chlorination DBPs is the removal of natural organic matter (NOM) with which chlorine reacts. This will reduce all of the halogenated organic by-products while actually helping to maintain effective disinfection and means that there is no need to monitor a very wide range of by-products, the great majority of which always occur at concentrations below guideline values or health-based guidance. However on occasion, for example chlorination at low pH, THMs will be reduced but HAAs will increase. There is therefore a strong argument for water companies to check HAAs when establishing treatment modifications to reduce THM levels.

6.3 Analytical Techniques for Monitoring the Additional Parameters

6.3.1 Overview

The majority of the additional determinands are organic compounds and this section is therefore focussed on the analysis of those compounds. The analysis of specific pesticides will not be considered here since their likelihood of occurrence in drinking water will be very much dependent on the patterns of use in particular catchments and the monitoring of those substances is already well covered elsewhere. Amongst the organics, the biggest group consists of the 'disinfection by-products' (DBPs) which can be formed as a consequence of chlorination disinfection. The second biggest group is the 'halogenated hydrocarbon solvents', followed by the 'BTEX' group which for convenience here also includes the other monoaromatics and MTBE which may all be present in gasoline. The remaining organics represent several types of substance and originate from a wide variety of sources.

In order to look at the potential for analysis by conventional methods, the octanol/water (log Kow) and air/water partition coefficients (Henry's Law Coefficient: HLC) of the substances have been listed (see Table 6.2). Log Kow provides a good indication of the partitioning between water and solvent (or the organic phase of a solid phase extraction (SPE) cartridge) and HLC of partitioning between water and air as used in headspace (HS), purge and trap (P&T) and closed-loop-stripping (CLS) methods. Thus those substances that have a log Kow of about 2 or greater should be fairly readily extracted from water using solvent extraction or SPE based methods – the higher the log Kow value then the greater the efficiency of solvent/SPE extraction. Those substances with an HLC greater than about 3×10^{-7} atm m^3mol^{-1} [0.0304 Pa m^3mol^{-1}]: substance have a more favourable partitioning to air than water itself and should be extracted by HS, P&T or CLS methods, once again with extraction efficiency increasing with increasing HLC. This shows that most of the organics should be amenable to analysis by either a solvent extraction/SPE method or a HS/P&T/CLS method or, in a few cases, both of these. After extraction, analysis would be mostly by GCMS, preferably using a modern SIM/scan instrument to obtain both high sensitivity and good specificity. Some of the compounds are also amenable to analysis by GC-ECD and this can provide high sensitivity and reasonable specificity of detection. Additionally, some of the more polar DBPs are also amenable to LCMS analysis, but this would be best used in MSMS mode to provide sufficient sensitivity and specificity.

However, there are already many methods of analysis that have been developed, validated and published for the majority of these organic substances in drinking water samples and some of these are covered in the following sections. References are only provided for methods that are not already in common or widespread use in drinking water analysis laboratories in the UK or where they offer particularly useful insights. Some further information on methods of analysis and potential limits of detection are also provided in the section on Drinking Water Treatability (S 6.4).

Table 6.2 Overview of Analytical Methods for Monitoring Additional Parameters

Parameter monitored in other jurisdictions but not England and Wales	CAS RN	HLC	Log Kow	Propensity for Monitoring Using Current Methodology
Inorganics				
Asbestos	1332-21-4	N/A	N/A	Needs a specific method based on electron microscopy
Barium	7440-39-3	N/A	N/A	These elements could potentially be analysed by ICP-MS if it were specifically set up for them.
Beryllium	7440-41-7	N/A	N/A	
Hydrogen sulphide	7783-06-4	N/A	N/A	A specific method would need to be developed for drinking water as this is a gas at room temperature, however it can be detected at low concentrations by odour.
Iodide	-	N/A	N/A	Ion chromatography methods are available
Iodine	7553-56-2	N/A	N/A	
Molybdenum	7439-98-7	N/A	N/A	All of these elements could potentially be analysed by ICP-MS if it were specifically set up for them.
Silver	7440-22-4	N/A	N/A	
Thallium	7440-28-0	N/A	N/A	
Tin	7440-31-5	N/A	N/A	
Uranium	7440-61-1	N/A	N/A	
Zinc	7440-66-6	N/A	N/A	
Volatile organics				
Chlorinated hydrocarbon solvents				
1,1,1-trichloroethane	71-55-6	**1.72E-02**	**2.49**	All of these could be analysed using a purge and trap or modern headspace SIM/Scan GCMS but would need to be set up with correct ions etc.
1,1,2-Trichloroethane	79-00-5	**8.24E-04**	1.89	
1,1-dichloroethane	75-34-3	**5.62E-03**	1.79	
1,1-dichloroethene	75-35-4	**2.61E-02**	**2.13**	
1,2-Dichlorobenzene	95-50-1	**1.92E-03**	**3.43**	
1,2-dichloroethene (see Dichloroethenes)				
1,2-Dichloropropane (1,2-DCP)	78-87-5	**2.82E-03**	1.98	
1,3-Dichlorobenzene	541-73-1	**2.63E-03**	**3.53**	
1,4-Dichlorobenzene	106-46-7	**2.41E-03**	**3.44**	
Chlorobenzene (mono)	108-90-7	**3.11E-03**	**2.84**	

Parameter monitored in other jurisdictions but not England and Wales	**CAS RN**	**HLC**	**Log Kow**	**Propensity for Monitoring Using Current Methodology**
cis-1,2-Dichloroethene (dichloroethylene)	156-60-5	**4.08E-03**	1.86	
Dibromoethane, 1,2-	106-93-4	**6.67E-04**	1.96	
Dichloromethane	75-09-2	**3.25E-03**	1.25	
Hexachlorocyclopentadiene	77-47-4	**2.70E-02**	**5.04**	
trans-1,2-Dichloroethene (dichloroethylene)	156-59-2	**4.08E-03**	1.86	
BTEX and other fuel related compounds				
Ethylbenzene	100-41-4	**7.88E-03**	**3.15**	All of these BTEX could be analysed using a purge and trap or modern headspace SIM/Scan GCMS but would need to be set up with correct ions etc. MTBE is routinely analysed with the BTEX group of compounds. With the exception of MTBE the others are also routinely analysed by solvent extraction/GCMS.
Styrene	100-42-5	**2.75E-03**	**2.95**	
Toluene	108-88-3	**6.64E-03**	**2.73**	
Xylenes (total)				
1,2-Xylene	95-47-6	**5.18E-03**	**3.12**	
1,3-Xylene	108-38-3	**7.18E-03**	**3.2**	
1,4-Xylene	106-42-3	**6.90E-03**	**3.15**	
Methyl tertiary-butyl ether (MTBE)	1634-04-4	**5.87E-04**	0.94	
Others				
Cyanogen chloride	506-77-4	**3.74E-05**	-0.38	Would need a new method.
Dioxane, 1,4-	123-91-1	**4.80E-06**	-0.27	This is difficult to extract from water because of its water solubility, but specific methods exist.
Semi-volatile organics				
Di(2-ethylhexyl) adipate (DEHA; a Plasticiser)	103-23-1	**4.34E-07**	**8.12**	These are part of standard SVOC suites which are available for drinking water, but not routinely applied.
Di(2-ethylhexyl) phthalate (DEHP; a Plasticiser)	117-81-7	2.70E-07	**7.6**	These are part of standard SVOC suites which are available for drinking water, but not routinely applied.
Dioxin (2,3,7,8-TCDD)	1746-01-6	**5.00E-05**	**6.8**	Many methods exist but would need to be specifically applied to drinking water.
Disinfection by-products (DBPs)				
Haloacetic acids (HAAs)				

Parameter monitored in other jurisdictions but not England and Wales	CAS RN	HLC	Log Kow	Propensity for Monitoring Using Current Methodology
Chloroacetic acid (monochloroacetate)	79-11-8	9.42E-09	0.22	Methods are available for all of these but they are not routinely applied to drinking water in the UK.
dibromoacetic acid	631-64-1	2.98E-07	0.7	
Dichloroacetic acid (DCA)	79-43-6	**3.52E-07**	0.92	
monobromoacetic acid	79-08-3	2.55E-07	0.41	
monochloroacetic acid	79-11-8			
Trichloroacetic acid (TCA)	76-03-9	1.35E-08	1.33	
Chlorophenols				
2,4,6-trichlorophenol	88-06-2	**2.60E-06**	**3.69**	Methods for chlorophenols exist and are already applied by some laboratories to drinking water.
2,4-dichlorophenol	120-83-2	**2.19E-06**	**3.06**	
2-chlorophenol	95-57-8	**1.12E-05**	**2.15**	
2,3,4,6-Tetrachlorophenol	58-90-2	**8.84E-06**	**4.45**	
Others				
Chloramines--total				The DPD test may be sufficient depending on the LoD required.
Chlorate				Ion chromatography methods are available
Chlorinated furanones				Methods as for propanones
Chlorite				Ion chromatography methods are available
Chloropicrin	76-06-2	**2.05E-03**	**2.09**	Methods using HPLC are available (developed for explosives monitoring in waters) but are not routinely applied to drinking water.
Formaldehyde	50-00-0	**3.37E-07**	0.35	With matrix modification, purge and trap GCMS might cope with these, but would need to be developed for drinking water. Monochloroamine can be done by DPD test.
Monochloramine	10599-90-3	7.86E-17	-1.19	
N-nitrosodimethylamine (NDMA)	62-75-9	**1.82E-06**	-0.57	There are methods for this compound in drinking water but they are not routinely applied in the UK
Trichloroacetaldehyde (chloral hydrate)	75-87-6	2.91E-09	0.99	With matrix modification, purge and trap GCMS might cope with this, but would need to be developed for drinking water.
Haloacetronitriles				
Bromochloroacetonitrile	83463-62-1	**9.91E-06**	0.38	
Dibromoacetonitrile	3252-43-5	**8.20E-06**	0.47	

Parameter monitored in other jurisdictions but not England and Wales	**CAS RN**	**HLC**	**Log Kow**	**Propensity for Monitoring Using Current Methodology**
Dichloroacetonitrile	3018-12-0	**9.42E-05**	0.29	
Trichloroacetonitrile	545-06-2	**1.82E-02**	**2.09**	
Algal toxins				
Microcystin-LR (Cyanobacterial Toxin)				Methods are available for these compounds but are not routinely applied for drinking water in the UK
Others				
Dialkytins (see Organotins)				Methods are available for these compounds but are not routinely applied for drinking water in the UK
EDTA (Ethylenediamine tetraacetic acid)	60-00-4			
Nitrilotriacetic acid (NTA)				

6.3.2 Disinfection By-Products (DBPs)

The DBP group includes all of the following substances:

Disinfection by-products
Haloacetic acids (HAAs)
Chloroacetic acid (a Chloroacetic acid)(monochloroacetate)
Monochloroacetic acid
Dibromoacetic acid
Dichloroacetate (cation of dichloroacetic acid)
Dichloroacetic acid (DCA; a Chloroacetic acid)
Monobromoacetic acid
Trichloroacetate (the anion of trichloroacetic acid)
Trichloroacetic acid (TCA; a Chloroacetic acid)
Haloacetronitriles (HANs)
Bromochloroacetonitrile (a Haloacetonitrile)
Dibromoacetonitrile
Dichloroacetonitrile (Haloacetonitrile)
Trichloroacetonitrile (a Haloacetonitrile)
Chlorophenols
2,4,6-trichlorophenol (a Chlorophenol)
2,4-dichlorophenol (a Chlorophenol)
2-chlorophenol (a Chlorophenol)
2,3,4,6-Tetrachlorophenol
Others
1,1,1-trichloropropanone (a Chloroketone)
1,1,3-trichloropropanone (a Chloroketone)
1,1-dichloropropanone (dichloroacetone; a Chloroketone)
1,3-dichloropropanone (a Chloroketone)
Monochloramine
Chloramines--total
Chlorate
Chlorinated furanones
Chlorite
Chloropicrin
Formaldehyde
Trichloroacetaldehyde (chloral hydrate)
N-nitrosodimethylamine (NDMA)
Cyanogen chloride

The USEPA carried out a major survey on the Occurrence of Disinfection By-Products (DBPs) of Health Concern in Drinking Water in the USA and published the results of that Nationwide study in 2002 (Krasner et al. 2002). Approximately 50 DBPs that received the highest ranking for potential toxicity and that were not included in the USEPA's Information Collection Rule (ICR) were selected for this occurrence study. The DBPs, denoted as 'high priority' DBPs in the report, included such compounds as MX [3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone], brominated forms of MX (BMXs), halonitromethanes, iodo-trihalomethanes, and many brominated species of halomethanes, haloacetonitriles, haloketones and haloamides. Because no quantitative analytical methods existed at that time for most of the high priority DBPs, optimized analytical methods were initially developed as part of the project. The 50 high priority DBPs and the USEPA Information Collection Rule and regulated DBPs that were analysed for in the survey are shown in the following Tables, 6.3 and 6.4:

Table 6.3 DBPs analysed in USEPA Survey, 2002

DBPs Analysed in USEPA Survey
MX and MX-Analogues
3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX)
3-Chloro-4-(dichloromethyl)-2-(5H)-furanone (red-MX)
(E)-2-Chloro-3-(dichloromethyl)-butenedioic acid (ox-MX)
(E)-2-Chloro-3-(dichloromethyl)-4-oxobutenoic acid (EMX)
2,3-Dichloro-4-oxobutenoic acid (Mucochloric acid)
3-Chloro-4-(bromochloromethyl)-5-hydroxy-2(5H)-furanone (BMX-1)
3-Chloro-4-(dibromomethyl)-5-hydroxy-2(5H)-furanone (BMX-2)
3-Bromo-4-(dibromomethyl)-5-hydroxy-2(5H)-furanone (BMX-3)
(E)-2-Chloro-3-(bromochloromethyl)-4-oxobutenoic acid (BEMX-1)
(E)-2-Chloro-3-(dibromomethyl)-4-oxobutenoic acid (BEMX-2)
(E)-2-Bromo-3-(dibromomethyl)-4-oxobutenoic acid (BEMX-3)
Haloacids
3,3'-Dichloropropenoic acid
Halomethanes:
Dibromoiodomethane
Chlorodiiodomethane
Bromodiiodomethane
Chlorotribromomethane
Bromomethane (methyl bromide)
Dibromomethane
Bromochloromethane
Bromochloroiodomethane
Dichloroiodomethane
Iodoform
Carbon tetrachloride
Halonitromethanes
Chloronitromethane

DBPs Analysed in USEPA Survey
Dichloronitromethane
Bromochloronitromethane
Bromodichloronitromethane
Dibromochloronitromethane
Tribromonitromethane (bromopicrin)
Bromoacetonitrile
Chloroacetonitrile
Tribromoacetonitrile
Bromodichloroacetonitrile
Dibromochloroacetonitrile
Haloketones
Chloropropanone
1,3-Dichloropropanone
1,1-Dibromopropanone
1,1,3-Trichloropropanone
1-Bromo-1,1-dichloropropanone
1,1,1,3-Tetrachloropropanone
1,1,3,3-Tetrachloropropanone
1,1,3,3-Tetrabromopropanone
1,1,1,3,3-Pentachloropropanone
Hexachloropropanone
Haloaldehydes
Chloroacetaldehyde
Dichloroacetaldehyde
Bromochloroacetaldehyde
Tribromoacetaldehyde
Haloacetates:
Bromochloromethyl acetate
Haloamides
Monochloroacetamide
Monobromoacetamide
Dichloroacetamide
Dibromoacetamide
Trichloroacetamide
Non-Halogenated Aldehydes and Ketones
2-Hexenal
5-Keto-1-hexanal
Cyanoformaldehyde
Methylethyl ketone (2-butanone)
6-Hydroxy-2-hexanone
Dimethylglyoxal (2,3-butanedione)
Volatile organic compounds (VOCs) and Miscellaneous DBPs
1,1,1,2-Tetrabromo-2-chloroethane
1,1,2,2-Tetrabromo-2-chloroethane

DBPs Analysed in USEPA Survey
Methyl-*tert*-butyl ether [1634-04-4]
Benzyl chloride [100-44-7]

Table 6.4 USEPA Information Collection Rule and regulated DBPs

USEPA Information Collection Rule and regulated DBPs
Halomethanes
Chloroform
Dibromochloromethane
Bromoform
Bromodichloromethane
Haloacetonitriles
Dichloroacetonitrile
Bromochloroacetonitrile
Dibromoacetonitrile
Trichloroacetonitrile
Haloketones
1,1-Dichloropropanone
1,1,1-Trichloropropanone
Haloacetic acids
Monochloroacetic acid
Monobromoacetic acid
Dichloroacetic acid
Bromochloroacetic acid
Dibromoacetic acid
Trichloroacetic acid
Bromodichloroacetic acid
Dibromochloroacetic acid
Tribromoacetic acid
Halonitromethanes
Chloropicrin (trichloronitromethane)
Haloaldehydes
Chloral hydrate (trichloroacetaldehyde)
Oxyhalides
Bromate Chlorate Chlorite

The methods developed for these analyses used liquid-liquid extraction (LLE) with MTBE as the primary concentration method for quantitative extraction, with analyses based on SPE concentration and/or P&T methods used to provide confirmation of presence. The LLE method was followed by simultaneous GC separation on two different columns with Electron Capture Detection (ECD) and the other extraction/concentration methods were followed by GCMS. All samples were stabilized after collection and prior to analysis by using 31 mg l^{-1} of ascorbic acid and enough sulphuric acid to lower the pH to 3.5. Full details of all of the methods used are provided in the final report (Krasner et al. 2002).

A useful short review of methods of analysis of DBPs in drinking water from a US regulatory perspective was published in 2002 (Xie 2002). A critical review of the use of LCMS based analytical methods for the analysis of DBPs was published recently (Zwiener and Frimmel 2004). A review of the role of GCMS and LCMS in the discovery of DBPs was published in 2002 (Richardson 2002).

Cyanogen chloride is a volatile compound which is probably amenable to analysis by HS and P&T methods. A solvent extraction method has been published for the simultaneous determination of cyanogen chloride and cyanogen bromide in chlorinated waters using a simplified microextraction GC/ECD technique (Sclimenti et al. 1995).

6.3.3 Halogenated Hydrocarbon Solvents

The halogenated hydrocarbon solvents on the list of substances monitored in drinking water outside of England and Wales are shown in the following Table 6.5:

Table 6.5 Halogenated hydrocarbon solvents monitored in drinking water outside of England and Wales

Halogenated hydrocarbon Solvents
1,1,1-trichloroethane
1,1,2-Trichloroethane
1,1-dichloroethane
1,1-dichloroethene
1,2-Dibromo-3-chloropropane (DBCP)
1,2-Dichlorobenzene
1,2-dichloroethene (see Dichloroethenes)
1,2-Dichloropropane (1,2-DCP)
1,3-Dichlorobenzene
1,4-Dichlorobenzene (see dichlorobenzenes)
Carbon tetrachloride
Chlorobenzene (mono)
cis-1,2-Dichloroethene (dichloroethylene)
Dibromoethane, 1,2-

Halogenated hydrocarbon Solvents
Dichloromethane
Ethylene dibromide, 1,2
Ethylene dibromide, 1,1
Hexachlorocyclopentadiene
Tetrachloroethylene (PCE)
trans-1,2-Dichloroethene (dichloroethylene)
Trichloroethylene (TCE)

These are volatile compounds with relatively low water solubility which are readily analysed by HS and P&T extraction/concentration techniques followed by GC-ECD and/or GCMS for separation, identification and quantitation. There are many methods available for analysis of these compounds in waters, including drinking waters.

6.3.4 BTEX and other fuel related compounds

The BTEX and other fuel related compounds on the list of substances monitored in drinking water outside of England and Wales are shown in the following Table 6.6:

Table 6.6 BTEX and other fuel related compounds monitored in drinking water outside of England and Wales

BTEX and other fuel related compounds
Ethylbenzene
Styrene
Toluene
Xylenes (total)
1,2-Xylene
1,3-Xylene
1,4-Xylene
Methyl-t-butyl ether (MTBE)

These are also volatile compounds with relatively low water solubility which are readily analysed by HS and P&T extraction/concentration techniques followed by GCMS for separation, identification and quantitation. There are many methods available for analysis of these compounds in waters, including drinking waters.

6.3.5 Other Organics

Other organic compounds on the list of substances monitored in drinking water outside of England and Wales are shown in the following Table 6.7:

Table 6.7 Other organic compounds monitored in drinking water outside of England and Wales

Other organics
Semi-volatile organics (SVOCs)
Di(2-ethylhexyl) adipate (DEHA;a Plasticiser)
Di(2-ethylhexyl) phthalate (DEHP;a Plasticiser)
Dioxin (2,3,7,8-TCDD)
Algal toxins
Microcystin-LR (Cyanobacterial Toxin)
Others
Dioxane, 1,4-
EDTA (Ethylenediamine tetraacetic acid)
Nitrilotriacetic acid (NTA)

This is a very diverse group of organics which requires a range of methods of analysis. The SVOCs DEHA and DEHP can be analysed by a solvent extraction and GCMS analysis method and there are many methods available for these compounds in water. Dioxins require complex methods of fractionation and clean-up after solvent extraction, prior to analysis using a high resolution GCMS-SIM method and relatively large amounts of water need to be extracted in order to provide the specificity and sensitivity of detection required for the particularly toxic congeners such as 2,3,7,8-TCDD.

Specific methods are also available for the analysis of the algal toxin Microcystin-LR and the organotins in water samples.

6.4 Water Treatment as a Barrier

6.4.1 Overview for additional WHO Parameters

The possibilities for minimising the concentrations of substances listed in drinking water are briefly discussed in this section. WHO has produced a useful summary of suitable treatment methods and related analytical methods and this is shown in Table 6.8. Some additional information on removal methods is provided below.

Table 6.8 WHO data on drinking water treatment achievability and limit of detection of analytical methods (WHO 2006)

	Drinking Water Treatment Achievability	**Limit of Detection**
Inorganics		
Barium	0.1 mg l^{-1} should be achievable using either ion exchange or precipitation softening; other conventional processes are ineffective	0.1 µg l^{-1} by ICP/MS
Molybdenum	Not readily removed from drinking water	0.25 µg l^{-1} by graphite furnace AAS; 2 µg l^{-1} by ICP/AES
Uranium	1 µg l^{-1} should be achievable using conventional treatment, e.g. coagulation or ion exchange	0.01 µg l^{-1} by ICP/MS; 0.1 by solid fluorimetry with either laser excitation or UV light.
Volatile organics		
Chlorinated hydrocarbon solvents		
1,2-Dichlorobenzene	0.01 mg l^{-1} should be achievable using air stripping	0.01 – 0.25 µg l^{-1} by gas-liquid chromatography with ECD; 3.5 µg l^{-1} by GC using a photoionization detector
1,2-dichloroethene	0.01 mg l^{-1} should be achievable using GAC or air stripping	0.17 µg l^{-1} by GC with MS
1,2-Dichloropropane (1,2-DCP)	1 µg l^{-1} should be achievable using GAC	0.02 µg l^{-1} by purge-and-trap GC with ECD or GGC/MS
1,3-Dichlorobenzene	Rarely found in drinking water	
1,4-Dichlorobenzene	0.01 mg l^{-1} should be achievable using air stripping	0.01 – 0.25 µg l^{-1} by gas-liquid chromatography with ECD; 3.5 µg l^{-1} by GC using a photoionization detector
Dibromoethane, 1,2-	0.1 µg l^{-1} by ion chromatography should be achievable using GAC	0.01 µg l^{-1} by ion chromatography by microextraction GC/MS
Dichloromethane	20 µg l^{-1} should be achievable using air stripping	0.3 µg l^{-1} by purge-and-trap GC with MS detection
BTEX and other fuel related compounds		
Ethylbenzene	1 µg l^{-1} should be achievable using air stripping	0.002 – 0.005 µg l^{-1} by GC with photoionization detector; 0.03 – 0.06 µg l^{-1} by GC/MS
Styrene	20 µg l^{-1} may be achievable using GAC	0.3 µg l^{-1} by GC with photoionization detection and confirmation by MS
Toluene	1 µg l^{-1} should be achievable using air stripping	0.13 µg l^{-1} by GC with FID; 6 µg l^{-1} by GC/MS
Xylenes (total)	5 µg l^{-1} should be achievable using GAC or air stripping	0.1 µg l^{-1} by GC/MS; 1 µg l^{-1} by GC with FID
Others		

	Drinking Water Treatment Achievability	**Limit of Detection**
Dioxane, 1,4-	Not removed using conventional water treatment processes; effectively removed by biological activated carbon treatment	0.1 - 50 µg l^{-1} by GC/MS
Semi-volatile organics		
Di(2-ethylhexyl) phthalate (DEHP; a Plasticiser)	No data available	0.1 µg l^{-1} by GC/MS
Disinfection by-products (DBPs)		
Haloacetic acids (HAAs)		
Chloroacetic acid (monochloroacetate)	No information available	2 µg l^{-1} by GC with ECD; 5 µg l^{-1} by GC/MS
Dichloroacetic acid (DCA)	Concentrations may be reduced by installing or optimizing coagulation to remove precursors and/ or by controlling pH during chlorination	<0.1 – 0.4 µg l^{-1} by GC with ECD; practical quantification level 1 µg l^{-1}
Trichloroacetic acid (TCA)	Concentration in drinking water generally <0.1 mg l^{-1}. Concentrations may be reduced by installing or optimizing coagulation to remove precursors and/or by controlling pH during chlorination.	1 µg l^{-1} by GC with ECD or GC/MS
Chlorophenols		
2,4,6-trichlorophenol	Concentrations in drinking water generally < 0.15 µg l^{-1} by ion chromatography. If necessary concentrations can be reduced using GAC	0.01 µg l^{-1} using GC with ECD
Chlorate	Chlorate concentrations arising from use of sodium hypochorite are ~ 0.1 mg l^{-1}.	5 µg l^{-1} by ion chromatography with suppressed conductivity detection
Chlorite	When chlorine dioxide is used as the final disinfectant at typical doses, the resulting chlorite concentration should be <0.2 mg l^{-1}. If ClO_2 is used as a pre-oxidant, resulting chlorite concentration may need to be reduced using ferrous iron or activated carbon.	5 µg l^{-1} by ion chromatography
N-nitrosodimethylamine (NDMA)		
Monochloramine	Possible to reduce to < 0.1 mg l^{-1} by reduction; normal practice to supply water with chloramines residual of few tenths of mg l^{-1} to act as preservative during distribution	10 µg l^{-1} by colorimetric methods
Trichloroacetaldehyde (chloral hydrate)		

	Drinking Water Treatment Achievability	**Limit of Detection**
Haloacetronitriles		
Bromochloroacetonitrile		
Dibromoacetonitrile	Reduction of organic precursors will reduce formation	0.03 µg l^{-1} by GC with an ECD
Dichloroacetonitrile	Reduction of organic precursors will reduce formation	0.03 µg l^{-1} by GC with an ECD
Trichloroacetonitrile		
Algal toxins		
Microcystin-LR (Cyanobacterial Toxin)	Oxidation through ozone or chlorine at sufficient concentrations and contact times, as well as GAC and some PAC applications.	0.1 – 1 µg l^{-1} by HPLC following extraction of cells with 75% aqueous methanol. 0.1 – 0.5 µg l^{-1} using immunoassay kits (ELISA)
Others		
EDTA (Ethylenediamine tetraacetic acid)	0.01 mg l-1 using GAC plus ozonation	1 µg l^{-1} by potentiometric stripping analysis
Nitrilotriacetic acid (NTA)	No data available	0.2 µg l^{-1} using GC with a nitrogen-specific detector

6.4.2 Disinfectant By-products (DBPs)

DBPs are by definition formed during treatment. The appropriate means of managing their formation depends on the by-products. For most chlorination DBPs the enhanced removal of precursors and care in the use of chlorine to minimise the amount applied consistent with adequate disinfection is the way in which they are managed. For the control of bromate formed during ozonation the most usual management approach is to optimise the conditions under which ozonation is operated, usually on an individual supply basis. Uncertainty remains as to the appropriate management of chloramination by-products, but this is the subject of current research in the UK. Chlorite from chlorine dioxide is managed by controlling the dose of chlorine dioxide. Although chlorine dioxide use has largely fallen out of favour in the UK, the DWI approval already regulates the dose of chlorine dioxide to below that which would give combined concentrations of chlorite and chlorate below the WHO guideline value as a condition of the approval process. Control of bromate from formation as a consequence of electrolytic generation of hypochlorite from high bromide brine is controlled by specifying the quality of the salt used in making the brine. Similarly the formation of chlorate in stored hypochlorite is controlled by specification of storage conditions.

All of these approaches should be considered in the development of DWSPs and are part of normal practice.

Assessment of the need for managing the formation of NDMA in chloramination and the means of doing so are under investigation. However, NDMA may be formed in wastewater and where this is the case there may be a need to ensure that NDMA does not pose a risk in wastewater reuse schemes. There are limited options for NDMA removal but research, commissioned by DWI and the Scottish Executive, on its occurrence and control is underway in response to the increasing use of chloramination to maintain a disinfectant residual in distribution while reducing THM formation.

6.4.3 Other substances

Several treatment processes are currently in place in the UK and generally these will reflect the nature of the source and the risks associated with that source. As a consequence surface waters, which are at greatest risk, receive significantly greater treatment and what were once considered advanced treatment options, such as ozonation, granular activated carbon filtration and membrane filtration, are now the norm. It is therefore not unusual for very extensive treatment to be installed on river water sources, from storage in a raw-water reservoir through enhanced coagulation/sedimentation and clarification, ozonation, granular activated carbon filtration and finally chlorination. Such treatment, which was designed to remove pesticides to below 0.1 µg l^{-1}, will also remove a wide range of other potential contaminants. This was demonstrated by an EC funded research project on endocrine disrupting compounds (POSEIDON 2004), which were removed to very low concentrations. Many of the organic contaminants listed, e.g. dioxins, are relatively lipophilic and will adsorb to particulate matter which is readily removed, or they will be adsorbed on granular activated carbon.

6.5 Discussion and Recommendations

6.5.1 Discussion

A number of substances not specifically included in the Drinking Water Regulations for England and Wales have been considered by other jurisdictions, including WHO, for the development of guidelines or standards for drinking water. These include some inorganic substances that are primarily constituents of water arising from natural sources, some volatile chlorinated organic compounds, several petroleum-derived compounds and a number of miscellaneous non-volatile compounds, including the naturally occurring cyanotoxin, microcystin-LR. WHO has emphasised that it is not appropriate to incorporate all of the chemicals included in the Guidelines for Drinking Water Quality in national standards but that only those substances considered necessary should be included. Inclusion in national standards carries requirements for chemical monitoring that can be resource intensive and the drinking water Directive for Europe incorporates strict requirements for monitoring for all substances included. This can lead to a large number of determinations that are of little value.

In the third edition of the Guidelines, WHO introduced the concept of drinking water safety plans (DWSPs). This was endorsed by an international group of water industry representatives, regulators and drinking water quality experts in the Bonn principles that were eventually enshrined in the International Water Association Bonn Charter. This approach has now been formally incorporated in the regulations for England and Wales and is based on hazard identification and risk assessment followed by management procedures to mitigate those risks, which should also be prioritised in order to ensure that resources are directed where they will have the greatest impact. This approach provides a framework for managing risks from source to tap and helps to ensure that hazards, such as substances that are potentially of concern for drinking water, are identified. Investigation of the presence of such substances in drinking water sources and in drinking water is then targeted to where they are likely to be found and takes into account existing barriers. By doing this it is possible to demonstrate that the barriers are appropriate and that they are functioning properly so that the need for extensive chemical analysis of specific substances is substantially reduced. This approach is not only more efficient in terms of directing resources where they will have most impact but it also means that water quality can be assured over a much wider range of *potential* contaminants than would otherwise be possible. Chemical monitoring of the final water merely informs that there is a problem, while the DWSP approach is designed to ensure that controls are in place and that problems do not occur. Chemical monitoring then becomes a final check.

Although there are no systematic data on the listed substances for which guidelines or standards have been set by other jurisdictions, the data that are available usefully indicate that the majority of substances, if they are present, occur at concentrations below the health-based guidelines derived by WHO. Many of the substances identified in the list are pesticides and these were not considered further in the current report because the politically based regulatory values in Europe are below health-based values and cover all pesticides.

Several of the substances listed in this report are inorganic and most of these are present naturally as constituents of water, although there may also be anthropogenic sources that contribute to concentrations in water. Most of these substances have been assessed by the Environment Agency as part of their groundwater monitoring programme and are not of concern for drinking water. As a result of greater awareness of uranium found in groundwater by other member states, DWI commissioned an in-depth study which found that a small number of samples from private water supplies exceeded the current WHO provisional guideline value, but not the USEPA standard. Uranium is under further consideration by WHO in the light of new human data which indicates that the provisional WHO guideline value is excessively conservative. An early investigation as part of the Regional Heart Study indicated that molybdenum concentrations may exceed the WHO guideline value in some areas. Since molybdenum is an essential element it requires a different approach to risk assessment. DWI has commissioned a study of molybdenum in drinking water in England and Wales and WHO is keeping the guideline for molybdenum under review. When the data from this study are available then the implications for health will be reassessed.

Asbestos fibres are not routinely monitored in drinking water because WHO considers that there is no credible evidence for such fibres posing a risk to health. Although inhaled asbestos is of concern this is largely a function of shape and form and the shape and form of fibres in water are very different. Successive assessments have concluded that there is no significant risk from asbestos in drinking water. An early study by WRc (DWI 1982) did measure the levels of asbestos fibres in UK drinking water and concluded that levels were below the USEPA standard, which is considered to be conservative.

Many of the substances listed in this report are volatile chlorinated organic molecules, most of which are used as solvents or result from the breakdown of solvents. These do not occur at greater than trace concentrations in surface waters because they volatilise to atmosphere, but if they are spilt or discharged to soil and are able to reach groundwater they may persist for a considerable time. Tri- and tetrachloroethene, and carbon tetrachloride are included in the regulations and all waters are therefore checked for the presence of these substances. Because of their chemical similarity it is probable that most other volatile chlorinated organic substances listed in this report would also be detected and action taken if the concentrations were close to health-based guideline values. It is important that where tri- and terachloroethene and carbon tetrachloride are found that the presence of other substances and breakdown products expected under anaerobic conditions is also monitored.

BTEX compounds (benzene, toluene, ethyl benzene, xylenes) and MTBE are also reviewed in this report. While benzene is included in the regulations, the others, which are considerably less toxic, are not. However, for all of these fuel derived substances the odour threshold in water is very low and they are almost invariably unacceptable to consumers at considerably lower concentrations than the health-based values. They are, therefore, included in the regulations under the requirements that taste and odour should be acceptable to consumers. They are monitored when incidents, usually spills, occur, which is often before the substances concerned actually reach drinking water.

The additional substances reviewed in this report include the cyanotoxin microcystin-LR, DEHP, DEHA, dioxins, EDTA and NTA. This is a diverse group of compounds but of this group, dioxins have been shown not to occur in drinking water because of their low water solubility and high potential to adsorb to particulate matter and sediment, which is readily removed in drinking water treatment. While cyanotoxins do occur in raw water, their potential presence can be readily identified by the fact that they are only present in significant concentrations in association with large blooms of cyanobacteria. In addition they are readily removed by several treatment processes. Monitoring is generally unhelpful for detecting algal toxins and the guideline value primarily provides a benchmark for assessing the efficiency of treatment.

DEHA is used primarily in food contact materials and is not usually found in drinking water. WHO has not set a formal guideline value for this substance. DEHP is, however, widely used and there is clear evidence that it does reach drinking water at low concentrations, although about 50% of that found in raw water is removed during treatment. Measured concentrations are well below the WHO guideline value but there is an argument for obtaining some more recent data in view of the pressure to decrease its use. DEHP may be identified in survey mode GC-MS, in which case data will exist in several water companies. However, because of its ubiquitous presence in articles it is often difficult to obtain a low background level unless specific, targeted monitoring is used.

EDTA and NTA are chelating agents that have been found, apparently at concentrations well below WHO guidelines, in many waters receiving treated wastewater. EDTA is used as a food additive and NTA as a detergent builder. Both appear to be removed by advanced water treatment processes and are not expected to be present at concentrations of concern. It might be informative to seek some recent data on concentrations in raw and treated waters in order to confirm the effectiveness of current water treatment, but this would not be a high priority.

Several disinfection by-products are included in the list because they are included in the WHO Guidelines, but WHO provided a more comprehensive list as a benchmark against which to assess the importance of such substances DBPs have received a great deal of research and media attention, sometimes a s a consequence of misunderstanding of the overall situation with respect to their formation. European standards include a value for total trihalomethanes (TTHMs) while WHO sets guideline values for individual substances. The standard of 100 $\mu g\ l^{-1}$ as a maximum is broadly equivalent to the USEPA standard of 80 $\mu g\ l^{-1}$ measured as an average and is well within the WHO guideline values for the individual substances. Two jurisdictions include a total haloacetic acids (HAA) value or values for di- and trichloroacetic acid because these are the other dominant chlorination DBPs. The most appropriate mechanism for controlling chlorination DBPs is the removal of natural organic matter (NOM) with which chlorine reacts. This will reduce all of the halogenated organic by-products while actually helping to maintain effective disinfection and means that there is no need to monitor a very wide range of by-products, the great majority of which always occur at concentrations below guideline values or health-based guidance. However, on occasion, for example chlorination at low pH, THMs will be reduced in concentration while HAAs will be increased. There is, therefore, a strong argument for water companies to check HAAs when establishing treatment modifications to reduce THM levels.

Although many additional substances have been included in the guidelines or standards produced by other authorities or jurisdictions, a large proportion of these are already accounted for by existing standards and practices. Although there is no requirement for these to be monitored in drinking water, best practice dictates that investigations should be carried out by water companies on a risk basis. The evidence gathered in this study shows that this is certainly the case for some water companies, but the response was not universal. This is disappointing in view of the importance of being able to respond to legitimate questions about the occurrence of these substances, which are deemed to be of sufficient importance by other jurisdictions. However, drinking water safety plans (DWSPs) formally introduce the need for comprehensive hazard and risk assessment of drinking water supplies to determine the need for mitigating the risks identified and the priorities for such action where existing barriers are deemed inadequate. DWSPs are now accepted as best practice around the world and will fully demonstrate whether these additional parameters are of significance for drinking water throughout England and Wales.

6.5.2 Recommendations

- Data on raw water sources that would be of considerable interest when determining drinking water quality is collected by the Environment Agency and Defra, either directly or through commissioned research. It is recommended that lines of communication be established to ensure that such data are made available to DWI in order to assist in judging the need for any action and to allow DWI to respond to any legitimate questions about potential contaminants of drinking water.

The most important inorganic substances for which more data were required are uranium and molybdenum. However, DWI has already commissioned work on both of these substances, and work on uranium has now been completed. Consideration should be given to some specifically targeted investigations into the presence of thallium in drinking water and raw water sources, taking into account natural and industrial sources of thallium to raw water.

It would be appropriate to target monitoring for the additional volatile chlorinated organic substances listed in this report where tri-and tetrachloroethene and carbon tetrachloride have been identified in anaerobic groundwater, or where they have reached groundwater following passage through anaerobic conditions.

Data show that the health risks for drinking water associated with microcystins from cyanobacteria in the UK are very low and most water companies successfully manage drinking water sources to minimise the numbers of cyanobacteria. However, where water companies may need to rely on drinking water treatment as a barrier against cyanobacterial toxins, it would be appropriate to investigate microcystin-LR before and after treatment during a bloom in order to demonstrate that treatment is capable of a sufficient level of removal.

The data on DEHP is relatively limited and it would be of value to have a better view of the range of concentrations in drinking water, possibly by closer examination of water company GC-MS scans. However, because of its ubiquitous presence in articles it is often difficult to obtain a low background level of DEHP in analyses unless specific, targeted monitoring is used.

Although the data that exist indicate that EDTA and NTA are present in raw and drinking water at concentrations well below the WHO guidelines, it would be useful to have some modern data on their occurrence in waters receiving significant inputs of wastewater. However, this is not considered to be a high priority.

When water companies are introducing or assessing reductions in THMs it would be appropriate to consider whether HAAs have also reduced.

ABRREVIATIONS

ADI	Acceptable Daily Intake
ADWG	Australian Drinking Water Guide
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
CCL	Drinking Water Contaminant Candidate List (USA)
CDW	Federal-Provincial-Territorial Committee on Drinking Water (Canada)
CLS	Closed Loop Stripping
DBP	Disinfection by-product
DCA	Dichloroethane
DEHA	Di(2-ethylhexyl) adipate
DEHP	Di(ethylhexyl)phthalate
DPD	Diethyl Paraphenylene Diamine
DWSNZ	Drinking Water Standards for New Zealand
DWQS	Drinking Water Quality Standards
DWSP	Drinking Water Safety Plan
ELISA	Enzyme Linked ImmunoSorbent Assay
ECD	Electron Capture Detector
EDTA	Ethylenediaminetetraacetic acid
FID	Flame Ionisation Detector
GC	Gas Chromatography
GCMS	Gas Chromatography Mass Spectrometry
HAAs	Haloacetic acids
HLC	Henry’s Law constant
HPLC	High Pressure Liquid Chromatography
HS	Headspace
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ICR	Information Collection Rule
LC	Liquid chromatography
LoD	Limit of Detection
MAC	Maximum Acceptable Concentration
MAV	Maximum Acceptable Value
MCL	Maximum Contaminant Level
MTBE	Methyl t-butyl ether
MS	Mass spectrometry
NDMA	N-nitrosodimethylamine
NHMRC	National Health & Medical Research Council (Australia)
NPDWR	National Primary Drinking Water Regulation (USA)
NOM	Natural Organic Matter
NSDWR	National Secondary Drinking Water Regulation (USA)
NTA	Nitrilotriacetic acid
P&T	Purge and Trap
SDWA	Safe Drinking Water Act (USA)
SIM	Selected Ion Monitoring
TCA	Trichloroethane
TCE	Trichloroethene

THMs	Trihalomethanes
TTHMs	Total Trihalomethanes
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WHO	World Health Organization

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ANNEXES

Annex 1 Non UK Drinking Water Monitoring Data

Inorganics

Parameter	Summary
Barium Reported concentration range: 15 to 380 µg l^{-1}	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, barium was detected in 9% of wells at >100 µg l^{-1}. The median concentration was 15 µg l^{-1} and the maximum was 380ug/l. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered. Country: USA (Texas) Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, the median concentration was 108.9 µg l^{-1}.
Beryllium	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, beryllium was detected in 0.2% of wells at > 4 µg l^{-1} , and in 7% of wells at > 0.2 µg l^{-1} . The median concentration was 0.012 µg l^{-1} and the maximum was 6.6 µg l^{-1}. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were

Parameter	Summary
	filtered.
Molybdenum Reported concentration range: 7.6 µg l^{-1} to >250 µg l^{-1}.	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, concentrations of up to >250 µg l^{-1} were reported. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered. Country: USA (Texas) Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, the median concentration was 7.6 µg l^{-1}.
Silver Reported concentration range: <0.0002 µg l^{-1} to 0.1 µg l^{-1}.	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, the median concentration was <0.0002 µg $l^{-1}$and the maximum was 0.034 µg l^{-1}. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered. Country: USA (Texas) Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, the median concentration was 0.1 µg l^{-1}.
Tin	Country: Norway

Parameter	Summary
	Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, the median concentration was 0.008 µg l^{-1} and the maximum was 46 µg l^{-1}. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered.
Zinc Reported concentration range: 0.008 µg l^{-1} to 3600 µg l^{-1}.	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, zinc was detected in 3% of wells at >300 µg l^{-1}. The median concentration was 14ug/l and the maximum was 3600ug/l. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered. Country: USA Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, the median concentration was 8.9 µg l^{-1}. Country: Saudi Arabia Ref: Al Saleh (1996) Summary: In a study of 59 water samples from water coolers in 32 schools, a mean concentration of 154.07 µg l^{-1} was reported. Country: Saudi Arabia Ref: Al Saleh and Al Doush (1998) Summary: In a study of residential tap-waters from 10 houses, and 21 brands of bottled drinking water, a mean concentration of 204.36 µg l^{-1} was reported. Country: Egypt Ref: Moneeb (2006)

Parameter	Summary
	Summary: In a study of 6 tap-water samples, a mean concentration of 331 µg l^{-1} was reported. Country: Not stated Ref: Minear (1982), cited in Moneeb (2006) Summary: Reported concentrations in tap-waters ranged from 3 to 2100 µg l^{-1}. No further details obtained. Country: China Ref: Xu et al (2006) Summary: In a study of 188 tap-water samples, mean concentrations of 0.9mg l^{-1} were reported. Country: Hong Kong Ref: Ho et al (2003) Summary: In a study of tap-water from 2 residences (sampled at 3-monthly intervals from 2001 to 2002), concentrations of 0.012mg l^{-1} to 0.017mg l^{-1} were reported.
Uranium Reported concentration range: 2 µg l^{-1} - 750 µg l^{-1}.	Country: Norway Ref: Frengstad et al (2000) Summary: In a study of water from 476 groundwater wells and boreholes, uranium was detected in 18% of wells at >20 µg l^{-1}, in 3% of wells at >100 µg l^{-1} and in 0% of wells at >1700 µg l^{-1}. The median concentration was 2.5 µg l^{-1} and the maximum was 750 µg l^{-1}. It is not clear whether any of the sampled sources had undergone treatment between the aquifer and the tap or well-head from which they were abstracted. However, after abstraction, none of the samples were filtered. Country: Finland Ref: Asikainen and Kahlos (1979), cited in Frengstad et al (2000) Summary: Reported concentrations were >14 µg l^{-1}. No further details obtained. Country: Norway

Parameter	Summary
	Ref: Banks et al (1995), cited in Frengstad et al (2000) Summary: Reported concentrations were up to 170 µg l^{-1}. No further details obtained. Country: Norway Ref: Reimann et al (1996), cited in Frengstad et al (2000) Summary: Reported concentrations were up to 2 µg l^{-1}. No further details obtained. Country: USA Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, the median concentration was 3.7 µg l^{-1}. Country: USA Ref: Focazio et al (2006) Summary: In a study of self-supplied water from 2390 domestic wells, uranium-238 was detected in 2.04% of samples. However, the detection limit was not stated, so this finding is of limited value. Country: Not stated Ref: Sloto (2000), cited in Focazio et al (2006) Summary: In a study of 363 wells, uranium-238 was not detected in 45% of samples, and two wells contained concentrations of >30 µg l^{-1}.
Asbestos (fibres per litre) Ascarite (II) (R)	Country: USA Ref: Andersen et al (1993) Summary: In a study of municipal water supplies, asbestos was reported at a concentration of > 1 million fibres per litre (MFL). No further details were obtained.

Volatile organics

Parameter	Summary
1,2-Dichloropropane (1,2-DCP) Reported concentration range: 0.3 µg l^{-1} to 22.3 µg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: In an analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) a mean concentration of 1.8 µg l^{-1} was reported. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking waters (i.e. post-treatment, pre-distribution), concentrations of 0.3 µg l^{-1} to 22.3 µg l^{-1} were reported over the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations of <1 µg l^{-1} to approximately 2 µg l^{-1} were reported over the period 1985 – 1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of water from 2110 community water systems, concentrations of 1 µg l^{-1} to 2.1 µg l^{-1} were reported over the period 1993-1998. Country: USA Ref: Focazio et al (2006) Summary: 1,2-DCP was detected in 0.58% of 4757 domestic wells used for self-supply of domestic water. However, the detection limit was not stated, so this finding is of limited value.

Parameter	Summary
1,4-Dichlorobenzene Reported concentration range: 0.22 µg l^{-1} to 50 µg l^{-1}.	Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution), concentrations of 0.22 µg l^{-1} to 3.2 µg l^{-1} were reported for the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations from <1 µg l^{-1} to approximately 50 µg l^{-1} were reported for the period 1985 – 1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of water from 2110 community water systems, concentrations of 0.7 µg l^{-1} to 1.3 µg l^{-1} were reported for the period 1993-1998.
Cyanogen chloride Reported concentration range: 0.4 µg l^{-1} to 2.2 µg l^{-1}.	Country: Australia Ref: Simpson and Hayes (1998) Summary: In a 6-month study of 16 water samples (from 7 water authorities across 5 states), concentrations of <0.8 µg l^{-1} to 1 µg l^{-1} were reported during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: Spain Ref: Cancho et al (2000) Summary: In a study of finished water (i.e. post-treatment, pre-distribution) from a water treatment plant in Barcelona, a concentration of <1 µg l^{-1} was reported. Country: Not stated Ref: Krasner et al (1989), cited in Cancho et al (2000) Summary: Concentrations of 0.4 µg l^{-1} to 2.2 µg l^{-1} were reported in drinking water. No further

Parameter	Summary
	details obtained.

Chlorinated hydrocarbons

Parameter	Summary
	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 1.9 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis.
Carbon tetrachloride Reported concentration range: 0.1 µg l^{-1} to 50 µg l^{-1}.	Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: A study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution) reported concentrations of 0.1 µg l^{-1} to 6.3 µg l^{-1} for the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations of <1 to approx. 50 µg l^{-1} were reported over the period 1985 – 1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of water from 2110 community water systems, concentrations of 0.32 µg l^{-1} to 2.8 µg l^{-1} were reported for the period 1993-1998.

Parameter	Summary
	Country: Italy Ref: Zoccolillo et al (2005) Summary: In a study of water from community water systems concentrations of 8.82 µg l^{-1} were reported in tap water, 8.92 µg l^{-1} in commercial bottled water, and 18.7ug/l in "contaminated" commercial bottled water. However, no details were given as to the nature of the contamination, or the size of the sampling campaign.
cis-1,2-Dichloroethene (dichloroethylene) Reported concentration range: 0.18 µg l^{-1} to 148 µg l^{-1}.	Country: USA Ref: Focazio et al (2006) Summary: cis-1,2-dichloroethylene was reported in 0.54% of 4671 domestic wells used for self-supply of domestic water. However, the detection limit was not stated so this finding is of limited value. Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 2 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution), concentrations of 0.18 µg l^{-1} to 148 µg l^{-1} were reported for the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations of <1 µg l^{-1} to approximately 10 µg l^{-1} were reported for the period 1985 – 1995.

Parameter	Summary
	Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of water from 2110 community water systems, concentrations of 1.1 µg l^{-1} to 2 µg l^{-1} were reported for the period 1993-1998.
Dichloromethane Reported concentration range: 0.4 µg l^{-1} to 27 µg l^{-1}.	Country: USA Ref: Focazio et al (2006) Summary: Dichloromethane was detected in 1.04% of 4622 domestic wells used for self-supply of domestic water. However, the detection limit was not stated, so this finding is of limited value. Country: USA (Texas) Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, median concentrations of up to 0.5 µg l^{-1} were reported. Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 1.6 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution), concentrations of 0.4 µg l^{-1} to 27 µg l^{-1} were reported for the period 1981-1982.

Parameter	Summary
	Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations of from <1 µg l^{-1} to approximately 2 µg l^{-1} were reported for the period 1985 – 1995.
1,1,1-trichloroethane Reported concentration range: 0.0122 – 1.9 µg l^{-1}	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 1.9 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: Italy Ref: Zoccolillo et al (2005) Summary: Concentrations of 12.2 ng l^{-1} and <1 ng l^{-1} were reported in typical Italian mineral water (from commercial bottled sources) and “contaminated” Italian mineral water (from commercial bottled sources), respectively. However, no details were available regarding the nature of the contamination or the size of the study.
1,1,2-Trichloroethane Reported concentration range: 0.5 µg l^{-1} to 8.9 µg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 8.9 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis.

Parameter	Summary
	Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution), concentrations of 0.5 µg l^{-1} to 3.6 µg l^{-1} were reported for the period 1981-1982.
1,1-dichloroethane Reported concentration range: 0.1 µg l^{-1} to 60 µg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 0.9 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: A study of 945 samples of finished drinking waters (i.e. post-treatment, pre-distribution) reported concentrations of 0.1 µg l^{-1} to 24 µg l^{-1} for the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater from 2948 drinking and non-drinking water wells, concentrations of <1 µg l^{-1} to approximately 60 µg l^{-1} were reported for the period 1985 – 1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of water from 2110 community water systems, concentrations of 0.5 µg l^{-1} to 1.2 µg l^{-1} were reported for the period 1993-1998.

Parameter	Summary
1,1-dichloroethene	Country: USA Ref: Focazio et al (2006) Summary: 1,1-dichloroethene was detected in 0.58% of 4671 domestic wells used for self-supply of domestic water. However, the detection limit was not stated so this finding is of limited value. Country: USA Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 3.2 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis.
trans-1,2-Dichloroethene (dichloroethylene) Reported concentration range: 0.51 µg l^{-1} to 50 µg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 3.6 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: A study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution) reported concentrations of 0.51 µg l^{-1} to 46.2 µg l^{-1} over the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwaters from 2948 drinking and non-drinking water wells, concentrations of <1 µg l^{-1} to approximately 50 µg l^{-1} were reported for the period 1985 – 1995.

Parameter	Summary
	Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of waters from 2110 community water systems, concentrations of 1.1 μg l^{-1} to 2 μg l^{-1} were reported for the period 1993-1998.

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Parameter	Summary
Ethylbenzene Reported concentration range: 0.34 μg l^{-1} to 50 μg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 3.7 μg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking waters (i.e. post-treatment, pre-distribution), concentrations of 0.34 μg l^{-1} to 39 μg l^{-1} were reported for the period 1981-1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwaters from 2948 drinking and non-drinking water wells, concentrations of approximately 1 μg l^{-1} to approximately 50 μg l^{-1} were reported for the period 1985 to 1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary:In a study of waters from 2110 community water systems, a concentration of 0.7 μg l^{-1}

Parameter	Summary
	is reported for the period 1993 - 1998. Country: Taiwan Ref: Kuo et al (1997) Summary: In a study of 171 samples from 3 regions of Taiwan, a mean concentration of 0.36 µg l^{-1} was reported. The wording of the report implies that the samples were of tap-water, although this is not explicitly stated. Country: Canada Ref: Wang et al (2002) Summary: In a study of 2 samples of groundwater (used for drinking water supply), concentrations of 0.86 and 36.08 µg l^{-1} were reported.
Toluene Reported concentration range: 0.05 µg l^{-1} to 109 µg l^{-1}.	Country: USA Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 4.8 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 samples of finished drinking water (i.e. post-treatment, pre-distribution), concentrations of 0.05 µg l^{-1} to 76.9 µg l^{-1} were reported for the period 1981 – 1982. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of samples from 2110 community water systems, concentrations of 1.1 µg l^{-1} to 2.6 µg l^{-1} were reported for the period 1993-1998.

Parameter	Summary
	Country: Taiwan Ref: Kuo et al (1997) Summary: In a study of 171 samples from 3 regions of Taiwan, a mean concentration of 0.36 µg l^{-1} was reported. The wording of the report implies that the samples were of tap-water, although this is not explicitly stated. Country: Turkey Ref: Kavcar et al (2006) Summary: A study of bottled water from 100 houses, in 9 districts of Izmir, reported a mean concentration of 0.09 µg l^{-1}. Country: USA Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, median concentrations were reported to range from 0.8 µg l^{-1} to 0.9 µg l^{-1}. Country: Canada Ref: Wang et al (2002) Summary: 2 samples of groundwater (used for drinking water supply) were reported to contain concentrations of 0.59 µg l^{-1} to 7.3 µg l^{-1}.
Xylenes (total) Reported concentration range: 0.01 µg l^{-1} to 54.79ug/l.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 6.1 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis. Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004)

Parameter	Summary
	Summary: In a study of 945 samples of finished drinking waters (i.e. post-treatment, pre-distribution) concentrations of 0.44 µg l^{-1} to 50.2 µg l^{-1} were reported for the period 1981 -1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwaters from 2948 drinking and non-drinking water wells, concentrations of approximately 1 µg l^{-1} to approximately 50 µg l^{-1} were reported for the period 1985 -1995. Country: USA Ref: Westrick et al (1984), cited in Williams et al (2004) Summary: In a study of samples from 2110 community water systems, concentrations of 17 µg l^{-1} to 54.79 µg l^{-1} were reported for the period 1993 – 1998. Country: Turkey Ref: Kavcar et al (2006) Summary: In a study of bottled water from 100 houses in 9 districts of Izmir, a mean concentration of 0.01 µg l^{-1} was reported for *p*-Xylene. Country: Canada Ref: Wang et al (2002) Summary: In a study of 2 samples of groundwater (used for drinking water supply), concentrations of 0.17 and 54.79 µg l^{-1} were reported.
Methyl tertiary-butyl ether (MTBE) Reported concentration range: 80 ng l^{-}1to >10,000 µg l^{-1}.	Country: USA (California) Ref: Williams et al (2004) Summary: An analysis of the monitoring database of the Californian Department of Health Services (covering 15900 samples from drinking water sources, over a 20- to 30-year period) reported a mean concentration of 6 µg l^{-1}. It is unclear whether the samples all came from raw water supplies, or whether some of the samples had undergone treatment and/or distribution prior to analysis.

Parameter	Summary
	Country: USA Ref: Grady and Casey (2001), cited in Williams et al (2004) Summary: In a study of 945 finished water samples (i.e. post-treatment, pre-distribution), concentrations of 0.3 µg l^{-1} to 210 µg l^{-1} were reported, from 1981 to 1982. Country: USA Ref: Squillace et al (1999), cited in Williams et al (2004) Summary: In a study of untreated groundwater samples from 2948 drinking and non-drinking water wells, reported concentrations ranged from <1 µg l^{-1} to >10,000 µg l^{-1} between 1985 and 1995. Country: USA Ref: Focazio et al (2006) Summary: In a study of samples from 3334 domestic wells used for self-supply of domestic water, the reported detection frequency was 6.12 %. However, the detection limit was not stated, so this finding is of limited value. Country: Germany Ref: Kolb and Puttmann (2006) Summary: An 18-month study of 50 community supply wells reported that MTBE was detected in 46% of 83 finished water samples. Country: Italy Ref: Piazza et al (2001), cited in Kolb and Puttmann (2006) Summary: Reported tap-water concentrations from 80ng l^{-1} to 400ng l^{-1}. No further details obtained. Country: Germany Ref: Sacher et al (2002) and Achten (2002), both cited in Kolb and Puttmann (2006) Summary: Tap-water concentrations of 17 to 110 mg l^{-1}. No further details obtained.

Semi-volatile organics

Parameter	Summary
Di(2ethylhexyl) phthalate (DEHP; a Plasticiser) Reported concentration range: 0.05 µg l^{-1} to 11 µg l^{-1}.	Country: Poland and Germany Ref: Luks-Betlej et al (2001) Summary: A study of drinking water from 2 sites (one in Poland, one in Germany) reported concentrations of 0.05 µg l^{-1} to 0.06 µg l^{-1}. Country: Not stated Ref: Mihovec-Grdic et al (2002) Summary: In a study of 9 samples, the mean concentration was reported to be 0.247 µg l^{-1}. The report does not make clear whether the water was sampled from taps, treatment plants or raw water sources. Country: Japan and USA Ref: WHO (1996), cited in Mihovec-Grdic et al (2002) Summary: Concentrations of 1.2 µg l^{-1} to 1.8 µg l^{-1} were reported in drinking water from the USA, and 0.05 µg l^{-1} to 11 µg l^{-1} in drinking water from Japan.
Dioxin (2,3,7,8-TCDD) Reported concentration range: 0.03pg l^{-1} to 56.45pg l^{-1}.	Country: Japan Ref: Kim et al (2002) Summary: In a study of 45 water treatment facilities (samples taken on two separate occasions), raw (i.e. untreated) water concentrations of total Dioxins ranged from 4.24pg/l to 56.45pg l^{-1} (0.019pg-TEQ l^{-1} to 0.015pg-TEQ l^{-1}). Also in raw water, the mean concentration of TeCDDs was 9.38pg l^{-1} (0.0083pg-TEQ l^{-1}) in raw water. In finished water, (i.e. post-treatment, pre-distribution), the mean concentration of TeCDDs was 1.188pg l^{-}1 (0.0008pg-TEQ l^{-1}). Country: Russia Ref: Maystrenko et al (1998) Summary: In a study of >250 tap-water samples from two sites in Bashkortostan (one in the industrial city of Ufa, and one from a rural site the other side of the Urals), dioxin levels in

Parameter	Summary
	drinking water were reported from <0.1ppq to 4.95ppq (i.e. pg l^{-1}). The concentration of 2,3,7,8-TCDD in drinking water was at/below the limit of detection (0.03pg l^{-1} to 0.06pg l^{-1}). NB: The authors of this study state that their results showed good agreement with reported levels from other industrial regions in North America and Europe, although the sources of dioxins may differ. Country: Korea Ref: Choi et al (2007) Summary: In a study of raw water from drinking water plants, the concentration of 2,3,7,8-TCDD was <35 ng l^{-1}. A sample of tap water (from a single domestic tap) was found to contain <0.15 ng l^{-1} 2,3,7,8-TCDD.

Disinfection by-products

Chlorophenols

Parameter	Summary
2,4,6-trichlorophenol	Country: Australia Ref: Simpson and Hayes (1998) Summary: In a 6-month study of 16 samples (from 7 water authorities across 5 states), concentrations of up to 1.3ug/l were reported during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water.

Parameter	Summary
2,4-dichlorophenol	Country: Australia Ref: Simpson and Hayes (1998) Summary: In a 6-month study of 16 samples (from 7 water authorities across 5 states), concentrations of up to 0.6 µg l^{-1} were reported during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water.
2-chlorophenol	Country: Australia Ref: Simpson and Hayes (1998) Summary: In a 6-month study of 16 samples (from 7 water authorities across 5 states), this substance was not detected during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water.

Haloacetic acids (HAAs)

Parameter	Summary
Haloacetic acids (HAAs) Reported concentration range: <0.2 µg l^{-1} to 210 µg l^{-1}.	Country: USA (Utah) Ref: Nieminski et al (1993), cited in Williams et al (1997) Summary: A study of plant effluent from 35 water treatment plants reported a mean HAA concentration of 17.3ug/l. Country: Not stated Ref: Krasner et al (1989), cited in Williams et al (1997) Summary: A study of 35 samples from a single water treatment plant reported an HAA concentration of 20 µg l^{-1}. No further details obtained.

Parameter	Summary
	Country: Turkey Ref: Ates et al (2007) Summary: In a study of 29 raw water samples (taken monthly, throughout 2004, from surface water used for drinking water supply), concentrations of 18 μg l^{-1} to 149 μg l^{-1} were reported. Country: Korea Ref: Kim et al (2002) Summary: A study of drinking water treatment systems from 4 cities reported a mean concentration of 9.23 μg l^{-1}. It is not clear whether the samples were taken pre- or post-treatment and/or distribution. Country: Finland Ref: Nissinen et al (2002) Summary: A study of 39 water treatment plants reported concentrations from <0.2 μg l^{-1} to 210 μg l^{-1} in raw water, finished water and distributed (i.e. tap) water (sampled at distances of 10km and 24 km from the plants). Country: China Ref: Liu and Mou (2004) Summary: A study of 10 brands of supermarket bottled water from Beijing reported concentrations of up to 71.8 μg l^{-1}. Country: The Netherlands Ref: Peters et al (1991) Summary: A study of 20 water treatment plants reported concentrations of 0.5 μg l^{-1} to 14.7 μg l^{-1}. The detection frequency in samples from surface water sources was 100%, compared to 0% in samples from groundwater sources (the limit of detection was 0.1ug/l). The report implies that the samples were taken post-treatment, although this is not explicitly stated.
	Country: Canada Ref: Williams et al (1997) Summary: A study of finished and distributed water from 53 water treatment plants reported

Parameter	Summary
Dichloroacetic acid (DCA)	concentrations of 0.3 µg l^{-1} to 163.3 µg l^{-1}. TCA was not detected in raw water. Country: Canada Ref: LeBel et al (1997) Summary: In a study of finished and distributed water (2 water treatment plants, sampled monthly for 1 year), concentrations ranged from 1.8 µg l^{-1} to 53.2 µg l^{-1}. Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 15 µg l^{-1}.
Trichloroacetic acid (TCA) Reported concentration range: <0.02 µg l^{-1} to 1630 µg l^{-1}.	Country: Australia Ref: Simpson and Hayes (1998) Summary: A 6-month study of 16 samples (from 7 water authorities across 5 states) reported concentrations were <0.02 µg l^{-1} to 14 µg l^{-1} during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: Greece Ref: Golfinopoulos and Nikolaou (2005) Summary: In a study of 4 water treatment plants in Athens, concentrations in 4 finished water samples (i.e. post-treatment, pre-distribution) were 5.1 µg l^{-1} to 18.1 µg l^{-1}. Concentrations in 32 distributed (i.e. tap) water samples were 5.8 µg l^{-1} to 16.4 µg l^{-1}. Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of 1.57 µg l^{-1} to 17.71 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document.

Parameter	Summary
	Country: Canada and China Ref: Wang et al (2007) Summary: In 3 Canadian water treatment plants, the mean concentration in treated water (prior to distribution) was found to be 9.53 μg l^{-1}. In 3 water treatment plants in Beijing, the mean concentration was found to be 2.39 μg l^{-1} (also in treated water, prior to distribution). Country: Switzerland Ref: Muller et al (1996) Summary: The mean concentration in treated drinking water was found to be 670 μg l^{-1}. Country: France Ref: Benanou et al (1998) Summary: Reported concentrations were 0.8 μg l^{-1} to 11.6 μg l^{-1} in surface waters (from 15 rivers), 8 μg l^{-1} in dam waters (from 2 reservoirs) and <0.1 μg l^{-1} to 0.1 μg l^{-1} in groundwaters (3 wells). Country: USA Ref: Berry et al (1997) Summary: In a study of municipal water (i.e. household or vended water) from 9 households, median concentrations ranged from 5.4 μg l^{-1} to 5.9 μg l^{-1}. Country: Korea Ref: Kim et al (2002) Summary: In a study of water from drinking water systems in 4 Korean cities, the mean concentration was 2.56 μg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Brazil Ref: Stumpf et al (1997) Summary: In a study of tap water from 2 waterworks, concentrations of approximately 28 μg l^{-1} to approximately 42 μg l^{-1} were reported during May 1995.

Parameter	Summary
	Country: Canada Ref: Williams et al (1997) Summary: A study of finished and distributed water from 53 water treatment plants reported concentrations of 0.1 µg l^{-1} to 473.1 µg l^{-1}. TCA was not detected in raw water. Country: Canada Ref: LeBel et al (1997) Summary: A study of finished and distributed water from 2 water treatment plants (sampled monthly for 1 year) reported concentrations of 0.2 µg l^{-1} to 21.9 µg l^{-1}. Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 5 µg l^{-1}. Country: USA, The Netherlands, Germany Ref: Lahl et al (1984), Norwood et al (1986), Peters et al (1991), Uden and Miller (1983), all cited in Peters et al (1991) Summary: These studies reported concentrations in drinking waters between µg l^{-1} and 160 µg l^{-1}. No further details obtained. Country: Not explicitly stated, but likely to be USA Ref: CALEPA (1999), Weisel et al (1999), USEPA (2001), all cited in Lewis et al (2004) Summary: These authors reported concentrations of 0.1 µg l^{-1} to 1630 µg l^{-1} in drinking water. No further details obtained.
Chloroacetic acid Reported concentration range: 0.54 µg l^{-1} to 3 µg l^{-1} .	Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of 0.54 µg l^{-1} to

Parameter	Summary
	1.08 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document at present. Country: Brazil Ref: Stumpf et al (1997) Summary: A study of tap-water from 2 water treatment plants in Brazil reported a concentration of approximately 3 µg l^{-1} during 1995.
Monochloroacetate	Country: Australia Ref: Simpson and Hayes (1998) Summary: A 6-month study of 16 samples (from 7 water authorities across 5 states) reported concentrations from 10 µg l^{-1} to 244 µg l^{-1} during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: Greece Ref: Golfinopoulos and Nikolaou (2005) Summary: In a study of 4 water treatment plants in Athens, reported concentrations in 4 finished water samples and 32 tap-water samples were 1.5 µg l^{-1} to 52.6 µg l^{-1} and 2.5 µg l^{-1} to 44.4 µg l^{-1}, respectively. Country: Canada and China Ref: Wang et al (2007) Summary: In 3 Canadian water treatment plants, the mean concentration was found to be 1.53 µg l^{-1}. In 3 water treatment plants in Beijing, the mean concentration was not detected. Samples were of treated water, prior to distribution. Country: Korea Ref: Kim et al (2002) Summary: In a study of drinking water systems in 4 cities, the mean concentration was 1.23 µg l^{-}

Parameter	Summary
	[1]. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Canada Ref: LeBel et al (1997) Summary: In a study of finished and distributed water (2 water treatment plants, sampled monthly for 1 year), concentrations ranged from <0.1 µg l^{-1} to 0.5 µg l^{-1}. Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 90 µg l^{-1}.
Monochloroacetic acid	Country: Canada Ref: LeBel et al (1997) Summary: In a study of finished and distributed water (2 water treatment plants, sampled monthly for 1 year), concentrations ranged from 0.2 µg l^{-1} to 3.9 µg l^{-1} . Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 90 µg l^{-1}.
Monobromoacetic acid	Country: Canada Ref: LeBel et al (1997) Summary: In a study of finished and distributed water (2 water treatment plants, sampled monthly for 1 year), concentrations were <0.01 µg l^{-1}. Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 10 µg l^{-1}.

Parameter	Summary
	NB: further data may be available, but a thorough search of the literature has not been completed as this chemical was not in the original list supplied. The above data were picked up incidentally, while searching for information about other chemicals, but may not give the full picture.
Dibromoacetic acid	Country: Canada Ref: LeBel et al (1997) Summary: In a study of finished and distributed water (2 water treatment plants, sampled monthly for 1 year), concentrations were <0.01 µg l^{-1}. Country: Thailand Ref: Varanusupakul et al (2007) Summary: Samples of bottled water and tap-water (from a laboratory tap) were reported to contain up to 5 µg l^{-1}. NB: further data may be available, but a thorough search of the literature has not been completed as this chemical was not in the original list supplied. The above data were picked up incidentally, while searching for information about other chemicals, but may not give the full picture.

Others

Parameter	Summary
Chlorate Reported concentration range: 0.9 µg l^{-1} to 1700 µg l^{-1}.	Country: Korea and USA Ref: Quinones et al (2007) Summary: Bottled and municipal water supplies from the USA contained 270ug/l, while 7 samples from a city water supply in Korea contained 0.96 µg l^{-1} to 28 µg l^{-1} .

Parameter	Summary
	Country: Finland Ref: Pantsar-Kallio and Manninen (1998) Summary: A study of samples from water treatment plants reported concentrations of up to 800 μg l^{-1} in raw water (3 samples), and up to 1700 μg l^{-1} in finished water (7 samples). Country: China Ref: Liu and Mou (2004) Summary: 10 brands of supermarket bottled waters from Beijing were found to contain up to 0.9 μg l^{-1} .
Trichloroacetaldehyde (chloral hydrate) Reported concentration range: <0.1 μg l^{-1} to 23.4 μg l^{-1}.	Country: Greece Ref: Golfinopoulos and Nikolaou (2005) Summary: In a study of 4 water treatment plants in Athens, reported concentrations from 4 finished water samples and 32 distributed water samples were 0.3 μg l^{-1} to 11 μg l^{-1} and 0.1 μg l^{-1} to 12.5 μg l^{-1} , respectively. Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of 0.39 μg l^{-1} to 2.59 μg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document. Country: Brazil Ref: Stumpf et al (1997) Summary: A study of tap-water from 2 water treatment plants reported a concentration of approximately 21 μg l^{-1} during May 1995. Country: Canada Ref: Williams et al (1997) Summary: In a study of samples from 53 water treatment plants, concentrations of <0.1 μg l^{-1}

Parameter	Summary
	to 22.5 µg l^{-1} were reported in finished water and distributed water. Chloral hydrate was not detected in raw water. Country: Australia Ref: Simpson and Hayes (1998) Summary: In a 6-month study of 16 samples (from 7 water authorities across 5 states), concentrations of 0.2 µg l^{-1} to 19 µg l^{-1} were reported during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: Canada Ref: LeBel et al (1997) Summary: In a study of 2 water treatment plants (sampled monthly for 1 year), reported concentrations ranged from <0.1 µg l^{-1} to 23.4 µg l^{-1} in finished water and distributed water.
Chloropicrin Reported concentration range: <0.1 µg l^{-1} to 2.5 µg l^{-1}.	Country: Australia Ref: Simpson and Hayes (1998) Summary: A 6-month study of 16 samples (from 7 water authorities across 5 states) reported concentrations of up to 0.3 µg l^{-1} during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: Korea Ref: Kim et al (2002) Summary: In a study of drinking water systems in 4 Korean cities, the mean concentration was 1.45 µg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Canada Ref: LeBel et al (1997) Summary: In 3 water treatment plants (sampled monthly for 1 year), concentrations ranged from <0.1 µg l^{-1} to 1.5 µg l^{-1} in finished water and distributed water.

Parameter	Summary
	Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 tap-water samples from 15 cities reported concentrations of up to 0.119 µg l^{-1}. Country: Brazil Ref: Stumpf et al (1997) Summary: A study of two water treatment plants reported a concentration in tap water of approximately 0.5 µg l^{-1} in May 1995. Country: Canada Ref: Williams et al (1997) Summary: A study of 53 water treatment plants reported concentrations of <0.1 µg l^{-1} to 2.5 µg l^{-1} in finished and drinking waters. Chloropicrin was not detected in raw water.
Formaldehyde Reported concentration range: 2 µg l^{-1} to 13 µg l^{-1}.	Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Concentrations of up to 2 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document at present. Country: Australia Ref: Simpson and Hayes (1998) Summary: A 6-month study of 16 samples (from 7 water authorities across 5 states) reported concentrations of 2 µg l^{-1} to 13 µg l^{-1} during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water.

Parameter	Summary
1,1-dichloropropanone Reported concentration range: 0.307 µg l^{-1} to 10.8 µg l^{-1}.	Country: Greece Ref: Golfinopoulos and Nikolaou (2005) Summary: A study of 4 water treatment plants in Athens reported concentrations of up to 10.8 µg l^{-1} (in 4 finished water samples) and up to 7.7 µg l^{-1} (in 32 tap-water samples). Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 samples of tap-water from 15 Greek cities, conducted over a 4-year period, reported concentrations up to 0.307 µg l^{-1}. Country: Korea Ref: Kim et al (2002) Summary: A study of drinking water systems in 4 Korean cities reported a mean concentration of 0.96 µg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution.
1,1,1-trichloropropanone Reported concentration range: 0.846 µg l^{-1} to 2.75 µg l^{-1}.	Country: Greece Ref: Golfinopoulos and Nikolaou (2005) Summary: A study of 4 water treatment plants in Athens reported concentrations of up to 1.7 µg l^{-1} (in 4 samples of finished water) and up to 1.8 µg l^{-1} (in 32 samples of tap-water). Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 samples of tap-water from 15 Greek cities, conducted over a 4-year period, reported concentrations up to 0.846 µg l^{-1}. Country: Korea Ref: Kim et al (2002) Summary: A study of drinking water systems in 4 Korean cities reported a mean concentration

Parameter	Summary
	of 2.75 µg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution.
Chlorinated furanones Reported concentration range: 0.9 ng l^{-1} to 58.37 ng l^{-1}.	Country: Australia Ref: Simpson and Hayes (1998) Summary: A 6-month study of 16 samples (from 7 water authorities across 5 states) reported concentrations of Mutagen-X of up to 33 ng l^{-1} during 1994-1995. The samples were taken from 2 sites in the distribution systems of each water authority. All samples were of treated, distributed drinking water. Country: China Ref: Huixian et al (1995) Summary: Concentrations of Mutagen-X in 4 tap-water samples taken during 1994 ranged from 3.8 ng l^{-1} to 58.37 ng l^{-1}. Country: Taiwan Ref: Suzuki and Nakanishi (1995) Summary: Concentrations in 4 tap-water samples taken during 1994 ranged from 0.9 ng l^{-1} to 6.4 ng l^{-1}.

Haloacetonitriles

Parameter	Summary
Dichloroacetonitrile	Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 tap-water samples from 15 cities reported concentrations of up to 1.048 µg l^{-1}.

Parameter	Summary
Trichloroacetonitrile Reported concentration range: 0.0007 µg l^{-1} to 0.2 µg l^{-1}.	Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of up to 0.16 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document. Country: Greece Ref: Kampioti and Stephanou (2002) Summary: In a study of 108 tap-water samples from 15 cities, concentrations of up to 0.0007 µg l^{-1} were reported. Country: Korea Ref: Kim et al (2002) Summary: In a study of drinking water systems from 4 Korean cities, trihaloacetonitrile was not detected (limit of detection = 0.1 µg l^{-1}). The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Canada Ref: LeBel et al (1997) Summary: A study of 2 water treatment plants (sampled monthly for 1 year) reported concentrations from <0.1 µg l^{-1} to 0.2 µg l^{-1} in finished water and distributed water.
Bromochloroacetonitrile Reported concentration range: <0.1 µg l^{-1} to 1.95 µg l^{-1}.	Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of 0.25 µg l^{-1} to 1.3 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in

Parameter	Summary
	this document. Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 tap-water samples from 15 cities reported concentrations up to 0.361 µg l^{-1}. Country: Korea Ref: Kim et al (2002) Summary: A study of drinking water systems from 4 Korean cities reported a mean concentration of 1.95 µg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Brazil Ref: Stumpf et al (1997) Summary: A study of tap-water from 2 water treatment plants reported a concentration of approximately 0.5 µg l^{-1}, in May 1995. Country: Canada Ref: LeBel et al (1997) Summary: A study of finished and distributed water from 2 water treatment plants (sampled monthly for 1 year) reported concentrations from <0.1 µg l^{-1} to 0.5 µg l^{-1}.
Dibromoacetonitrile Reported concentration range: <0.1 µg l^{-1} to 2.35 µg l^{-1}.	Country: Japan Ref: Kawamoto and Makihata (2004) Summary: In a 6-month study, 8 tap-water samples were abstracted repeatedly during 2000-2001 (4 sampling occasions) from the Hyogo Prefecture. Mean concentrations of 0.06 µg l^{-1} to 0.69 µg l^{-1} were reported. NB: Raw water concentrations were also measured, although these have not been included in this document at present.

Parameter	Summary
	Country: Greece Ref: Kampioti and Stephanou (2002) Summary: A study of 108 tap-water samples from 15 cities reported concentrations of up to 0.278 µg l^{-1}. Country: Korea Ref: Kim et al (2002) Summary: A study of drinking water systems from 4 Korean cities reported a mean concentration of 2.35 µg l^{-1}. The study does not state whether the samples were taken pre- or post-treatment, or pre- or post-distribution. Country: Canada Ref: LeBel et al (1997) Summary: Finished water and drinking water samples (sampled monthly for 1 year, from 2 water treatment plants) contained <0.1 µg l^{-1} to 2.2 µg l^{-1}

Algal toxins

Parameter	Summary
Cyanobacterial toxins (Microcystin-LR) Reported concentration range: 33.2 ng l^{-1} to 35.3 µg l^{-1}.	Country: France Ref: Maatouk et al (2002), cited by Hoeger et al (2004) Summary: Concentration in finished waters: 33.2 ng l^{-1} ± 8ng l^{-1}. No further details obtained. Country: Australia Ref: Falconer (1983) and Hoeger (2003), both cited by Hoeger et al (2004) Summary: Concentration in raw water: <8 µg l^{-1} in raw water; up to 0.5 µg l^{-1} in finished water. No further details obtained. Country: China Ref: Ling (2000), cited by Hoeger et al (2004)

Parameter	Summary
	Summary: 0.2 μg l^{-1} to 35.3 μg l^{-1} in raw water; <= 1.4 μg l^{-1} in finished water. No further details obtained. Country: Brazil Ref: Teixera et al (1993), cited by Hoeger et al (2004) Summary: 0.15 μg l^{-1} to 0.87 μg l^{-1} in raw water; 0.9 μg l^{-1} to 0.18 μg l^{-1} in finished water. No further details obtained. Country: Canada Ref: Lambert et al (1996), cited by Hoeger et al (2004) Summary: 0.27 μg l^{-1} to 2.28 μg l^{-1} in raw water; 0.5 μg l^{-1} to 0.12 μg l^{-1} in finished water. No further details obtained. Country: Czech Republic Ref: Blaha and Marsalek (2001), cited by Hoeger et al (2004) Summary: <= 0.8 μg l^{-1} in raw water; up to 7.79 μg l^{-1} in finished water. No further details obtained. Country: Finland Ref: Lahti et al (2001) and Lepisto (1994), both cited by Hoeger et al (2004) Summary: 0.1 μg l^{-1} to 1.9 μg l^{-1} in raw water; 0.01 μg l^{-1} to 0.1 μg l^{-1} in finished water. No further details obtained. Country: UK Ref: Codd (2000) Summary: A study of UK freshwaters reports detection frequencies of 26% to 52% (positive for MC) between 1989 and 1999. No further details obtained.

Others

Chemical Name (or Group Name)	Summary
EDTA (Ethylenediamine tetraacetic acid) Reported concentration range: 1.1 µg l^{-1}l to 27 µg l^{-1}l.	Country: Germany Ref: Schmidt et al (2004) Summary: This review reported concentrations of EDTA in raw water ranged from 1.1 µg l^{-1} to 11 µg l^{-1}. In distributed water that is regularly polluted with EDTA, concentrations of up to 7 µg l^{-1} were reported. Details of individual studies reviewed were not obtained. Country: Brazil Ref: Stumpf et al (1997) Summary: Tap-water samples from 2 waterworks were reported to contain 2 µg l^{-1} EDTA in May 1995. Country: Germany Ref: Klopp and Patsch (1994), cited in Stumpf et al (1997) Summary: Concentrations up to 27 µg l^{-1}. No further details obtained.
N-nitrosodimethylamine (NDMA)	Country: Vietnam Ref: Duong et al (2003) Summary: Finished water from a single water treatment plant in Hanoi was found to contain no detectable NDMA (i.e. < 0.02 µg l^{-1}). Country: Not stated Ref: Mitch et al (2003). cited in Charrois and Hrudey (2005) Summary: NDMA was detected in drinking water. No further details were obtained.

Chemical Name (or Group Name)	Summary
Iodide/Iodine Reported concentration range: <0.1 µg l^{-1} to 16 µg l^{-1}.	Country: Finland Ref: Pantsar-Kallio and Manninen (1998) Summary: A study of drinking water treatment plants reported concentrations of Iodide of <0.1 µg l^{-1} to 0.2 µg l^{-1} in raw water and <0.1 µg l^{-1} in finished water. Concentration of Iodine species (total) were 0.2 µg l^{-1} to 1.1 µg l^{-1} in raw water, and 0.1 µg l^{-1} to 0.7 µg l^{-1} in finished water. Concentrations of iodate were <0.2 µg l^{-1} to 0.4 µg l^{-1} in raw water, and <0.2 µg l^{-1} to 0.7 µg l^{-1} in finished water. The number of samples was 3 (raw water) and 7 (finished water). Country: China Ref: Liu and Mou (2004) Summary: Iodide was not detected in 10 brands of bottled water from supermarkets in Beijing. Country: Denmark Ref: Andersen et al (2002) Summary: A study of 22 water treatment plants (selected to be representative of the range of Iodine concentrations across the country, rather than to reflect high levels in particular), reported concentrations up to 16 µg l^{-1} in drinking water from groundwater supplies.
Organotins (including Dialkyltins) Reported concentration range: 22ng Sn l^{-1} to 290 ng Sn l^{-1}l.	Country: Canada Ref: Sadiki and Williams (1996) Summary: In a study of 45 municipalities, tap-waters were sampled at 4 different points of use during 1993. Raw and freshwater samples were also collected. Tap-water concentrations of butyltin and methyltin were up to 43.6 ng Sn l^{-1} and 22 ng Sn l^{-1}, respectively. Butyltin was not detected in raw water. NB: the cities sampled in this study were chosen to give a representative survey of organotin levels in drinking water, rather than to focus on areas of known contamination.

Chemical Name (or Group Name)	Summary
	Country: Canada Ref: Sadiki and Williams (1999) Summary: In a study of 6 provinces, 49 sites were sampled in 2 campaigns. 3 to 6 samples of raw water, finished water and tap-water were taken from each site in each campaign. Concentrations of dibutyltin, dimethyltin, monobutyltin and monomethyltin were up to 52.5 ng Sn l^{-1}, 49.1 ng Sn l^{-1} and 28.5 ng Sn l^{-1} and 290 ng Sn l^{-1}, respectively. Country: Greece Ref: Nikolaou et al (2007) Summary: Diphenyltin and triphenyltin were not detected in raw water and tap-water from 4 water treatment plants in Athens.
Trichloroacetone (a Chloroketone)	Country: Brazil Ref: Stumpf et al (1997) Summary: A study of tap-water from 2 water treatment plants reported concentrations of approximately 11 µg l^{-1} in May 1995.

Annex I References

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