3 Lessons learnt from outbreaks of waterborne cryptosporidiosis

3.1 Review of incidents

3.1.1 This section reviews incidents during the last ten years in which Cryptosporidium oocysts were detected in public drinking water supplies or where there was a suspected public drinking water related outbreak of cryptosporidiosis. The objective of the review is to establish whether there was any correlation between outbreaks of cryptosporidiosis and events which might pose a challenge to the integrity of the treatment or distribution process.

3.1.2 The Group is aware of twenty five outbreaks of cryptosporidiosis in the United Kingdom since 1988 that have been associated with the consumption of public drinking water supplies. These are listed in Table 3.1. The association with mains water varies from possible to probable to strong. Fourteen incidents have involved increased reporting of cases of cryptosporidiosis but in the absence of any reported detection of oocysts in water supplies. These may illustrate the limitations of current sampling and analytical techniques or indicate that the source was not the water supply. In eleven incidents, an increase in reported cases of cryptosporidiosis was associated with detection of oocysts in water supplies. The Group is also aware of eighteen notifications in England and Wales since 1990 involving detection of oocysts in water supplies but without any detectable increase in the level of cryptosporidiosis in the community which supports the practice of not over-reacting to low levels of oocysts in water supplies.

3.1.3 Most outbreaks occurred in situations where oocysts were not detected in water supplies. The tabulated data indicate that the majority of outbreaks of waterborne cryptosporidiosis occurred in situations in which the integrity of treatment had been compromised or where the treatment provided may have been less than adequate. In only two incidents was the correlation less than convincing.

3.1.4 Research funded by the Department of the Environment, Transport and the Regions (DETR 1998) on modelling the risk of infection has indicated that pathogens are non-randomly distributed in drinking water and may be associated with particles arising from turbidity events. It is significant that the majority of outbreaks identified were associated with situations in which turbidity increased although the regulatory standard for turbidity was not necessarily contravened. The groundwater incidents confirm that contamination of groundwater can be a significant risk factor. Time of year and climatic conditions may also be a risk factor, given that most incidents were reported during the late autumn to early spring period.

3.1.5 The Group concluded from its examination of these incidents that outbreaks of water related cryptosporidiosis do not just ‘happen’. There appears to be a strong correlation between outbreaks and situations where an inadequacy was identified in the treatment provided or in the operation of the treatment process, or where there was overloading of the treatment process. The unifying factor in all situations was the potential for peaks in
turbidity to have been present in the treated water leaving the works. The fact that turbidity events were not recognised in all cases could be a reflection of inadequacy in the continuity of turbidity monitoring or in the calibration and control of the equipment.

### Table 3.1 UK outbreaks of cryptosporidiosis associated with public drinking water supplies April 1988 – April 1998

<table>
<thead>
<tr>
<th>Date</th>
<th>Source/treatment characteristics (all water received normal chlorine based disinfection)</th>
<th>Oocysts detected in treated water</th>
<th>Approximate number of cases of cryptosporidiosis</th>
<th>Association with water</th>
<th>Conclusions/ comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 1988</td>
<td>Surface water with coagulation and rapid gravity filtration</td>
<td>Yes</td>
<td>27</td>
<td>Strong</td>
<td>Agricultural slurry contamination of water in distribution</td>
</tr>
<tr>
<td>Mar 1989</td>
<td>Impounded reservoir supply, coagulation, rapid gravity filtration</td>
<td>Yes</td>
<td>500+</td>
<td>Strong</td>
<td>Contamination of source water with animal wastes, breakthrough of treatment</td>
</tr>
<tr>
<td>Mar 1989</td>
<td>Surface water, coagulation, rapid gravity filtration</td>
<td>Yes</td>
<td>Number of cases included in 500+ reported above</td>
<td>Strong</td>
<td>River flows abnormally low, severe diarrhoea in cattle upstream of intake</td>
</tr>
<tr>
<td>Apr 1989</td>
<td>Surface water, no filtration</td>
<td>Yes</td>
<td>244</td>
<td>Probable</td>
<td>Unfiltered water, potential point source discharge from sewage treatment works and farm drains and non-point discharge from grazing animals</td>
</tr>
<tr>
<td>Dec 1989</td>
<td>Lowland river with bankside storage, roughing filters and slow sand filtration</td>
<td>No</td>
<td>477</td>
<td>Strong</td>
<td>Outbreak followed by-passing of filters</td>
</tr>
<tr>
<td>Dec 1990</td>
<td>Lowland tidally influenced river, direct abstraction, gravity filtration</td>
<td>No</td>
<td>47</td>
<td>Probable</td>
<td>Rapid fluctuations in source water quality at the time of the outbreak</td>
</tr>
<tr>
<td>Apr 1991</td>
<td>Spring, well and stream supply, crude filtration</td>
<td>No</td>
<td>5</td>
<td>Possible</td>
<td>Possible agricultural contamination of well supply, inadequate treatment</td>
</tr>
<tr>
<td>Apr 1992</td>
<td>Surface water, no filtration</td>
<td>Yes</td>
<td>50</td>
<td>Probable</td>
<td>Unfiltered water, potential point source discharge from sewage treatment works and farm drains and non-point discharge from grazing animals</td>
</tr>
<tr>
<td>Jul 1992</td>
<td>Lowland river with direct abstraction, separation process and bankside infiltration with no filtration</td>
<td>No</td>
<td>108</td>
<td>Probable</td>
<td>Possible link with groundwater turbidity</td>
</tr>
<tr>
<td>Nov 1992</td>
<td>Upland reservoir and surface water supplying aqueduct, slow sand filtration</td>
<td>Yes</td>
<td>125</td>
<td>Strong</td>
<td>Heavy rainfall in the catchment, high raw water turbidity, increase in treated water turbidity</td>
</tr>
<tr>
<td>Nov 1992</td>
<td>Groundwater, no filtration</td>
<td>No</td>
<td>47</td>
<td>Probable</td>
<td>Outbreak probably caused by faecal contamination from cattle housed adjacent to the well head</td>
</tr>
<tr>
<td>Apr 1993</td>
<td>Stream source, no filtration</td>
<td>Yes</td>
<td>3</td>
<td>Probable</td>
<td>Inadequate treatment, source open to potential animal contamination</td>
</tr>
<tr>
<td>Apr 1993</td>
<td>Groundwater from fissured strata, no filtration</td>
<td>No</td>
<td>40</td>
<td>Probable</td>
<td>Outbreak possibly caused by rapid recharge of surface water contaminated with oocysts</td>
</tr>
</tbody>
</table>
### Table 3.1: UK outbreaks of cryptosporidiosis associated with public drinking water supplies April 1988 – April 1998 (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Source/treatment characteristics (all water received normal chlorine based disinfection)</th>
<th>Cryptosporidium oocysts detected in treated water</th>
<th>Approximate number of cases of cryptosporidiosis</th>
<th>Association with water</th>
<th>Conclusions/comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apr 1993</td>
<td>Upland reservoir, no filtration</td>
<td>No</td>
<td>48</td>
<td>Probable</td>
<td>Possible run-off from grazing, very heavy rainfall</td>
</tr>
<tr>
<td>Jun 1993</td>
<td>Upland reservoir and surface water supplying aqueduct, slow sand filtration</td>
<td>No</td>
<td>97</td>
<td>Probable</td>
<td>Outbreak caused by poor operating practices and excessive head on the filters</td>
</tr>
<tr>
<td>Jun 1994</td>
<td>Spring fed natural impoundment, upflow filtration</td>
<td>No</td>
<td>8</td>
<td>Probable</td>
<td>Possible animal waste contamination following heavy rain</td>
</tr>
<tr>
<td>Feb 1995</td>
<td>Spring supply, no filtration</td>
<td>No</td>
<td>40</td>
<td>Strong</td>
<td>Heavy rain washed in waste animal material</td>
</tr>
<tr>
<td>Aug 1995</td>
<td>Lowland river with direct abstraction, separation process and bankside infiltration with no filtration</td>
<td>Yes</td>
<td>575</td>
<td>Strong</td>
<td>Plant operating above design output, evidence of turbidity peaks in the bankside infiltration water</td>
</tr>
<tr>
<td>Jan 1996</td>
<td>Lowland river with coagulation and filtration</td>
<td>Yes</td>
<td>126</td>
<td>Strong</td>
<td>Outbreak occurred when works was under strain with excess flow causing solids breakthrough</td>
</tr>
<tr>
<td>Mar 1996</td>
<td>Surface water with bankside storage, rapid gravity filtration, no coagulant</td>
<td>No</td>
<td>20</td>
<td>Probable</td>
<td>Outbreak caused by breakthrough of solids as a result of inadequate treatment during an algal bloom</td>
</tr>
<tr>
<td>Apr 1996</td>
<td>Lowland river with full treatment</td>
<td>No</td>
<td>80</td>
<td>Probable</td>
<td>Probable association with water but no evidence of plant operation problems</td>
</tr>
<tr>
<td>Feb 1997</td>
<td>Groundwater from fissured strata, no filtration</td>
<td>Yes</td>
<td>345</td>
<td>Probable</td>
<td>Outbreak caused by infiltration of surface water containing oocysts</td>
</tr>
<tr>
<td>Feb 1997</td>
<td>Lowland river, coagulation and filtration</td>
<td>No</td>
<td>22</td>
<td>Probable</td>
<td>Outbreak possibly associated with turbidity peak in filtered water</td>
</tr>
<tr>
<td>May 1997</td>
<td>Spring supply, partial filtration</td>
<td>No</td>
<td>34</td>
<td>Possible</td>
<td>Possible run-off from spring grazing</td>
</tr>
<tr>
<td>Apr 1998</td>
<td>Surface water, no filtration</td>
<td>Yes</td>
<td>303</td>
<td>Possible</td>
<td>Unfiltered water, potential point source discharge from sewage treatment works and farm drains and non-point discharge from grazing animals</td>
</tr>
</tbody>
</table>

1 The definitions of strong, probable and possible association with water are given in Tillet et al (1998).
4 Personal communication from Expert Group Secretariat.
5 Conclusions and comments are those of the Drinking Water Inspectorate, health authorities, SCIEH, DWI NI or water utilities.

3.1.6 The Group considers that the circumstances of these incidents do not alter the conclusion from the previous Expert Group reports (Badenoch 1990; 1995) that well operated appropriate conventional water treatment plants using processes designed for removal of particulate material minimise the risk of Cryptosporidium contaminating drinking water supplies. However, in the light of its assessment of incidents the Group has a number of recommendations. These are listed in Chapter 5, Advice to Water Utilities.
3.1.7 The Drinking Water Inspectorate (DWI) has published reports on four incidents in England where public drinking water supplies were associated with outbreaks of cryptosporidiosis (DWI 1993; 1997a; 1997b; 1998). One of these incidents is considered in the next section.

3.2 Cryptosporidiosis in north west London and Hertfordshire, spring 1997

3.2.1 The outbreak of cryptosporidiosis in north west London and Hertfordshire, in early spring 1997, with 345 confirmed cases, which was associated with drinking water derived from underground strata was one of the main reasons for re-convening the Expert Group. The DWI assessment of the incident was published in June 1998 (DWI 1998). It made recommendations specifically to the water utility involved on matters concerned with water quality monitoring, emergency procedures, risk assessment of groundwater sources, and implementation of recommendations contained in the two Reports of the Expert Group on Cryptosporidium in Water Supplies. It also made recommendations to all water utilities on matters concerned with risk assessment of groundwater sources and water quality monitoring; and to the Incident Management Team on matters associated with communications. The Group was concerned to note that it was necessary for the DWI report to refer to implementation of the recommendations from the two previous Expert Group reports. As most of these recommendations are still sound and relevant the Group recommends that all water utilities review their implementation of the Badenoch recommendations. The main Badenoch recommendations are listed in Appendix A1.

3.2.2 The DWI assessment of the north west London and Hertfordshire incident concluded that there were lessons to be learnt for all water utilities. It recommended that all water utilities:

(i) carry out risk assessments of groundwater sources to identify vulnerable sources requiring more rigorous surveillance;

(ii) consider the routine use of tracer tests as a measure of groundwater source vulnerability to pollution, especially those sources identified by risk assessment as most susceptible;

(iii) increase surveillance of shaft and adit chalk water sources vulnerable to fast infiltration of recharge; and

(iv) review their operational sampling programmes and establish where none exists or where the programme is shown to be deficient, a regular sampling and analytical programme for all separate sources of raw water.

3.2.3 The DWI report also recommended that a national survey of shaft and adit systems be undertaken to provide a better understanding of such systems, especially in chalk aquifers.

3.2.4 The Expert Group endorses these recommendations to water utilities as part of their risk assessment programme.
3.3 Identifying and reporting the potential presence of oocysts in drinking water

3.3.1 The Group considers that there are four broad ways that a water utility could become aware of oocysts in the water supply. It notes that there are differences in the way this information would be handled in England and Wales, Scotland and Northern Ireland.

3.3.2 Water utility detects oocysts in a sample of treated water. In England and Wales and Northern Ireland the laboratory would normally notify the local operations manager or scientist. Further investigations would be made and the local authority environmental health department and local health authority Consultant in Communicable Disease Control (CCDC) or equivalent should be informed in accordance with locally agreed arrangements for notification. In Scotland, notification within the utility is the same but the local authority, Consultant in Public Health Medicine (CPHM) and the Scottish Office are informed.

Recommendations

3.3.3 The Group recommends that the water utility should investigate immediately when oocysts are detected in raw water to establish if any circumstances exist to allow Cryptosporidium to enter water supplies. Investigations should include review of recent treatment plant operational data.

3.3.4 The water utility should develop local liaison arrangements with the local authority and health authority for rapid appraisal of the potential health risk, particularly when oocysts are detected in final water or in distribution.

3.3.5 Water utility detects a change of operational circumstance which potentially risks oocysts contaminating drinking water supplies. Water utility response is essentially the same in England and Wales, Scotland and Northern Ireland with investigation by a treatment specialist or local operations manager. The most crucial step however, is early recognition and interpretation of the change of operational circumstance by a plant operative or local manager.

Recommendation

3.3.6 The Group recommends that water utilities should ensure that employees operating assets producing drinking water are aware of the types of circumstance which can potentially put water supplies at risk of Cryptosporidium contamination. Procedures should be in place to ensure rapid recognition and appraisal of risks associated with any relevant change in operational circumstance.

3.3.7 Local health authority gets notification of an increase in stools containing Cryptosporidium oocysts. There are important differences in reporting practice between England and Wales and Northern Ireland and Scotland. In Scotland details on every positive stool are sent by most CPHMs to the water utility for it to provide information on water supply source and treatment plant. The CPHM then collates these reports and comes to a view if there is evidence of a water-related clustering of cases. In England and Wales and Northern Ireland, the CCDC receives stool notification but rarely contacts the water utility immediately unless there is evidence accumulating to indicate clustering or patterns above expected background rates. Only when the CCDC is concerned about clusters or higher frequencies of isolation will the water utility be routinely asked to provide details of the water supply to each case. Ready availability to the CCDC/CPHM of local water supply zone maps will aid cluster identification.
3.3.8 The Group is anxious to avoid over or under reaction by health authorities and to not recommend a burdensome administrative process.

**Recommendation**

3.3.9 The Group recommends that water utilities should provide copies of water supply zone maps to CCDCs/CPHMs or their equivalent and health authorities should make early contact with the local water utility if an outbreak of cryptosporidiosis is suspected.

3.3.10 The national disease surveillance centre is the first to detect a cluster of cases. It is possible for the Centre for Disease Surveillance and Control (CDSC) for England and Wales and the Scottish Centre for Infection and Environmental Health (SCIEH), to establish case clustering when epidemiological data are pooled from each health authority area. It is usual for both centres to report findings to the local medical officer rather than directly to a water utility. The Group is aware that case reporting rates to CDSC and to SCIEH differ because cryptosporidiosis is a laboratory reportable disease in Scotland, but these centres routinely monitor outbreaks. For that reason, these centres do have a role to play in making drinking water safer. The national centres are able to show, over time, areas where there are higher than average rates of cryptosporidiosis incidence. However, in England and Wales, any attempt to link with water supplies is presently constrained, as cases are not coded by postcode. This makes integration of case locations into utility Geographic Information Systems (GIS) time consuming and inaccurate.

**Recommendations**

3.3.11 Human cryptosporidiosis should be made a laboratory reportable disease in England and Wales and consideration should be given to making the disease notifiable. This should provide earlier identification of increased incidence of cryptosporidiosis and greater consistency in case reporting and recording.

3.3.12 The Group recommends that, wherever possible, health authorities should make postcodes of cases of human cryptosporidiosis available to water utilities to help both organisations identify as early as possible if particular water sources are involved and to allow regional trends to be assessed.

3.4 Risk assessment

3.4.1 Research has highlighted the ability of oocysts of *Cryptosporidium* to survive in the aquatic environment and their tolerance of the disinfection process used in conventional water treatment. A consequence of this resistance to disinfection is that oocysts of *Cryptosporidium* can still be present when coliform bacteria, the traditional indicators of drinking water quality, have been inactivated.

3.4.2 To try and ensure freedom from risk of *Cryptosporidium*, other control strategies have had to be considered. Waterborne outbreaks occur even though oocysts cannot be detected in the water. This supports the general view that the ‘contamination’ occurs for only a few hours during which time it would be complete chance that routine samples coincided with the event. Random spot sampling is, therefore, unlikely to be effective for operational monitoring and a recommendation on continuous sampling or sampling triggered by turbidity events is made at 5.4.9. However, risk assessment, as recommended in the previous Expert Group reports (Badenoch 1990; 1995) has become an accepted strategy for the water industry.
3.4.3 Water utilities are now expected to make an assessment of the risk of contamination by oocysts for all water abstractions, including springs and groundwaters. If they judge there is a significant or unacceptable risk of contamination, utilities are expected to make an assessment of the effectiveness of the installed treatment in removing oocysts and the risk of an oocyst being present in the water supply. Utilities should review the assessments from time to time, particularly when there is a change in circumstances potentially affecting the risk.

3.4.4 Such assessments are not intended to predict *Cryptosporidium* outbreaks but they can highlight where they are most likely to occur. Changes in catchments and at treatment works can have significant affects on risk and it is important that these are reported and incorporated into assessments at regular reviews. Treatment works staff should be trained to be aware of the potential effect on the final water quality of even very small changes in the catchment or the treatment stream.

3.4.5 Risk assessment for water catchments and treatment works should cover anything in the catchment area that has the potential to allow *Cryptosporidium* into raw water. At the treatment works it should cover any factors which do not present a barrier to *Cryptosporidium*, or could contribute to *Cryptosporidium* breaking through filters, or which do not alert staff to filter breakthrough. Areas for consideration include the following.

### The type of water source
- groundwaters and the likelihood of surface water influence
- security of underground springs
- surface water with direct abstraction or short duration storage facilities
- reservoirs and storage time
- river gravels

### Agricultural activity in the catchment
- slurry and dung spreading
- sludge to land spreading
- slurry and dung stores
- abattoirs or livestock markets with land drainage

### Animals in the catchment
- waste from animal housing
- cattle
- sheep
- deer herds
- pig farms
- wild animals
- birds (high numbers, wild or farmed)*

(*Probably only a source of *Cryptosporidium baileyi*)
Sewage contamination of the raw water

- sewage works
- septic tanks and cess pits
- storm water outlets

Water treatment factors

- full physical-chemical treatment
- partial physical-chemical treatment
- disinfection only
- is treatment process not used fully on every occasion
- is process known to be problematic
- does filter flow change suddenly
- is there a significant increase in turbidity before or after filter wash
- are there significant blips in turbidity during treatment runs
- are there signs of significant media loss or severe cracks in filter surface
- is backwash and/or sludge supernatant water recycled
- are turbidity meters on individual filters
- is turbidity alarm based on individual works performance
- are turbidity meters connected to alarm systems.

3.4.6 Microbiological risk assessment (MRA) is an emerging methodology to predict the risks to drinking water consumers from small numbers of pathogens breaking through into drinking water supplies. MRA models work by assessing the daily pathogen exposures to drinking water consumers and then translating those exposures into a risk by way of a dose-response curve. Limited dose-response data from human volunteer studies are available for *C. parvum* (DuPont *et al* 1995).

3.4.7 Current MRA models assume that pathogens are randomly distributed within the drinking water supply and therefore exposures to pathogens through drinking water is modelled by the Poisson distribution. There is considerable evidence however that bacteria are heterogeneously distributed in the drinking water supply and that treatment will cause clustering to occur. Intensive sampling studies using aerobic bacterial spores have shown that drinking water treatment removed 94–98% of spores but increased the clustering of those remaining. It is possible that oocysts are similarly affected. Through clustering a small proportion of consumers could be exposed to high doses through drinking water and models which do not consider rare high count of oocysts in samples could cause risk to human health to be underestimated (DETR 1998).

3.4.8 For these reasons the Group concludes that risk assessment should be based on a combination of factors including the degree of exposure of the catchment to oocysts, the treatment processes currently in place and the history of cryptosporidiosis in the community. Monitoring systems and water treatment requirements should be reviewed against the level of risk.


