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The Need for Greater Protection for Drinking Water Supplies

Abstract

The provision of safe drinking water of sufficient quantity is an ongoing worldwide challenge and this review highlights some of the risks still inherent in the supply of drinking water, despite the numerous advances in water treatment technology, record levels of investment by the water industry and increasingly robust national and supra-national legislation. Consequently there are still many issues ahead for the water industry – in both the UK and across Europe as a whole – to address.

For example, one area where effort must be particularly focussed is within the catchment, up to the point of abstraction. Although the total number of water pollution incidents by source within the catchment in England and Wales has declined during the period 1996-2006 inclusive, it is a matter of concern that there appears to be an increase in the percentage of incidents over the same period in the 'other' category (which includes incidents where the source of the pollution could not be identified).

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Despite overall compliance in 2006 with the drinking water regulations in England and Wales being at its highest level of 99.96%, the number of drinking water events recorded during the period 1996-2006 inclusive has increased markedly, from 176 in 1996 to 502 in 2006.

We must therefore facilitate a fundamental shift in how we ensure the safety of our drinking water, from a reactive, end-of-pipe testing situation, to a proactive, risk-based approach. Although many of the hazards giving rise to these risks cannot be removed entirely from the drinking water supply chain, the implementation of Drinking Water Safety Plans should reduce the risks to more acceptable levels.

Nevertheless, the impact these Plans will have on micro-pollutants, such as xenobiotics, is questionable, unless a comprehensive monitoring and sampling policy for these parameters is implemented, in order to ensure the risk assessment process is robust and well informed.

Keywords

Abstraction, catchment; contamination; cryptosporidiosis; Drinking Water Inspectorate; Drinking Water Safety Plans; drinking water quality; Environment Agency; risk assessment; xenobiotics.

Introduction

A reliable supply of clean drinking water of sufficient quantity is essential to protect the health of individuals and communities. Indeed, In November 2002, the United Nations Committee on Economic, Social and Cultural Rights affirmed that access to adequate amounts of clean water for personal and domestic uses is a fundamental human right of all people (United Nations 2007b). However, this right has no basis in international law, despite the efforts of campaigners such as Green Cross International (Green Cross International 2007). Nevertheless, it is anticipated that global initiatives such as the World Health Organisation's (WHO) Drinking Water Safety Plans will strive to help deliver this most basic of human rights.

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In the context of the need for greater protection for drinking water supplies, it is therefore useful to consider – on global, European and UK scales – the pressures on water resources and the challenges governments face in attempting to provide everyone with safe drinking water.

Drinking Water and Public Health: An International Overview

At the end of the 20th century there were just over 6 billion people living on our planet, whilst by 2025 this figure is projected to increase by approximately one third to just under 8 billion (US Census Bureau 2008). The provision of a safe supply of drinking water in sufficient quantity to all these people will arguably be the one of the biggest challenges facing the world, particularly when it is considered that, currently, more than half the water in our rivers and lakes – 90% of the world's liquid fresh water – is polluted, putting a billion people at risk (Ward 2002). 40% of the world's population carry their water home from wells, rivers, ponds or puddles outside of their homes, whilst almost one in five of all the people living on the planet don't have access to an adequate supply of clean water (Ward 2002).

The WHO states that 1.1 billion people lack access to safe water supplies, whilst 2.6 billion people lack adequate sanitation (United Nations 2007a; World Health Organisation and UNICEF 2005), and in its view this has led to widespread microbial contamination of drinking water (Vuorinen 2007). Consequently, a child dies every eight seconds from drinking contaminated water (de Villiers 2001).

When presented with such statistics, a typical first impression is that the figures have been skewed by the lack of facilities in the developing world. Indeed, roughly 40% of the population of the African continent do not have access to improved water supply and sanitation (Hutton and Haller 2004). However, what is less well known are the issues developed countries face.

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For example, looking beyond Europe, America would most probably be cited as the country where the safest water can be found. Superficially, this would appear to be the correct response, as the whole of the North American sub-continent has access to improved water supply and sanitation (Hutton and Haller 2004). Nevertheless, the United States' Natural Resources Defense Council estimates that some 53 million inhabitants of that country drink tap water contaminated with lead, faecal bacteria or other serious pollutants (Barlow and Clarke 2002). As a result, each year about 560,000 people may suffer from a moderate to severe waterborne infection, and that 7.1 million people will contract a mild to moderate waterborne infection (Dufour et al. 2003). Because of pollutants like industrial herbicides and insecticides, nearly 40% of the rivers and streams in the United States are too dangerous for fishing, drinking or swimming (Barlow and Clarke 2002).

Elsewhere in the world, many parts are experiencing gradual destruction and increased pollution of fresh water resources, and numerous nations are finding it increasingly difficult to ensure an adequate supply of drinking water for their people (Hunter et al. 2000b).

Contamination of course does not always arise from man's activities – it can also be natural, the scale which can be significant. For example, upwards of 77 million of the total population of 125 million of Bangladesh may be exposed to undesirable levels of arsenic through their drinking water (World Health Organisation 2003b).

The European Situation

Here in the WHO's European region (which consists of all the countries within Europe, the Russian Federation, the former Soviet satellite countries, Cyprus, Iceland, Turkey and Israel), as at 2000, approaching 1 in 20 of its inhabitants (or 26 million (World Health Organisation & United Nations Children's Fund 2000)) were without access to an improved water supply[3]. In urban areas, 100% of the population had

[3] The WHO and UNICEF Joint Monitoring Programme for Water Supply and Sanitation considers the following to be 'not improved' – unprotected well, unprotected spring, vendor-provided water, bottled

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access to an improved water supply, but amongst the rural population this figure was only 87% (World Health Organisation & United Nations Children's Fund 2000).

Thanks to initiatives such as the Drinking Water Directive (European Union 1998), consumers of public water supplies throughout Europe are confident that the water is safe to drink, although a large number will be ignorant of the standards to which the water has been treated (Anderson 2003). But is this confidence well grounded?

A joint report produced by the WHO and the European Environment Agency stated that "although high standards have been reached in some countries [in the WHO's European region], outbreaks of waterborne diseases continue to occur across Europe, and minor supply problems continue to occur in all countries" (Bartram et al. 2002). This report goes on to state that "the standard of treatment and disinfection of drinking water is inconsistent across Europe and … can be insufficient", and that "reliable data are lacking on the quality of the source water and the drinking water supplied, and the detection and investigation of outbreaks are generally poor in most countries".

A UK Perspective

A review by Galbraith et al (1987) found that there were 34 outbreaks of waterborne disease recorded in the UK between 1937 and 1986, comprising over 11,794 cases and at least six deaths. However, the majority of these outbreaks (21) were due to contaminated public water supplies, whilst the remaining 13 outbreaks arose from contaminated private water supplies (Galbraith et al. 1987; Watkins et al. 2001).

Contrast these results with a similar one undertaken by Hunter et al, but for a much more recent period (1991 to 1998), which found there were 35 outbreaks of disease

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water and tanker truck provision of water – whilst the following are considered to be 'improved' – household connection, public standpipe, rainwater collection, borehole, protected dug well and protected spring. (World Health Organisation & United Nations Children's Fund 2000).

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linked to drinking water in the UK; by comparison, during the same period there were 113 in the United States (Hunter et al. 2000a).

According to Watkins et al (2001) the link between drinking water and the occasional outbreak of gastrointestinal illness is beyond doubt, and the WHO encourages the use of health-based targets when considering the risks associated with public water distribution systems. However, this type of analysis is difficult to carry out in developed countries such as the UK where the incidence of mortality or illness linked to the public water supply is very low and cannot be reliably measured (Dufour et al. 2003).

For example, in the case of a low-level incident (such as an intense rainfall event in a heavily-grazed upland catchment containing an impounding reservoir use for public water supply), a significant proportion of gastrointestinal illness of a waterborne origin such as cryptosporidiosis is likely to be undetected by the health authorities as the symptoms are usually mild and only last a few days, so people will generally not be sufficiently concerned to see their GP (Dufour et al. 2003).

Because of this element of under-reporting, care has to be taken when reviewing incidences of cryptosporidiosis in the UK, such as the data presented in Table 1 which relates to the period 1996 to 2006 inclusive (World Health Organisation Regional Office for Europe 2007).

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	4	9	9	5	3	1	0	1	0	3

Table 1: Number of cases of cryptosporidiosis per 100,000 population in the UK

These data appear to show a slight downward trend over the 10-year period, although they must be interpreted with some caution due to the small number of data points. Also, not only must under-reporting be taken into consideration, but visitors who contract diseases such as cryptosporidiosis whilst on holiday contribute a significant proportion of cases of such illness in a number of European countries, including the UK. Tourists are especially likely to contract enteric diseases, such as gastroenteritis, from pathogens the resident population may be able to tolerate (Bartram et al. 2002).

Contamination of Drinking Water Supply Chains

If drinking water supply chains were hermetically sealed, with uncontaminated precipitation falling on catchments, the risk of this water being polluted on its way to perfectly performing purification plants was zero, and then delivered via chemically inert, leak-free pipes, there would be no need for this paper. The reality though, is that these supply chains can potentially be exposed to an immense number of risks, for example, arising from contamination incidents, industrial accidents, poor catchment management, deficiencies in treatment, distribution or monitoring or even malicious intent (Gray and Thompson 2003). Consequently, the safety of, and confidence in, tap water around the world varies markedly.

With regards to the provision of drinking water, contamination of water supplies can be grouped into a number of different categories (such as private and public water supplies, or relating to their source or the size of the supplies), but for the purposes of this paper it is considered in terms of two broad categories – contamination occurring within the catchment prior to water being abstracted for treatment purposes, and contamination occurring post-abstraction (during treatment and its subsequent distribution to customers). An overview of the scope of these two definitions is given in the following sections, along with relevant data obtained from the appropriate regulators in England and Wales.

Pre-Abstraction Contamination

Within the catchment water contamination is a very general term that refers to the accidental as well as the deliberate introduction of undesired and/or harmful agents in surface waters or groundwaters (Persoone et al. 2003).

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Even with the generally high standards of drinking water that we currently enjoy across Europe, new threats (both natural and accidental) to the safety of our drinking water supplies have emerged or become of greater concern over the last few years, such as *Cryptosporidium* and *Giardia* (both of which are protozoan parasites (Health Protection Agency 2007a; b)), diffuse pollution and climate change.

Between 1972 and 1999, 35 new agents of disease were discovered (the significant ones are given in Table 2 (Hrudey and Hrudey 2004)), and many more have re-emerged after long periods of inactivity; the WHO has stated that the total of emerging and re-emerging waterborne pathogens is 175 (World Health Organisation 2003a).

YEAR IDENTIFIED	PATHOGEN
1972	Small round structured viruses (SRSVs, calciviruses)
1973	Rotaviruses
1976	*Cryptosporidium parvum*
1977	*Campylobacter spp.*
1983	*Escherichia coli O157:H7*
1992	*Vibrio cholerae O139:H7*

Table 2: Major waterborne pathogens causing diarrhoeal disease identified since 1972

According to the WHO, there are many reasons why human pathogens emerge or re-emerge (World Health Organisation 2003a). Climate change is one such significant reason, because if extremes of drought and rainfall intensify as predicted, this will create new environments; infectious diseases such as cryptosporidiosis would probably increase as a result (Vuorinen 2007).

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Water Pollution Incidents in England and Wales

The Environment Agency (EA) is the lead environmental regulator for England and Wales, and has responsibilities for the protection, remediation and improvement of our land, water and air (Environment Agency 2007a). As such, it is therefore responsible for investigating pollution incidents within catchments (which would fall under the heading of 'pre-abstraction contamination') and co-ordinating any subsequent clean-up operation.

The EA categorises each pollution incident according to its severity. There are four categories, with Category 1 being the most serious, whilst Category 4 has no impact on water, land and/or air. Category 1 water pollution incidents have the following characteristics (Environment Agency 2007b):

- Persistent and extensive effects on quality;
- Major damage to the ecosystem;
- Closure of a potable abstraction;
- Major impact upon amenity value;
- Major damage to agriculture and/or commerce; and
- Serious impact upon man.

Category 2 water pollution incidents (defined as significant but less severe) have the following characteristics (Environment Agency 2007b):

- Significant effect on quality;
- Significant damage to the ecosystem;
- Non-routine notification of abstractors;
- Reduction in amenity value;
- Significant damage to agriculture and/or commerce; and
- Impact upon man.

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Data published by the EA relating to water pollution incidents during the period 1996-2006 inclusive are presented in Table 3 (Environment Agency 2007c; d; e; f; g; h; j; Environment Agency: Matt Starr 2007).

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<table>
<tr><th></th><th>1996</th><th>1997</th><th>1998</th><th>1999</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th></tr>
<tr><td>Other</td><td rowspan="7">1666</td><td rowspan="7">1548</td><td rowspan="7">1366</td><td>191</td><td>306</td><td>410</td><td>346</td><td>306</td><td>280</td><td>234</td><td>277</td></tr>
<tr><td>Domestic/ residential</td><td>37</td><td>31</td><td>NDA</td><td>43</td><td>38</td><td>28</td><td>28</td><td>26</td></tr>
<tr><td>Waste facilities</td><td>NDA</td><td>35</td><td>38</td><td>18</td><td>20</td><td>19</td><td>19</td><td>10</td></tr>
<tr><td>Transport</td><td>74</td><td>90</td><td>43</td><td>36</td><td>27</td><td>31</td><td>25</td><td>18</td></tr>
<tr><td>S& W industry</td><td>164</td><td>161</td><td>171</td><td>168</td><td>198</td><td>137</td><td>157</td><td>136</td></tr>
<tr><td>Industrial</td><td>249</td><td>125</td><td>142</td><td>105</td><td>92</td><td>98</td><td>86</td><td>73</td></tr>
<tr><td>Agriculture</td><td>238</td><td>247</td><td>174</td><td>150</td><td>98</td><td>115</td><td>112</td><td>65</td></tr>
<tr><td>TOTAL</td><td>1666</td><td>1548</td><td>1366</td><td>953</td><td>995</td><td>978</td><td>866</td><td>779</td><td>708</td><td>661</td><td>605</td></tr>
</table>

Table 3: Number of water pollution incidents by source per year (Categories 1 and 2 only) (Note: NDA means 'No Data Available')

Prior to 1999 the EA did not record water pollution incidents by source, hence only the total of category 1 and 2 pollution incidents can be shown here for the years 1996, 1997 and 1998. Nevertheless, the marked decline in the total number of pollution incidents hides an important fact – the source of a significant number of pollution incidents cannot be identified, and these are included in the 'other' category. These data relating to 'other' sources is plotted in Figure 1 (Environment Agency 2007c; Environment Agency 2007d; Environment Agency 2007e; Environment Agency 2007f; Environment Agency 2007g; Environment Agency 2007h; Environment Agency 2007j; Environment Agency: Matt Starr 2007), and it can be seen that the percentage for 2006 is the highest value in the period for which data are available (Environment Agency 2007i).

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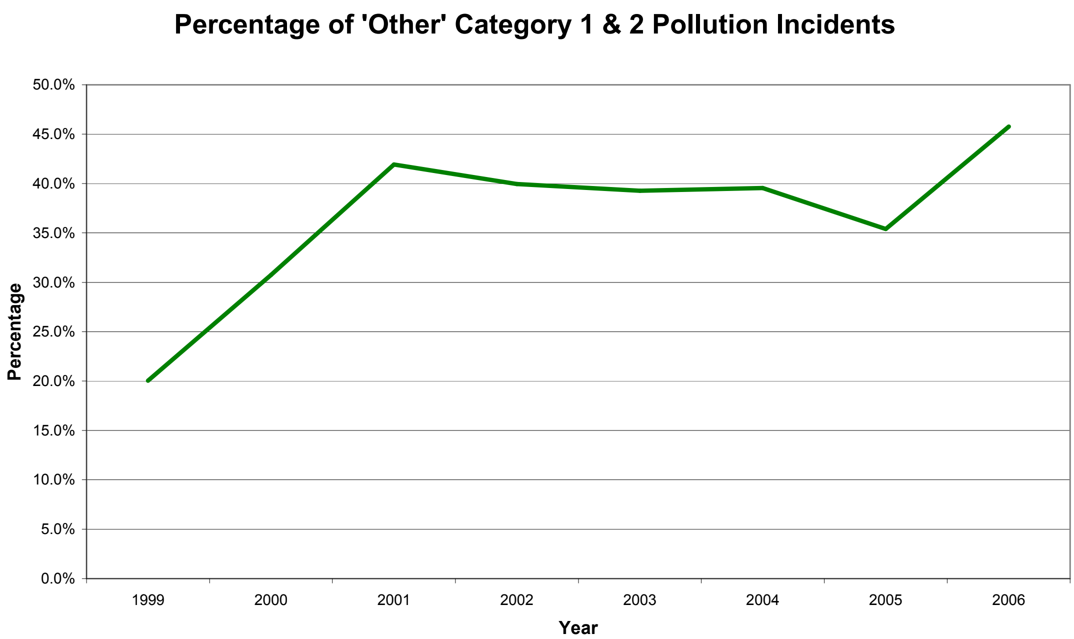

Figure 1: Percentage of Category 1 and 2 Pollution Incidents in the 'Other' Category for the Period 1999 to 2006 Inclusive (Categories 1 and 2 only)

Post-Abstraction Contamination

Just because a community has access to a high quality source of water from a relatively pollution-free catchment does not mean it is invulnerable to drinking water related illnesses. This is because distribution systems have the potential for efficiently transporting microbial pathogens (perhaps arising from a treatment failure or a back-siphonage incident) to large numbers of people.

A failure (accidental or otherwise) of the electrical supply in an area may lead to a partial shutdown of the system (Deininger 2003). A major fire may cause flow reversals within part of a distribution system, as the fire brigade draws water from it to supply its hoses, which could give rise to re-suspension of historic sediments within a main, or even instances of back-siphonage (Wessex Water 2007; World Health Organisation 2007).

Although we often tend to focus on such accidental contamination incidents, natural events such as tornados or major flood events can also adversely affect the quality of

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drinking water after it has entered the distribution system. For example, the unprecedented widespread floods across central England during Summer 2007 left up to 350,000 people in Gloucestershire without safe mains water supplies due to flooding at Mythe Water Treatment Works which had not been predicted, despite the forecasted heavy rain and flood warnings (BBC 2007a; Severn Trent Water 2007a; Severn Trent Water 2007b; Severn Trent Water 2007e). This Water Treatment Works was the sole source of supply for Gloucester, Cheltenham and Tewkesbury but was evacuated early on 22 July 2007 due to the site being flooded to a depth of 18 inches (Severn Trent Water 2007a). Full access was regained three days later, and mains water supplies were reinstated on a phased basis over the next few days (Severn Trent Water 2007c). As a precaution, customers were advised to boil the water, until analytical results confirmed the mains water was safe to drink, and the "boil water" notice was lifted on 7 August 2007 (Severn Trent Water 2007b).

A distribution system is vulnerable to earth movements, ranging from the micro end of the scale (such as caused by shrinkage and expansion of the clay – which itself is naturally corrosive to cast iron mains – in many parts of London, giving rise to the numerous bursts and leaks experienced by Thames Water (Guardian Unlimited 2007; Thames Water 2007a; b)) to the macro (such as earthquakes).

Incidents Affecting the Quality of Public Water Supplies in England and Wales

Because it is difficult to directly determine the influence drinking water has on non-outbreak levels of illness in developed countries, it is necessary to look at secondary indicators to identify potential risks. A number of such indicators are published by the Drinking Water Inspectorate (DWI), which acts for and on behalf of the Secretary of State for Environment, Food and Rural Affairs and the Welsh Assembly Government to ensure that water companies in England and Wales meet their regulatory obligations in terms of drinking water quality (Jackson 2003). In this context, as the EA is responsible for investigating incidents of pre-abstraction contamination, the DWI has responsibility for investigating incidents of post-abstraction contamination.

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Section 9 of the Water Undertakers (Information) Direction 1998 requires all water companies in England and Wales to notify the DWI of the occurrence of any event which, by reason of its effect or likely effect on the quality or sufficiency of water supplied by it, gives rise or is likely to give rise to a significant risk to the health of persons to whom water is supplied (UK Government 1998). Examples of events include discolouration arising from disturbance of oxidation products in water mains as a result of changes in flow, microbiological contamination, and loss of pressure and/or supply (Drinking Water Chief Inspector 2007).

An incident is a sub-set of events defined by the DWI to include:

- an unusual deterioration in water quality; or
- a significant risk to the health of consumers; or
- adverse water quality changes perceived by consumers as significant; or
- a cause for significant media interest (Drinking Water Chief Inspector 2001).

A non-incident is any other event notification which is not an incident.

The DWI reports yearly on the number of events reported to them, whilst another useful secondary indicator is the number of prosecutions brought by the DWI under Section 70 of the Water Industry Act 1991 (UK Government 1991) for water "unfit for human consumption".

Data relating to the event secondary indicator are presented in Table 4 (Drinking Water Chief Inspector 1991; 1992; 1997; 2001; 2002; 2003; 2004; 2005; 2006; 2007a; b; c) . Prior to February 1998 water companies were required to inform the DWI of significant changes to water quality in accordance with the Water Undertakers (Information) Direction 1992 (Drinking Water Chief Inspector 1998). After that date, water companies had to comply with the revised requirements of the Water Undertakers (Information) Direction 1998, so this change may account for the sharp rise in non-incidents from 1997 to 1998. Nevertheless, despite showing a decrease in the more serious threats to water quality from 1999 onwards, over the entire period of

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the dataset, the number of events has increased markedly, from 176 in 1996 to 502 in 2006.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Incidents	76	95	120	166	139	138	112	99	89	92	98
Non-incidents	100	102	180	222	290	321	286	254	215	369	404
TOTAL	176	197	120	388	429	459	398	353	304	461	502

Table 4: Number of events (incidents and non-incidents) reported to the DWI by water companies in England and Wales

Data relating to the prosecutions secondary indicator are presented in Table 5 (Drinking Water Inspectorate 2007) which appears to show a general decline in the number of prosecutions over the 11-year period, although any interpretations of the dataset must be viewed with some caution due to the small number of data points.

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
1	4	9	9	5	3	1	0	1	0	3

Table 5: Number of prosecutions of water companies in England and Wales by the DWI

Private Water Supplies in the UK

A private water supply is defined as being "a supply of water provided otherwise than by a water undertaker" (UK Government 1991) and it is generally derived from boreholes, wells and springs; approximately 1% of the UK's population obtains its drinking water from them (Watkins et al. 2001). Whilst water supplied by the water undertakers throughout the UK is generally of very high quality (which for 2006 resulted in an overall compliance of 99.96% with the Regulations in England and Wales, 99.76% in Scotland, and 99.34% in Northern Ireland (Drinking Water Chief

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Inspector 2007; Northern Ireland Drinking Water Inspectorate 2006; Scottish Water 2006)), private water supplies can sometimes be of dubious quality. Private water supplies are five times more frequently contaminated than private commercial water sources and the smaller the supply, the more likely it is to be contaminated (Clapham 2003). According to Watkins et al (2001) "it is likely that drinking water from private supplies accounts for a significant burden of gastrointestinal illness … in the UK".

A study by Said et al (2003) found that, for the period 1970 to 2000, private water supplies in England and Wales were involved in 36% of drinking water outbreaks, and gave rise to a 22-times higher risk of contracting diseases than public water supplies (Hrudey and Hrudey 2004).

If the quality of private water supplies is so bad, then why are there not significant instances of gastro-intestinal illnesses in rural communities? Clapham (2003) is of the opinion that, a resident population continually exposed to pathogens – including *Cryptosporidium* – eventually develop high immunity levels. In association with this theory, it is interesting to note that a study in 1996 found that people on private supplies consulted their doctor less often than those supplied by water companies, resulting in disease under-reporting (Clapham 2003).

The Relevance of Drinking Water Safety Plans

In order to detect whether post-abstraction contamination has occurred (or indeed, whether any pre-abstraction contamination has passed through the treatment stage), water companies have traditionally relied on a process called compliance monitoring to assess whether treated water is fit for human consumption, by testing samples taken from various stages of the treatment and distribution supply chain, typically as the water leaves the treatment works, from service reservoirs within the distribution system and from randomly chosen domestic properties (Canadian Council of Ministers of the Environment 2004).

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The principal drawbacks of this process are that the volume of water sampled, compared to the volume of water supplied and subsequently consumed, is miniscule, and that the process itself is retrospective (Hayes et al. submitted for publication); microbiological results will not start to be available until the day after the sample has been submitted for analysis, whilst more complicated tests (such as for pesticides) may take in the region of ten days. By then, if a problem is detected the water would have entered the distribution system and may well have been consumed (Dufour et al. 2003). It is conceivable that, in the case of a contamination event, consumers could have actually fallen ill before the event could be identified and satisfactorily resolved.

Another major problem with compliance monitoring is that it is virtually impossible to address the entire range of potential health concerns, as this process only deals with microbiological pathogens and/or contaminants for which a prescribed numerical guideline value or established method of analysis has been developed (Canadian Council of Ministers of the Environment 2004).

As such ‘end-product’ testing comes too late to ensure safe drinking water, the focus has to shift further up the drinking water supply chain, and a combination of integrated proactive techniques and approaches have to be adopted, such as:

- Catchment management (to minimise the occurrence of pre-abstraction contamination);
- Assessment and minimisation of risks; and
- Continual monitoring the quality of the water throughout the supply chain, from the top of the catchment to the consumer’s tap (Dufour et al. 2003; Fawell and Watkins 2003; Keirle and Hayes 2007).

Such a combination of techniques and approaches (which is collectively known as the multiple barrier concept) is leading towards a risk-based approach to ensure the safety of drinking water which, in order to be robust, would require information on:

- Sources of pre-abstraction contamination within the catchment, including their nature and location (which will enable peak contamination events to be

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predicted and effective catchment control measures to be identified and implemented);

- The natural variability over time of the quality of the abstracted water, and how it reacts to meteorological events (such as drought, storms and flooding);
- Efficacy of the different treatment processes employed at eliminating contamination peaks in the abstracted water; and
- Sources and risk of post-abstraction contamination (Dufour et al. 2003).

Consequently, 2004 saw the publication of two key documents – the Bonn Charter and the WHO's third edition of its Guidelines for Drinking Water Quality (International Water Association 2004; World Health Organisation 2004). These two complementary documents together describe a common framework for the effective provision of safe drinking water.

Originally developed by the water industry in Australia, Drinking Water Safety Plans have now been adopted by the WHO and are being actively promoted by it (Hall 2006). These Plans combine a number of systematic management approaches such as Hazard Analysis and Critical Control Point principles, management and assessment of risks and the multiple-barrier concept, and they can be broken down into three key components:

1) Management arrangements (including communication, capital and rehabilitation plans and documentation associated with quality assurance systems);
2) System assessment and design (to ensure the whole of the drinking water supply chain can provide consumers with a product of sufficient quality and quantity in order to comply with legal and environmental obligations); and
3) Operational optimisation and monitoring, so that if there is any deviation from normal operating parameters it can be speedily identified and prompt appropriate action taken (World Health Organisation 2004).

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Many water companies within the UK will already have developed a number of elements of the above components to one degree or another so the development and implementation of a Drinking Water Safety Plan will merely represent a review, update and consolidation of existing management systems and procedures, rather than the implementation of a completely new management regime (Hall 2006). Existing systems and procedures may include:

- Training plans;
- Communication policies;
- Emergency/incident plans;
- Distribution Operation and Maintenance Strategies;
- Site operational manuals; and
- Quality assurance systems developed in accordance with international standards, such as ISO 9001.

Discussion

The provision of safe drinking water of sufficient quantity is an ongoing worldwide challenge and this review has highlighted some of the risks still inherent in the supply of drinking water, despite the numerous advances in water treatment technology, significant levels of investment by water companies and increasingly robust national and supra-national legislation. Consequently there are still many issues ahead for the water industry – in both the UK and across Europe as a whole – to address.

For example, one area where effort must be particularly focussed is within the catchment, up to the point of abstraction. Although the total number of Category 1 and 2 water pollution incidents by source within the catchment has declined during the period 1996-2006 inclusive, it is a matter of concern that there appears to be an increase in the percentage of incidents over the same period in the 'other' category (which includes incidents where the source of the pollution could not be identified). This is a worrying development for the provision of safe drinking water supplies: How can water companies put effective control barriers in place, if they do not know what (or where) the hazards in the catchment are, and what risks they pose? Effective

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catchment management will surely have some impact on the presence of micro-pollutants in our natural environment, but this may only be limited at best.

Consequently, we must remain vigilant to the threats from existing hazards, emerging hazards and re-emerging hazards (such as new strains of pathogens thought to have been eradicated in many parts of the world). Instead of being satisfied with record levels of compliance with drinking water standards, we must therefore facilitate a fundamental shift in how we ensure the safety of our drinking water, from a reactive, end-of-pipe testing situation, to a proactive, risk-based approach. Such an approach is enshrined within Drinking Water Safety Plans, and it is anticipated that adoption of this approach, in combination with the requirements of the Water Framework Directive, will be very successful in reducing the risks associated with macro-pollutants such as pesticides and nitrates, as these are hazards that are well known, and much time and effort has been spent understanding their origins and the impacts they have on the environment and human health.

However, it is difficult to appreciate how risk assessments can be undertaken of micro-pollutants and emerging hazards if knowledge of them is poor and/or there is little information relating to their extent and potential impact on human health. It could be argued therefore that the providers of both private and public water supplies should be required to implement a comprehensive monitoring and sampling policy for these parameters, in order to ensure the risk assessment process is robust and well informed. Nevertheless, if such a policy were to be made mandatory, the cost would be prohibitive (Hayes et al. submitted for publication).

In the UK it has not been common to monitor water sources used for drinking water supply (let alone other environmental waters) exhaustively for the purpose of detecting trace pollutants, beyond those that are specifically regulated. The current focus of risk assessments associated with the implementation of the Drinking Water Safety Planning approach in the UK appears to be on macro-pollutants and which are listed within the drinking water Regulations (National Assembly for Wales 2001; UK

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Government 2000). This seems appropriate, as the parameters contained within the Regulations are generally well understood, and have established methods of analysis associated with them. It is therefore a relatively straightforward process to undertake risk assessments when such information is available.

Despite the lack of knowledge relating to some micro-pollutants and emerging hazards, Drinking Water Safety Plans must consider all potential hazards to supply chains, both on the macro- and the micro-scale. Nevertheless, it is not known whether the adoption of this approach – as well as other initiatives such as the Water Framework Directive – will have a significant impact on micro-pollutants (xenobiotics for example) that are poorly understood.

In theory, Drinking Water Safety Plans should be developed for each supply chain, although in practice this may neither be realistic or cost-effective for small systems, and a model plan (with guidelines for its development and application to the supply chain) may be more appropriate. Indeed, this is the approach the Scottish Executive took when it overhauled its private water supplies Regulations, by producing a technical manual containing guidance, risk assessment pro-formas and survey templates (Scottish Executive 2006a; b).

When it comes to public water supplies though, neither the Drinking Water Inspectorate (for England and Wales), nor the Drinking Water Quality Regulator for Scotland has formally issued any guidance on how to produce such a Plan; indeed, the only document within the public domain produced by either regulator was an introductory guide produced by the Drinking Water Inspectorate in October 2005 (Drinking Water Inspectorate 2005). Instead, the regulators appear content for water companies to develop their own individual formats, whilst having due regard to the guidelines produced by the WHO (World Health Organisation 2004).

Conclusions

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1) It can be deduced that compliance monitoring still has an important role to play in Drinking Water Safety Planning, but it is no longer the primary tool; instead, it is now to be used in conjunction with others.

2) The impact the implementation of Drinking Water Safety plans will have on micro-pollutants is questionable, without first acquiring data relating to their extent and potential impacts on human health, which undoubtedly would be at significant cost. It is therefore extremely questionable whether Drinking Water Safety Plans are the panacea that many anticipate them to be.

3) The stance the drinking water quality regulators have taken with regards to the implementation of Drinking Water Safety Plans is undoubtedly leading to duplication of efforts by water companies, and unnecessary expenditure. There is therefore an opportunity for the regulators to re-consider developing a standard Drinking Water Safety Plan model for the UK water industry, which can then be adapted by water companies to their own individual needs and circumstances. Alternatively, water companies themselves could come to a consensus for such a model.

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