Report of
Waterborne Cryptosporidiosis Subcommittee of the Scientific Advisory Committee

November 2004

ISBN: 0-9540177-6-5

TABLE OF CONTENTS

Membership of the Subcommittee

Name	Title	Organisation
Dr Bartley Cryan	Consultant in Medical Microbiology	Irish Society of Clinical Microbiologists
Ms Fiona Doyle	Infection Control Clinical Nurse Manager	Infection Control Nurses Association Replaced Lenora Leonard, November 2001 – June 2002, June 2004 to date
Dr Geraldine Duffy	Principal Research Officer	The National Food Centre Teagasc
Mr Oliver Fogarty	Senior Adviser	Dept. of Environment, Heritage and Local Government
Dr Tessa Greally	Specialist in Public Health Medicine	Faculty of Public Health Medicine, RCPI
Dr Lorraine Hickey	Medical Officer	National Disease Surveillance Centre. Replaced Tom O'Connell, July 2001
Dr Mary Horgan	Consultant in Infectious Diseases	Royal College of Physicians in Ireland
Dr Derval Igoe (Chair)	Specialist in Public Health Medicine	National Disease Surveillance Centre
Ms Lenora Leonard	Infection Control Clinical Nurse Specialist	Infection Control Nurses Association
Mr Tom McCarthy	Principal Environmental Health Officer	Environmental Health Officers Association Left in April 2002
Mr Gavin McDonnell	Principal Environmental Health Officer	Environmental Health Officers Association. Replaced Tom McCarthy, April 2002
Dr Anthony McNally	Senior Executive Scientific Officer	Dublin City Council
Mr John Mulcahy	Senior Water Engineer	Fingal County Council
Dr Tom O'Connell	Specialist Registrar in Public Health Medicine	National Disease Surveillance Centre Left in July 2001
Mr Brendan O'Reilly	Senior Medical Laboratory Scientist	Academy of Medical Laboratory Science

Foreword

Cryptosporidiosis is an important and common cause of human diarrhoeal illness, particularly in those who are immunocompromised. It can be transmitted via water that is contaminated with human or animal faeces. This report aims to inform and advise on the risk to public health from the detection of *Cryptosporidium* in drinking water and water used for recreational purposes; on what should be done to prevent water contamination with *Cryptosporidium*; and to provide public health guidelines on how to manage the situation when it is detected in water.

Although there have been many large-scale outbreaks of waterborne cryptosporidiosis associated with serious disease worldwide, assessing the risk to public health from detection of *Cryptosporidium* in water is complex. There are limits to our ability to detect *Cryptosporidium* in water and to assess its viability. In addition, the presence of *Cryptosporidium* in water does not invariably lead to human illness. As no threshold level of *Cryptosporidium* in water reliably predicts the likelihood of human illness, the report sets out factors that help interpret the significance of finding oocysts. The report recommends the establishment of local liaison groups, in which public health and local authorities work together well in advance of any incidents occurring.

Up to recently, information on the burden of illness due to *Cryptosporidium* was limited. However, in January 2004 cryptosporidiosis was made a notifiable disease, and laboratories are now required to notify all cases that they identify. Over time the pattern of illness due to cryptosporidiosis is becoming apparent, with a higher age-specific incidence in the young. There is a need however, for reference laboratory facilities for typing of *Cryptosporidium*. This would be a great resource for those dealing with water incidents and waterborne cryptosporidiosis outbreaks.

Prevention of cryptosporidiosis can be achieved if all providers of water for human consumption assess the risks posed using standard methods (the Scottish risk assessment model adapted by the Environmental Protection Agency for use in Ireland is recommended) and act on the findings to reduce the risk of contamination. To effectively remove or inactivate *Cryptosporidium* from water, liquid solid separation or inactivation technologies are needed.

This report recognises the complementary roles of policy makers, local authorities, health boards, clinicians and industry in ensuring the safety of drinking and recreational water. It also recognises the need for further research particularly in viability of oocysts detected in water, as this would allow for better prediction of the likelihood of human illness.

I would like to take this opportunity to thank the members of the committee for their very valuable contributions to the report, and to acknowledge the work and commitment of Dr Lorraine Hickey, in producing this report. As this is a rapidly evolving area, it is intended that these guidelines will be reviewed within two years.

Dr Derval Igoe
Chairperson of the Waterborne Cryptosporidiosis Subcommittee
November 2004

Summary of Recommendations

This subcommittee recognises the potential for serious disease and large-scale outbreaks due to waterborne cryptosporidiosis and the need for national guidelines to detect and prevent its occurrence. In making our recommendations we have taken into account the recent changes in the infectious disease regulations, Infectious Disease (Amendment) (No. 3) Regulations 2003, S.I. No. 707 of 2003, and the new water regulations, European Communities (Drinking Water) Regulations, 2000, S.I. 439 of 2000, which came into effect on 1st January 2004.

The responsibility for the provision of drinking water including its wholesomeness and cleanliness lies with the local authority. When human illness is linked to a water supply, the medical officer is responsible for investigating the source of infection, preventing its spread, and removing the conditions favourable to infection.

The following are the recommendations of the subcommittee:

Surveillance activities to detect and prevent waterborne cryptosporidiosis

- There should be a standardised policy for testing faecal samples for *Cryptosporidium.*
    - All faecal samples from symptomatic individuals should be tested for *Cryptosporidium* oocysts. However, if this is not possible e.g. due to lack of resources, we recommend that stool samples from symptomatic children less than 10 years should be screened, and consideration should be given to instituting routine testing of stools for *Cryptosporidium* oocysts in patients over 10 years of age if *Cryptosporidium* is detected with increased frequency in other stool samples in the laboratory.
- A national reference laboratory should be established for typing and provision of expert advice on *Cryptosporidium.* Typing of *Cryptosporidium* isolates should occur in outbreak situations and also in sporadic cases as this may help elucidate the source of infection.
- Information from surveillance of gastrointestinal illness in humans, including cryptosporidiosis, should be regularly shared with local authority colleagues on the local liaison groups.
- In assessing whether an outbreak is waterborne or not, the UK Public Health Laboratory Service guidelines on the association between human illness and water should be used (Appendix 2).
- In an outbreak situation, attack rates for cryptosporidiosis should be calculated for each water supply zone.
- Testing of water samples for *Cryptosporidium* should be undertaken in outbreak situations where there is epidemiological evidence which points towards drinking water as a likely source.

Health board and local authority response to detection of *Cryptosporidium* oocysts in water supplies

- Local liaison groups (LLGs), comprising representatives from the local authority and health board/authority, should be established **prior** to any incident occurring. The director of public health and the director of water services should initiate this process as a matter of urgency and devise a structure for liaison that is appropriate to their region. These LLGs already exist in some areas and are working well.

The function of the LLGs, acting as a support structure to the local authority in fulfilling its statutory obligations, should be as follows:

1. To support the local authority in fulfilling its statutory obligations with regard to local procedures for the monitoring of contamination of water, including contamination with *Cryptosporidium*.

2. To share information across agencies on trends in human gastro-intestinal illness and in cryptosporidiosis, and on the results of water quality sampling.

3. To provide access to maps and other information on water supply zones. The local authorities are using Geographic Information Systems (GIS) to map the public water supply schemes.

4. To identify and interpret locally the significance of deviations in water quality indicators such as turbidity.

5. To meet and review water anomalies, including the presence of *Cryptosporidium* oocysts in the water, and to advise on appropriate actions, using local knowledge.

6. To develop local incident response plans in the event of an incident and to agree joint working procedures.

7. To advise on when the medical officer (MO) should be notified.

8. To review results of risk assessments of water sources.

9. To look at the training needs of all personnel involved with the provision of potable water.

- As there is no internationally agreed threshold level of *Cryptosporidium* oocysts in water above which human illness is likely to occur, no threshold level is recommended in these guidelines.

- LLGs should use local knowledge to aid in interpretation of water quality indicator test results, including investigating whether the presence of *Cryptosporidium* oocysts in the water is linked to a cryptosporidial incident. The PHLS Advisory Committee on Water and the Environment has issued guidelines which should be considered when assessing the significance of detecting *Cryptosporidium* oocyst in water (Hunter, 2000).

The factors that influence whether an oocyst count is significant or not are:

- When and where the sample was taken.

- The number of oocysts detected per 10L of water and the results of any viability testing.

- The species or type of oocysts detected.

- The source and treatment of the affected water supply (groundwater/surface water/full chemical treatment/filtration only/no filtration).

- The distribution area of the water supply and size of the population supplied.

- Whether any problems with the supply, such as treatment failure or high turbidity, have been identified.

- High oocyst counts in consecutive samples.

- Whether there have been any recent changes in the source and/or treatment.

- The history of *Cryptosporidium* sampling for this supply and whether there have been similar detections in the past.

- How fast water travels through the distribution area (is it likely that any of the contaminated water is still in the distribution system).

- Whether waterborne outbreaks of cryptosporidiosis have been associated with the supply in the past.
- The level of immunity in the exposed population.

- Each local authority should have written protocols on what to do in the event of a cryptosporidial incident.
- When a cryptosporidial incident has occurred, the local authority should establish an incident response team (IRT).
- The medical officer, principal environmental health officer and other health board staff should be members of the IRT as appropriate.
- If there are any cases of illness linked to a cryptosporidial incident, then an outbreak control team should also be established by the medical officer, in the context of the infectious disease regulations, as per health board procedures.
- Each health board should have access to consultant microbiology advice.
- A National *Cryptosporidium* Expert Group should be established that would act as a resource for those involved in the management of incidents.

Prevention

Drinking water supplies

- The Scottish Risk Assessment model has been adapted by the Environmental Protection Agency (EPA) for use in Ireland by sanitary authorities. All providers of water for human consumption should be required to apply this risk assessment. These results should be made available to the LLGs. The recommendation on use of the Scottish Risk Assessment model is supported by the EPA in their recent handbook for sanitary authorities on implementation of the European Communities (Drinking Water) Regulations, 2000, S.I. 439 of 2000 (EPA, 2004).
- The risk assessment determines what action needs to be taken to minimise the risk. Sites that might be considered high-risk e.g. minimal treatment surface water supplies should be prioritised for risk assessment.
- Laboratory facilities for monitoring *Cryptosporidium* in water should be available regionally and nationally.
- A well-formulated and implemented catchment management plan can improve the level of protection from *Cryptosporidium* contamination. Existing legislation should be used to prevent contamination of source water.
- To effectively remove or inactivate *Cryptosporidium* from water, liquid solid separation or inactivation technologies are needed. These technologies should be used to treat surface water being used for drinking, given that chlorination is ineffective.

Swimming pools

- Consideration should be given to the introduction of a licensing system for swimming pool operators.
- The Environmental Health Officers Association policy document on health standards for swimming pools and other recreational pools in Ireland (EHOA, 2002) and the Pool Water

Treatment Advisory Group's guidelines for the UK, should be used as a guide for appropriate design and management of pools (PWTAG, 1999). The Morbidity and Mortality Weekly Report (MMWR) guidelines on cryptosporidiosis outbreak prevention and control are also recommended (CDC, 2001).

Immunocompromised individuals

- Physicians should make an individual assessment of a patient's risk of waterborne cryptosporidiosis, based on knowledge of the water supply that the individual is exposed to. The feasibility of this approach is dependent on the availability of information on sources of water supply for an individual and would rely on the risk assessment process.
- During outbreak situations, patients should be advised to boil water to eliminate *Cryptosporidium* spores.
- Patients should be advised on potential exposure risks and on ways of minimising risks associated with exposure.
- Patients should be aware that many lakes, rivers and some swimming pools might be contaminated with *Cryptosporidium*. They should avoid swimming in water that is likely to be contaminated, particularly during an outbreak.
- They should avoid drinking water directly from rivers and lakes.
- At risk patients should be provided with the information leaflet (Appendix 6).

Education

- Educational programmes are important means of preventing cryptosporidial infections. These programmes should be targeted at immunocompromised patients, the agricultural industry, local authority personnel, swimming pool and recreational water operators as well as the general public. Programmes should include information on the risks of cryptosporidial infection/contamination from various exposures and advice on avoiding or minimising the risks. Some initiatives already exist and are aimed at promoting good agricultural practice to protect water quality, e.g. the Nitrate Action Programme (DEHLG and Department of Agriculture and Food, 2003) and the code of Good Farming Practice (DAF, 2001).
- There should be initiatives to enforce the legislation on the proper disposal of animal waste and on the avoidance of run-off from agricultural land into potable water supplies.
- When new private water supplies are being proposed, owners should be made aware of the potential for water contamination and what can be done to reduce the risk.
- There should be initiatives to raise awareness of the Environmental Protection Agency (EPA) guidance manuals for the siting of on-site wastewater treatment systems for single houses, and for small communities, business, leisure centres and hotels (EPA, 2000 and 1999).

Research

Research should be undertaken to:

- Elucidate the prevalence, epidemiology and mode of transmission of *Cryptosporidium* in the Irish context.
- Improve tests to determine the viability and pathogenicity of oocysts isolated from the environment so that the degree of health risk posed by oocysts detected in drinking water can be better assessed.

Introduction

Cryptosporidium is a protozoan parasite that causes a diarrhoeal illness in humans known as cryptosporidiosis. It is especially common in AIDS patients and patients with other immune deficiency disorders. However, the illness can also occur in patients who are otherwise well.

Experience in other countries has forewarned us of the potential for serious disease and large-scale outbreaks. The largest documented outbreak involving public water supplies occurred in Milwaukee, USA, in 1993, where more than 400,000 people became ill and over 100 people died (Hoxie *et al*, 1997). Outbreaks have also been described in relation to swimming pools, well water, lake water and farm visits.

Because cryptosporidiosis has only recently been made a notifiable disease in Ireland, the burden of human cryptosporidial disease in this country is unknown. Two Irish studies on paediatric populations have shown that approximately 4% of acute diarrhoea in children is caused by cryptosporidiosis (Carson, 1989; Corbett-Feeney, 1987). Data from the Infoscan Laboratory Surveillance System, which covers three of the eight health boards/authorities and a population of approximately 1.2 million show that there are an average of 121 cases per annum of cryptosporidiosis, a rate of 10.1/100,000 population.

In 2000, the Department of Health and Children asked the National Disease Surveillance Centre to advise on the risk to public health from waterborne cryptosporidiosis, and on surveillance activities that should be undertaken. A subgroup of the Scientific Advisory Committee was established with the following terms of reference:

1. To advise on the risk to public health from *Cryptosporidium* in drinking water supplies and in water used for recreational purposes.

2. To advise on appropriate surveillance activities that should be undertaken to detect and prevent waterborne cryptosporidiosis.

3. To draw up national guidelines for the public health response to the detection of *Cryptosporidium* in water supplies.

4. To advise on prevention strategies that would minimise the risk in the general population, and in target groups such as immunocompromised individuals.

The subcommittee met on eight occasions, and prepared a draft paper for consultation. The consultation document was sent to interested parties and posted on the NDSC website for general consultation in August 2002. A number of submissions were received from interested parties (Appendix 7). The subcommittee met on a further three occasions to consider the submissions and prepare this final document. The subcommittee would like to thank all those who contributed to the preparation of this document.

Clinical Aspects of Cryptosporidiosis Infection

1.1 Introduction

Cryptosporidium is a protozoan parasite that is known to infect and reproduce in the epithelial cells lining the digestive and respiratory tracts of most vertebrates including fish, birds, reptiles and mammals. It was first discovered in the early part of the twentieth century but its importance was only realised in the 1970's by veterinary workers who discovered that it caused a diarrhoeal illness in cattle. In 1976, it was identified as the cause of the diarrhoeal illness in humans known as cryptosporidiosis. With the onset of the AIDS epidemic its true pathological potential was appreciated and it is now recognised as a common enteric pathogen throughout the world (Khan, 2001).

1.2 Pathogen

Cryptosporidium is one genus of the protozoan phylum Apicomplexa, class Sporozoasida, subclass Coccidiasina referred to as coccidians (Mandell *et al*, 2000). Although up to 23 *Cryptosporidium* species have been named, only eight are regarded as individual species based on biological characteristics (Kosek *et al*, 2001). Until recently *Cryptosporidium parvum* was thought to be a single species with two distinct genotypes – type 1 (human) and type 2 (bovine). Genotype 1 has now been reclassified as a separate species *C. hominis.* It is isolated almost exclusively from humans and is associated with human-to-human transmission. Type 2 (bovine), now known as *C. parvum*, is isolated from human and bovine hosts and other animals such as sheep and goats and is associated with animal-to-human transmission (Morgan-Ryan *et al*, 2002). As many studies quoted in this document were carried out using the traditional classification, in the rest of this report the term *C. parvum* refers to the original classification where two distinct genotypes are recognised – type 1 (human) and type 2 (bovine).

The life cycle of *Cryptosporidium* is completed within a single host. It cannot grow outside of an infected host. The parasite multiplies in the gastrointestinal tract and tiny oocysts, 4-6 microns in diameter, are shed in very large numbers. As a result, contamination of the environment can reach a very high level in a short period of time. The excreted oocyst is fully infectious and may excyst within the host intestinal tract thereby initiating another autoinfectious cycle. This may explain why a few oocysts can lead to severe disease and why persistent infection may develop in immunocompromised persons (Mandell *et al*, 2000).

Oocysts are quite resilient and can survive for long periods in a cool, wet environment. They are also resistant to routine chlorination. However, they are generally susceptible to freezing, desiccation and moderate heating. A study of the effect of pasteurisation on the infectivity of *C. parvum* oocysts in water and milk, found that conditions of commercial pasteurisation i.e. 71.7°C for 15 seconds, are sufficient to destroy the infectivity of *C. parvum* oocysts (Harp *et al*, 1996).

1.3 Epidemiology

Cryptosporidiosis occurs throughout the world and in all age groups. In developed countries, *Cryptosporidium* is one of the most common causes of infective diarrhoea. A prospective study, conducted by the Public Health Laboratory Service in England and Wales, of 16,000 faecal specimens submitted for infective diarrhoea, found that *Cryptosporidium* was the third most common cause of infective diarrhoea (2.1% of cases) after *Salmonella* (3.3% of cases) and *Campylobacter* (7.6% of cases) (Meinhardt *et al*, 1996). The peak age of incidence was in children in the 1 to 5-year age group.

A study conducted in Cherry Orchard Hospital, Dublin, in 1987, found that 4% of admissions for gastroenteritis in children aged 14 years or younger were due to cryptosporidiosis (Carson, 1989). A similar study in Galway found *Cryptosporidium* in 4.3% of stool samples from children with acute diarrhoea (Corbett-Feeney, 1987).

Prior to the introduction of highly active anti-retroviral therapy (HAART), approximately 10% to 20% of AIDS patients developed cryptosporidiosis during the course of their illness. Once acquired, the infection usually persisted throughout the illness (Chin, 2000).

The true prevalence of cryptosporidiosis infection is not known as most countries do not have an active surveillance system for cryptosporidiosis and many laboratories do not routinely test faecal samples for *Cryptosporidium* oocysts.

1.4 Reservoir of infection

Cryptosporidium species have been found in humans, poultry and other birds, fish, reptiles, small mammals (rodents, cats, dogs) and large mammals (particularly cattle and sheep). It is predominately a parasite of neonatal animals, although older animals occasionally develop infections which are usually mild. Humans, on the other hand, can be infected at any age and previous exposure tends to confer only partial immunity to subsequent infection (Fayer, 1997).

In Ireland, cryptosporidiosis in animals is not notifiable and therefore the prevalence of the disease in animals is not known. A study conducted over a 6-year period on a lowland farm in the UK, found that *Cryptosporidium* was endemic in livestock and small wild animals (Sturdee *et al*, 2003). The cumulative 6-year prevalence for *C. parvum* were between 3-4% for cattle, 23-52% for calves depending on whether they were bought-in or home bred and around 30% for small wild mammals. The animal categories with the highest prevalence also shed the highest number of oocysts per gram of faeces. *Cryptosporidium* prevalence was highest in the autumn in all animal categories.

1.5 Transmission

Cryptosporidiosis is transmitted by the faecal-oral route, which includes person-to-person, animal-to-person, waterborne, foodborne and possibly airborne transmission. Person-to-person transmission has been described, particularly in day care and healthcare settings. Food has the potential to become contaminated with faeces from infected persons or animals. Uncooked food washed with contaminated water is another possible source of infection. Waterborne transmission accounts for a proportion of infections in travellers and for common-source epidemics.

The absence of routine genotyping in diagnosed cases of human cryptosporidiosis hampers attempts to apportion the burden of human disease between anthroponotic (human-to-human) and potentially zoonotic (animal-to-human) transmission cycles. However, in recent years useful evidence has begun to accumulate.

A geographic distribution for cryptosporidial infections has been found in some studies with *C. parvum* type 2 (bovine) responsible for more human infections in Europe than type 1 (human), and type 1 infections more common in the US, Australia, Thailand, South Africa and Kenya. However, the significance of these findings is not certain, as only a small number of isolates have been analysed in most studies (Alves *et al,* 2003).

A study of 1,705 faecal samples from humans and 105 from livestock animals in the UK reported that genotype 1 was detected in 37.8% of the samples from humans, genotype 2 was detected in 61.5%, a third genotype designated genotype 3 (*C. meleagridis*) was detected in 0.3%, and both genotypes 1 and 2 were recovered from 0.4% of samples. All samples from livestock yielded genotype 2. Of eight drinking water-related outbreaks, five were predominately due to genotype 1, one was due to genotype 2, and two involved both genotype 1 and 2. There were five outbreaks associated with swimming pools, two were due to genotype 1, one was due to genotype 2 and two involved genotype 1 and 2. Of 26 family outbreaks and one in a crèche, 13 were due to genotype 1 and 14 were due to genotype 2. Genotype 1 was isolated from one of 18 patients who had reported contact with animals and/or farms and genotype 2 was isolated from the remainder. A geographical and temporal variation in the distribution in the genotypes was observed among sporadic cases with a spring peak in cases due to genotype 2 and a late-summer-autumn peak in cases due to genotype 1. Genotype 1 was also more commonly associated with foreign travel (McLauchlin *et al*, 2000).

Fourteen outbreaks investigated in North America revealed that ten were caused by *C. parvum* human genotype and four were caused by the bovine genotype. Those caused by the bovine genotype occurred in rural areas mainly (Xiao *et al*, 2000).

Most outbreaks appear to be due to *C. parvum* human genotype even in geographic areas with a higher background transmission of the bovine genotype. It has been postulated that *C. parvum* human genotype is better adapted, and therefore more infective to humans. In one study, humans infected with *C. parvum* human genotype were found to excrete more oocysts and for a longer period than those infected with the bovine genotype (Xiao *et al*, 2000).

During the period of the foot and mouth (FMD) epidemic in the UK there was evidence of a change in the bimodal pattern of cryptosporidiosis infection with peaks in the spring and autumn. Genotyping of

specimens from 2000 and 2001 showed that most specimens submitted were of genotype 2 in the first half of the year whereas most were genotype 1 for the second half. During the FMD epidemic the proportion of genotype 2 isolates was lower than that for the same period in the previous year 2000. The results suggest that a decrease in genotype 2 infections in humans was associated with a decrease in human exposure to reservoirs of infection in livestock during the FMD epidemic (Smerdon *et al*, 2003).

1.6 Pathophysiology

Intestinal epithelial cells harbour the parasite in an intracellular, though extracytoplasmic, vacuole. The functional integrity of the brush border is destroyed with the subsequent loss of absorption surface leading to diarrhoea and fluid loss. The distribution of infection can be patchy within the principal site of infection, the small bowel. In some cases, *Cryptosporidium* is found in the pharynx, stomach, and large bowel. It has also been recovered from the respiratory tract, although the pathogenicity of the infection for human respiratory epithelium has not been determined. Involvement of the biliary tract can cause papillary stenosis, sclerosing cholangitis, or cholecystitis.

1.7 Clinical features

Asymptomatic infections can occur in both immunocompetent and immunocompromised hosts. In immunocompetent persons, symptoms develop after an incubation period of between 1-12 days with an average of about 7 days and consist principally of watery non-bloody diarrhoea, at times in conjunction with abdominal pain. Nausea, anorexia, fever, and/or weight loss are less common features. The severity of the illness varies considerably from one individual to another and in one patient from one day to another. Symptoms usually subside after 1 to 2 weeks but excretion of oocysts can persist for several weeks after clinical symptoms have subsided. Asymptomatic shedding of oocysts can occur.

In immunocompromised hosts, especially those with AIDS, diarrhoea can be chronic and persistent, causing clinically significant fluid and electrolyte depletion. Weight loss, wasting, and abdominal pain may be severe. Biliary tract involvement can manifest as mid-epigastric or right upper quadrant pain.

Cryptosporidium species would appear to rarely exhibit absolute true host specificity, and rather exhibit a range of host interactions. Many species would appear to be most frequently isolated from certain species of animal, but capable of causing disease in other species particularly if the host is immunocompromised. It was originally thought that *C. parvum* was the only species to infect humans. However, more recent studies have shown that *C. felis* and *C. meleagridis* can infect immunocompromised individuals (Morgan U *et al*, 2000).

Many aspects of cryptosporidiosis in farmed animals mirror human disease. Neonatal animals develop anorexia and profuse watery diarrhoea, with potential for dehydration and death in untreated cases. Probability, severity, and duration of disease are greatly influenced by concurrent infections with other enteropathogens, or immunosuppression. Cryptosporidiosis is the only major cause of diarrhoea in farm animals which lacks both a specific vaccine or anti-infective therapy. Chronic ill-thrift and poor growth rates are relevant long-term problems in food animals.

1.8 Treatment

Until recently, no chemotherapeutic agents effective against *Cryptosporidium* had been identified. However, a recent study in Zambia found that nitazoxanide had a significant effect on the resolution of diarrhoea, eradication of oocysts from the stools and mortality in HIV-seronegative children with cryptosporidiosis but not on those who were HIV-seropositive (Amadi, 2002). Treatment includes supportive care with replacement of fluids and electrolytes and administration of anti-diarrhoeal agents. Biliary tract obstruction may require surgical intervention. Prevention requires minimising exposure to infectious oocysts in human or animal faeces.

The Laboratory Diagnosis of Human Cryptosporidiosis and Detection of *Cryptosporidium* in Water

2.1 Diagnostic methods

A variety of techniques have been developed to identify *C. parvum* oocysts in faeces, sputum and bile (Current and Garcia 1991, O'Donoghue 1995). For the diagnosis of cryptosporidiosis, stool and other body fluid specimens should be submitted as fresh material or in 10% formalin or sodium acetate-acetic acid-formalin (SAF) preservatives.

2.2 Histopathology

The diagnosis of *Cryptosporidium* in stool specimens depends upon the identification of the 4-6mm spherical oocysts (or oocyst components) in stool or on the intracellular stages within biopsy specimens of human gastrointestinal mucosa (Clark 1999).

In haematoxylin and eosin-stained sections, developmental stages of the parasite appear as small, spherical, basophilic bodies (2-5 μm depending on the stage of the life cycle) within the microvillous region of the intestinal mucosa. Transmission electron microscopy can be used to confirm diagnosis and reveals distinct life cycle forms, each within a parasitophorous vacuole confined to the microvillous region of the host cell.

2.3 Concentration methods

Stool concentration techniques that are useful for identification of *C. parvum* oocysts include flotation of oocysts in Sheather's sugar solution, in zinc sulphate (specific gravity 1.18 or 1.2) or in saturated sodium chloride (specific gravity 1.27). Stool concentration techniques using sedimentation include formalin-ether and formalin-ethyl acetate. If one is using concentration methods to look for *C. parvum* oocysts in stool or other body fluid samples, it is advisable to centrifuge at >500 x g for at least 10 min.

2.4 Staining in stool specimens

Staining for *Cryptosporidia* in stool is a particularly effective means of diagnosing human cryptosporidiosis, as the entire bowel is sampled in this way - as opposed to tissue biopsy (Kao and Ungar 1994). Auramine-rhodamine staining of stool sediment smears followed by modified Ziehl-Nielsen (acid-fast) confirmatory staining is a sensitive and specific approach for the identification of *Cryptosporidium* oocysts in stool (MacPherson and McQueen 1993). The UK PHLS standard operating procedures for the laboratory diagnosis of cryptosporidial infection are detailed in Appendix 1.

2.5 Immunoassay of stool specimens

This method offers increased sensitivity and specificity compared to staining techniques. There are a number of immunoassays available for the detection of *Cryptosporidium* species. They include immunofluorescence (IFA) methods and enzyme immunoassays (EIA). Immunofluorescent methods may have the advantage of being less expensive and less labour-intensive than EIA (Kehl *et al* 1995). One paper describes a flow cytometry method whereby the oocysts are fluorescently labelled and counted in a flow cytometer. This proved to be more sensitive than direct immunofluorescent assay of seeded stool specimens (Valdez *et al* 1997).

2.6 Molecular detection methods

A number of methods for PCR-based detection of *Cryptosporidium* in clinical samples and drinking water have been reviewed (Clark 1999, Fricker and Crabb 1998, Morgan and Thompson 1998, Widmer 1998). Many authors have described PCR-based detection but no large comparative study has been performed to determine the ideal primers, PCR conditions or stool extraction methods to use with clinical samples (Clark 1999).

2.7 Detection of *Cryptosporidium* in water supplies

The detection of *Cryptosporidium* oocysts in water is problematical. This is due to the small size of the oocysts (4 – 6µm), their relatively low concentration in most environmental waters, and the difficulties in separating them from other abundant particles of similar size. A large variety of methodologies have been researched, and an extensive literature exists. Not all methods are suitable for routine monitoring purposes, and they differ substantially in their efficiency of oocyst isolation and enumeration. Water quality also influences recoveries. It is essential therefore that methodology be standardised to allow for accurate and comparable interpretation of results.

In conjunction with recently implemented legislation in the US and the UK, approved methodologies for sampling and detection of *Cryptosporidium* oocysts in water have been published. These are:

- USEPA Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA (EPA-821-R-99-006), April 1999.
- Drinking Water Inspectorate. Standard Operating Protocol for the Monitoring of *Cryptosporidium* oocysts in treated water supplies to satisfy Water Supply (Water Quality) (Amendment) Regulations 1999, SI No. 1524. June 1999.

In both methods oocysts are concentrated from the water by filtration. In the case of Method 1623, 10L bulk samples of water are submitted to the analysing laboratory for filtration in-house. The DWI Method stipulates continuous sampling on-site at a rate of 1L per minute over 24 hours through an approved sampling device. Filters used in this initial concentration step have a nominal pore size of 1.0µm. Captured oocysts are eluted from the filter matrix by washing with an aqueous buffered salt and detergent solution. Any oocysts in these washings are further concentrated by centrifugation.

The oocysts are then separated from other particulates using immunomagnetic bead separation (IMS). IMS involves magnetising the oocysts by attachment of magnetic beads conjugated to anti-*Cryptosporidium* monoclonal antibodies. A magnet retains the magnetised oocysts while the extraneous debris is washed away. The magnetic bead complex is then detached from the oocysts.

The oocysts are fixed on microscope slides and stained with fluorescently (FITC) labelled monoclonal antibodies and a fluorogenic vital dye (DAPI). The slides are scanned using epifluorescence microscopy for brilliant apple-green fluorescing, slightly ovoid or spherical objects 4 to 6 µm in diameter. Such objects are confirmed as *Cryptosporidium* oocysts by further examination using DAPI and Differential Interference Contrast (DIC) microscopy.

2.8 Viability assays

The above methods identify and enumerate *Cryptosporidium* oocysts in water but will not identify the species or genotype of *Cryptosporidium* isolated. DAPI and DIC microscopy cannot reliably determine the viability or infectivity of oocysts. Empty or excysted oocysts are not viable, and can be flagged as such in the scanning process. Current practice is to count such oocysts since their presence may indicate that water treatment has been compromised and a potential threat exists. This precautionary approach underlies water monitoring, and less importance is placed on the viability of individual oocysts.

Viability of oocysts has been assessed using a number of techniques including infectivity, excystation and dye inclusion tests. Infectivity and *in vitro* excystation testing is not feasible with the small number of oocysts generally encountered in environmental samples. Viability staining of nucleic acids in *C. parvum* oocysts, inactivated by heat and chemical agents, has shown that viability was related to infectivity for mice, but not to *in vitro* excystation.

The inclusion or exclusion of fluorogenic dyes has been used to assess the viability of oocysts detected in environmental samples by the methods outlined at 2.7 above. Live oocysts will include DAPI (4', 6-diamidino-2-phenylindole) into the nuclei of the four contained sporozoites, but will exclude PI (Propidium Iodide). Dead oocysts will include both PI and DAPI. It has been found that this DAPI-PI assay overestimates the viability of oocysts exposed to chemical disinfectants used in water treatment.

In Ireland, fluorogenic dyes (including DAPI), are used in conjunction with phase and DIC microscopy, to help confirm the identification of oocysts, and not as viability assays.

2.9 Current laboratory screening policies in the UK

Following the Badenoch Report's recommendation that laboratory policies for examining faecal samples for *Cryptosporidium* should be reviewed and standardised, a working group was set up in the UK to consider criteria for screening faecal samples for *Cryptosporidium* oocysts (Casemore and Roberts, 1993). They recognised that *Cryptosporidia* were an important cause of gastroenteritis in both immunocompromised and immunocompetent individuals. In a survey carried out by the PHLS, of stool samples examined for cryptosporidial oocysts, 60% of those which were positive occurred in children up to 15 years of age, and 90% of the positive results were found in people up to 44 years of age. They also recognised that that clinical diagnostic screening and reporting practices varied between different laboratories, which led to difficulties in interpreting reported figures.

They proposed that all diagnostic stool specimens should be screened for *Cryptosporidium* oocysts. If this was not feasible then all specimens from patients under 45 years should be tested, but at an absolute minimum, specimens from children aged 15 years or younger should be screened. Internal and external quality assurance was essential to accurately identify the organism implicated in individual cases of disease and outbreaks. They also recommended that all positive results should be reported to the Public Health Laboratory Service Communicable Disease Surveillance Centre (PHLS CDSC).

Recent surveys in the different health authority regions of England and Wales have indicated that laboratory practices still vary in relation to testing for *Cryptosporidium* (Crook *et al*, 2002; Chalmers *et al*, 2002). Eighty one percent of laboratories serving Wales and the North West of England routinely screened all diagnostic stool specimens for *Cryptosporidium* while 19% applied selection criteria. In the Eastern region of England, 26% of laboratories tested all diagnostic stool specimens for *Cryptosporidium* and in the South East, 58% of laboratories tested these samples for *Crytosporidium*. In Wales and North West England, 88% of laboratories reported confirmed cases to the regional Communicable Disease Surveillance Centre and 94% reported them to the local authority environmental health department. The PHLS CDSC have reiterated that in order to improve surveillance the above guidelines should be implemented.

2.10 Current laboratory screening practice in Ireland

On the 1st January 2004 cryptosporidiosis became a notifiable disease in Ireland and laboratories are now required to report positive results. However, laboratory policies for examining stools are not standardised. A national survey of laboratory practice was carried out in 2000 and provided information on which laboratories test for cryptosporidiosis, what criteria were used to determine whether stool samples were examined, and what laboratory methods were used (NDSC, personal communication). Questionnaires were sent to 54 laboratories around the country. Thirty seven (68.5%) laboratories returned the questionnaire. Of these, 19 (51.4%) tested for cryptosporidiosis. The technique used was direct microscopy in 17 laboratories and two laboratories did not specify the method used. Thirty-two per cent had an age cut off for cryptosporidiosis testing, varying from <5 years to 16 years but some of these had additional criteria for testing such as watery diarrhoea, adults with persistent diarrhoea or where clinically indicated.

2.11 Conclusion

Methods of detection of *Cryptosporidium* in humans and in environmental water samples are developing but the determinants of cryptosporidiosis are more problematic. Screening practices in laboratories vary, making interpretation of reported cases difficult. Defining transmission routes is a key element in the management of cryptosporidiosis outbreaks where the development of laboratory techniques has been of great benefit. The effectiveness of these laboratory techniques is partially due to the genetic variation observed within the *Cryptosporidium* genus. Laboratory research can also improve our understanding of the mechanism by which *Cryptosporidium* causes disease in humans. Since the genomic DNA sequence encodes all of the heritable information responsible for the development, disease pathogenesis, virulence, species permissiveness, and immune resistance, a comprehensive knowledge of the *C. parvum* genome will provide the necessary information required for cost-effective and targeted research into disease prevention and treatment (Widmer *et al*, 2002). Current research is focusing on several areas including sequencing the genome of *C. parvum*.

The determination of oocyst viability is necessary in order to assess the public health significance of *Cryptosporidium* oocysts in water. Various viability assays have been developed. However, all have limitations in their use in routine environmental samples. The committee recommends that further research is undertaken to improve tests to determine the viability and pathogenicity of oocysts isolated from the environment so that the degree of health risk posed by oocysts detected in drinking water can be better assessed.

2.12 Recommendations

This subcommittee recommends that:

- There should be a standardised policy for testing faecal samples for *Cryptosporidium.*
    - All faecal samples from symptomatic individuals should be tested for *Cryptosporidium* oocysts. However, if this is not possible e.g. due to lack of resources, we recommend that stool samples from symptomatic children under 10 years of age should be screened.
- A national reference laboratory should also be available for typing of *Cryptosporidium* isolates.
- Typing of *Cryptosporidium* isolates should occur in outbreak situations.
- Research is undertaken to elucidate the prevalence, epidemiology and means of transmission of *Cryptosporidium* in the Irish context.
- There is also a need for research to improve tests to determine the viability and pathogenicity of oocysts isolated from the environment so that we can better assess the degree of health risk posed by oocysts detected in drinking water.
- Testing of water samples for *Cryptosporidium* should be undertaken in outbreak situations where there is epidemiological evidence which points towards drinking water as a likely source.

The Risk to Public Health from Waterborne *Cryptosporidium*

3.1 Introduction

Cyptosporidium can be transmitted via water that is contaminated with human or animal faeces. *Cryptosporidium* oocysts from human faeces can enter surface waters through wastewater, leaky septic tanks, or recreational activities, while oocysts from other mammals can enter surface waters either directly or through runoff. There have been a number of documented outbreaks of cryptosporidiosis attributed to potable water, well water, spring water and surface water (lakes, rivers, streams). Several outbreaks have also been associated with contaminated recreational water in swimming pools, amusement park wave pools and water slides. However, when *Cryptosporidium* is found in water, outbreaks of human illness do not invariably follow, and there is no internationally recognised threshold level of *Cryptosporidium* contamination of water that indicates that human illness is likely to develop.

3.2 Linking detection of *Cryptosporidium* in water to human illness

The actual risk to health from *Cryptosporidium* in water supplies is not known. It is probably related to both parasite characteristics, dose size and the immunity of those exposed (Meinhardt *et al*, 1996).

The viability of oocysts is difficult to determine and consequently it is difficult to establish a safe level of oocysts in water. *Cryptosporidium* oocysts are very resistant to most disinfectants, including chlorine used in water treatment. They can remain dormant in cool, moist conditions for long periods of time. However, they are susceptible to freezing, moderate heat and desiccation. Laboratory methods for determining viability are inadequate at present.

A study by Okhuysen *et al* found substantial variation in the infectivity of different *C. parvum* isolates given to healthy seronegative human volunteers. The differences were manifest in the duration of the incubation period, the infectious dose and the proportion of individuals showing symptoms (Okhuysen *et al*, 1999).

The virulence of particular species of *Cryptosporidium* that are known to infect humans may explain some of the clinical diversity observed in cryptosporidiosis. *C. parvum* type 1 (now *C. hominis*) is thought to be more aggressive in humans than *C. parvum* type 2 (now *C. parvum*), with a longer period of oocyst shedding (Fayer R, 1997).

A study of healthy volunteers with no serological evidence of past infection with *C. parvum* found that 20% of subjects became infected after a dose of 30 oocysts, while 132 oocysts was the median infective dose (DuPont *et al*, 1995). However, the infective dose may vary according to the viability of the oocysts and the strain involved (some strains may be more virulent than others).

In any community, young infants and children are less likely to have had prior infection with *Cryptosporidium* than adults. It seems reasonable to assume that the risk of subsequent illness will be greater in populations not previously exposed to *Cryptosporidium*. Recent results of human infectivity studies indicate that previous *Cryptosporidium* infection confers only partial resistance to re-infection and that this resistance can be overcome by a larger infectious dose (Okhuysen *et al*, 1998). However, the authors suggested that illness may be less intense and associated with lower levels of oocyst excretion after repeated exposure to *C. parvum* and that repeated exposure may be necessary in order to develop complete immunity. They also found that diarrhoea occurred in the absence of detectable oocysts. This could be explained by the lack of sensitivity of diagnostic tests used.

The history of the quality of the drinking water supply is also relevant in interpreting the significance of the risk to public health when *Cryptosporidium* is detected in the water. The quality of drinking water is influenced by the source of the supply, the amount of pollutants present in the source supply, the treatment and monitoring process and the training and skill of the treatment plant operatives (Juranek, 1998). Surface water as a rule is more vulnerable to faecal contamination than ground water. Minor lapses in the treatment process are more likely to lead to illness in a community that uses pre-treatment contaminated water as a source of supply than communities that use clean water as a supply source. Properly treated water may be re-contaminated after it leaves the treatment plant. Pathogens may enter drinking water through damaged pipes, especially when sewage and water pipes are side-by-side.

Turbidity levels have been used as an indicator of water quality. Turbidity is a measure of suspended particles in the water. Research has indicated that *Cryptosporidium* is less likely to penetrate water treatment filters when the filtered water turbidity is kept very low and wide fluctuations in turbidity levels are avoided.

The PHLS Advisory Committee on Water and the Environment has issued guidelines to be considered when assessing the factors that influence whether an oocyst count is significant or not (Hunter, 2000). The factors that influence whether an oocyst count is significant or not are as follows:

- When and where the sample was taken.
- The number of oocysts detected per 10L of water and the results of any viability testing.
- The species or type of oocysts detected.
- The source and treatment of the affected water supply (groundwater/surface water/full chemical treatment/filtration only/no filtration).
- The distribution area of the water supply and size of the population supplied.
- Whether any problems with the supply, such as treatment failure or high turbidity, have been identified.
- High oocyst counts in consecutive samples.
- Whether there have been any recent changes in the source and/or treatment.
- The history of *Cryptosporidium* sampling for this supply and whether there have been similar detections in the past.
- How fast water travels through the distribution area (is it likely that any of the contaminated water is still in the distribution system).
- Whether waterborne outbreaks of cryptosporidiosis have been associated with the supply in the past.
- The level of immunity in the exposed population.

3.3 Attributing human cryptosporidiosis to a waterborne cause.

Guidelines for assessing the strength of association between human illness and water have been developed by the UK Public Health Laboratory Service (PHLS, 1996). Based on a combination of descriptive and analytic epidemiology, microbiological evidence, and water quality failure information, they suggest that outbreaks can be graded into grades A, B and C, indicating strong, probable and possible association with water. An algorithm form has been adapted for use in outbreak situations (Appendix 2).

(a) *Outbreaks associated with public water supplies*

One of the first large outbreaks of cryptosporidiosis occurred in Carrollton, Georgia, USA in January 1987. This outbreak was strongly associated with a potable water supply and an estimated 13,000 people became ill (Hayes *et al*, 1989). *Cryptosporidium* oocysts were isolated from the stools of 39% of patients with gastroenteritis around the time of the outbreak. The treatment plant obtained its source water from a river and the water was conventionally treated by coagulation, sedimentation, rapid sand filtration, and chlorine disinfection. Although the water quality was within regulatory limits, it was thought that changes in water treatment allowed oocysts to pass into the treated water in sufficient numbers to cause illness. Recycling of backwash water did not occur around the time of the outbreak. *Cryptosporidium* oocysts were found in treated water samples and in the source water. Low-level infection found in cattle from pastures upstream from the water treatment plant, and a blockage in a major sewer line, causing sewage to overflow into an area near the water intake site, were considered possible contributors to the contamination of the water supply.

The biggest documented outbreak of *C. parvum* occurred in April 1993, in Milwaukee USA. The source of the outbreak was Lake Michigan water, which was contaminated with *Cryptosporidium* oocysts. The contaminated water from Lake Michigan was chlorinated and filtered at one of two water works plants before entering the main water supply for the Milwaukee area. However, the water treatment process did not remove the oocysts which were found in ice made from the treated water in concentrations of 13.2 and 6.7 oocysts per 100 litres of water. Examination of the treatment plants' records revealed a marked increase in turbidity levels in treated water from one of the plants, in the weeks prior to the outbreak. Equipment used for the continuous monitoring of turbidity levels, and which aided plant operators in adjusting the dose of coagulant, was out of service. It is estimated that as a result of this outbreak more than 403,000 residents and visitors became ill and over 100 people died (Hoxie *et al*, 1997).

In 1994, a probable waterborne outbreak occurred in Nevada, USA, despite what was considered at the time to be a state–of–the-art water treatment facility that was fully automated and computerised (Goldstein *et al*, 1996). Investigations revealed no malfunction at the plant and no major repair works had been done at the plant or on the distribution system. *Cryptosporidium* oocysts were not detected in the water supply and recorded turbidity levels were below national standards. Epidemiological data suggested that the municipal drinking water was the source of the outbreak and because of the geographical spread, the contamination had occurred before the water reached the treatment plant or in the proximal portion of the distribution system before the system branched. The cases occurred over an extended period suggesting low-level, probably intermittent contamination. Subsequent investigations found presumptive oocysts (thought to be residual shells of intact oocysts) in the source water, filter backwash, and in one treated water sample. This indicated that oocysts could pass through the filtration system, and that the methods used to detect them were inadequate.

The first reported outbreak of cryptosporidiosis in the UK associated with treated drinking water occurred in 1988 (Smith *et al*, 1989). This outbreak in Ayrshire occurred in two towns with the same potable water supply. The incidence of diarrhoea in these two areas was two to five times higher than expected and oocysts were detected in the stools of 27 patients. Oocysts were found in the filter backwash, in the sludge and in the mains supply in concentrations ranging from 0.13 to 1000 per litre for liquid samples, and from 3 to 32 per gram for solid samples. No oocysts were detected in the untreated water. Contamination is believed to have occurred after water treatment as a result of runoff from a field containing cattle slurry infiltrating the water holding tank through a broken pipe.

The second big outbreak of cryptosporidosis in the UK occurred in Wiltshire and Oxfordshire, UK in 1989, and resulted in 516 confirmed cases (both children and adults) although up to 5000 people were reportedly affected (Richardson *et al*, 1991). The geographical distribution of cases matched the distribution of water supplies for three treatment works and *Cryptosporidium* oocysts were found at these works and in the treated water. Oocysts were isolated from raw water, backwash water from a filter and from water in the distribution system. Samples taken from customers' taps were found to contain oocysts in the range of 0.002 - 24 oocysts per litre. In this instance it was possible to calculate that rapid sand filtration had reduced the numbers of oocysts by 99% or more but that settlement tanks had only been 83% effective. The suspected cause of the outbreak was the inability of the filtration system to cope with an unusually high concentration of oocysts present in the water source following heavy rain (Lisle and Rose, 1995). Increased washing and slower filtration times resulted in a rapid decline in positive samples in the distribution system.

In the UK, a further outbreak of cryptosporidiosis occurred in Warrington, a town in Northwest England between November 1992 and February 1993 (Bridgman *et al*, 1995). Forty seven cases were recorded and there was strong statistical evidence between cases, and residence in an area supplied from two ground water sources. In a case-control study, a strong association between having drunk unboiled tap water and illness, and a dose response relationship were found. No oocysts were found in the water supply. There was heavy rainfall at the time of the outbreak and runoff water was found to be draining into the water supply from a field containing livestock faeces.

In July and August 1998, in Sydney, Australia, the municipal water supply became contaminated with *Cryptosporidium* occysts and a recommendation was given to the 3 million residents to boil their water. The Sydney Water Corporation reported detecting up to 1079 oocysts per litre of water at different sites in the distribution system. Enhanced surveillance using several approaches, including notifications, special surveys and analysis of results of ongoing surveillance systems, did not detect any measurable increase in cryptosporidiosis (New South Wales Health, 1998).

More recently, there were three outbreaks of cryptosporidiosis in Northern Ireland associated with public drinking water supplies. The first outbreak occurred in April and May 2000. *C. parvum* type 2 was identified in 129 cases. The highest notification rates were in children aged 9 years or younger suggesting a high level of immunity in the population from previous exposure. The supply was subject to continuous monitoring for *Cryptosporidium* and interestingly the levels of *Cryptosporidium* in the water during the relevant period prior to the outbreak were well below the trigger level for action of 1 oocyst per 10 litres of water, agreed in the protocols between the UK Department of Health, Social Services and Public Safety, and the Water Service. Investigations were consistent with the hypothesis that a bolus of *Cryptosporidium* oocysts had passed through the supply system associated with a period of increased turbidity, following heavy rainfall (Eastern Health and Social Services Board, 2000).

The second outbreak was strongly associated with *C. parvum* type 1, indicating a human source of infection. Oocysts were identified in the water supply at levels above the trigger level for action. Boil water notices were issued to households within the distribution system. Investigations revealed the possible source of infection to be a section of conduit damaged during the construction of an outflow for a septic tank at a private dwelling. In this outbreak all age groups were affected, indicating a low level of immunity in the population affected (Eastern Health and Social Services Board, 2001).

The third outbreak occurred in April 2001. The cause of the outbreak was thought to be ingress of wastewater from a blocked drain. *C. parvum* type 1 was found to be the cause of the outbreak and further analysis revealed that one subgenotype of the *C. parvum* human genotype isolated from the wastewater sample from the blocked drain was indistinguishable from the subgenotype found in most infected persons (Glaberman *et al*, 2002).

(b) *Outbreaks associated with well water*

The first identified outbreak of cryptosporidiosis in human populations probably due to well water occurred in July 1984, in Texas. The community affected received all their water supplies from the same well. The well water was not filtered before use but was chlorinated. Although no oocysts were detected in the chlorinated well water, faecal coliforms were detected indicating contamination by sewage had occurred. *Cryptosporidium* was identified as the aetiological agent from stool samples and serological tests. A significant association was found between drinking tap water and the occurrence of diarrhoea. The greater the proportion of daily fluid intake of tap water, the higher the attack rate of diarrhoea (D'Antonio *et al*, 1985).

In 1994, a further outbreak of cryptosporidiosis occurred in a rural community in Washington State, USA where water was supplied by two deep unchlorinated wells (Dworkin *et al*, 1996). Drinking unboiled well water was associated with being ill and a significant dose response relationship was found between water consumption and illness ($P = 0.004$). Water that was presumed to be treated wastewater from a piped irrigation system was found dripping along one well's outer casing, which was extensively rusted. *Cryptosporidium* oocysts were found in both well water and in treated wastewater.

(c) *Outbreaks associated with lake water*

In the summer of 1994, an outbreak of *C. parvum* occurred among visitors to a state park in New Jersey, USA (Kramer *et al*, 1998). Epidemiological evidence indicated a strong link between exposure to lake water and the illness ($P< 0.001$). The outbreak lasted 4 weeks and affected an estimated 2,070 people. Despite its large size the outbreak was not detected for several weeks. The most likely sources of the outbreak were contaminated runoff from rainwater and infected bathers. This outbreak was the first reported to be associated with recreational exposure to lake water.

(d) *Outbreaks associated with swimming pools*

It has increasingly been recognised that swimming pools may be a potential source of cryptosporidial infections (CDSC, 1999). *Cryptosporidia* are a particular risk in swimming pools because they are very resistant to chlorine; the filters used in many pools are inefficient at removing oocysts because of their small size; large numbers of oocysts are excreted by infected persons; and the infectious dose is small.

In England and Wales in 2000, there were 11 outbreaks of gastrointestinal disease associated with water. Nine outbreaks were due to *Cryptosporidium* and 7 of these were associated with swimming pools (CDSC, 2001).

In Yorkshire, in 1988, at least 62 people were infected from a swimming pool, the water of which was found to contain 500 oocysts per litre (Bayer and Wright, 1990). This contamination arose from broken drainage connections within the swimming pool complex, which allowed leakage from a public toilet into the swimming pool.

An outbreak occurred in Oxfordshire in 1999, in which 51 people were ill with cryptosporidiosis. A case control study implicated a local swimming pool as the source of infection. A review of the pool's operation records revealed that the level of chlorination had been increased in the months prior to the outbreak to compensate for faulty ozonisation of the water. *Cryptosporidium* oocysts were detected in the water from the strainer basket, flocculation gel and filter core sand of the swimming pool (CDSC, 1999).

An outbreak in Leicestershire in 1999 was linked to a local swimming pool (CDSC, 1999). A higher than normal rate of cryptosporidiosis was reported over a six-week period. Interviews with patients revealed that 14 cases had used a local pool before they became ill. This pool also used ozonation. It was closed and expert advice on the water treatment system was sought. Cysts of *Giardia* but not *Cryptosporidium* were detected in the main pool water and from scrapings from the pool sieve and filter sand.

Sixteen cases of cryptosporidiosis were detected in Solihull, West Midlands between late August and mid-October 1999, and all were associated with a single swimming pool (CDSC, 1999). *Cryptosporidium* oocysts were identified in samples of water from the adult (9/10L) and learner pools (188/10L). The pool was closed. Filters were backwashed and cleaned until counts were zero. No further cases were identified and the pool reopened.

During the summer of 2000, in the USA, five outbreaks of cryptosporidiosis linked to swimming pools were reported to the Centers for Disease Control and Prevention (CDC). In one of these outbreaks 700 people, with a mean age of 6 years, became ill. Swimming at a private club was strongly associated with the illness in the community and activities that increased the risk of pool water getting into the mouth, such as standing under a pool sprinkler, increased the risk of illness. Several faecal accidents in the pool had been noted, at least one of which was diarrhoeal (Veverka *et al*, 2001).

The first documented outbreak of cryptosporidiosis in New Zealand occurred in 1998, in the Hutt Health District. Cryptosporidiosis was strongly associated with the use of a particular local swimming pool. One hundred and twenty two people became ill and the median age of cases was 5 years. The pool used sand filters with an added flocculant for treatment. These treatments were designed to remove particles down to 10μm in size. The design of the pool allowed water from the learners' and main pool to mix. *Cryptosporidium* oocysts were found in samples from the learners' pool, post-filter and backwash water (Baker *et al*, 1998).

A more recent outbreak occurred among British holidaymakers returning from Majorca, Spain in July/August 2003. As of 14th August 2003, 391 suspected cases and 214 laboratory-confirmed cases had been reported among English, Welsh, Scottish and Northern Irish tourists who stayed at the same hotel (Galmes A *et al*, 2003). Thirty one Irish cases, from four different health boards, were notified to NDSC. Fifteen (48.4%) were laboratory-confirmed. *Cryptosporidium* oocysts were identified in the backwashed water from filters in the hotel swimming pool where the holidaymakers were staying. *C. parvum* type 2 (bovine) was isolated from some samples taken from Scottish tourists involved in the outbreak.

3.4 Irish outbreak information

In 1998, of the 38 gastrointestinal outbreaks reported to the Food Safety Authority of Ireland (FSAI), one was waterborne but the organism involved was not identified. No waterborne outbreaks were reported in 1999. Two were reported in 2000 but again no organisms were identified. However, in 2001 there was a cluster of cryptosporidiosis cases in children aged between 11 months and 7 years, in the Southern Health Board. There were 4 confirmed cases and 2 possible cases, with probable links to a swimming pool. Three of the children were hospitalised.

A second small outbreak occurred on a family farm in July 2001, in the North Eastern Health Board. Two children were ill and one was admitted to hospital. Well water or cattle were thought to be the likely source of infection.

In February 2002, two case of cryptosporidiosis were notified to the Midland Health Board. The two cases were linked to the same water source. A case-control study was undertaken. Over thirty individuals were

identified who were sick with gastroenteritis. All had used the same water supply. Stool sampling did not reveal any further cases of cryptosporidiosis and viral studies were also negative. Laboratory testing of the drinking water was negative for indicator organisms and *Cryptosporidium*. The case-control study showed a possible association between illness and the consumption of water (Jennings and Rhatigan, 2002).

The first reported outbreak of cryptosporidiosis in Ireland that was strongly associated with drinking water occurred in April 2002 in the Midland Health Board region (Jennings and Rhatigan, 2002). The water source was a spring-fed lake, serving a population of about 25,000 people. The water was chlorinated but not filtered. There were 26 confirmed cases of cryptosporidiosis. A further seven unconfirmed cases were reported. Four cases were admitted to hospital. Genotyping identified that seven of eight stool samples were *C. parvum* type 2. *Cryptosporidium* oocysts were detected in one of the samples from a domestic tap in concentrations of 1 oocyst/10 litre of water. Oocysts were also detected in untreated lake water in concentrations of 1.4 and 2.4 oocysts/10 litre. A risk assessment of the water distribution system and surrounding area identified a number of farming practices that could have resulted in contamination of the water source with farmyard slurry and farmyard manure. Environmental samples taken at a number of sites were positive for *Crytosporidium*. Heavy rains are thought to have facilitated the ingress of animal excrement into the lake.

3.5 Conclusion

Numerous outbreaks of waterborne cryptosporidiosis have been reported internationally. These outbreaks have involved both potable water and water used for recreational purposes. Detailed epidemiological investigation can provide evidence to help attribute cryptosporidiosis outbreaks to water even in the absence of the detection of *Cryptosporidium* oocysts in the water. The presence of oocysts in water (potable and recreational) may pose a health threat, although there is no agreed threshold level above which public health action is warranted. The significance depends on parasite factors such as the number, viability and species of oocysts involved, host/population immunity and water quality history of the supply. Genotyping of *Cryptosporidium* isolates is useful in determining the epidemiology of cryptosporidiosis because the host ranges of different types varies. It may also be useful in helping elucidate the source of a waterborne outbreak allowing patients' isolates to be compared with oocysts detected in water. The PHLS Advisory Committee on Water and the Environment has issued guidelines which should be considered when assessing the significance of detection of *Cryptosporidium* oocysts.

Water Supply/Sources and Monitoring for *Cryptosporidium* in Water in Ireland

4.1 Sources

Drinking water in Ireland originates from groundwater or surface water sources. Groundwater may come from natural springs where the groundwater naturally issues from the ground or from an artificial borehole drilled into the ground. Surface water comes from rivers, streams, lakes and reservoirs. The quality of the water will depend on its vulnerability to pollutants present in the surrounding environment. Surface water is generally more vulnerable to pollution than groundwater.

4.2 Structure and operation

There are a number of schemes through which water is supplied to consumers (table1).

Table 1: The structure and operation of water supplies to consumers in Ireland.

Type of Supply	Service Provider	Source Water Provider	No. Households Connected (approx.)
Public water supply	Local authority	Local authority	950,000
Group water supply with public source	Group scheme	Local authority	90,000
Group water supply with private source	Group scheme	Group scheme	50,000
Private supply	Individual	Individual	120,000

Source: DEHLG personal communication

There are about 120 public water schemes each supplying 5,000 or more consumers while many more supply less than 5,000 consumers. Approximately 260,000 households are connected to private and group water supply schemes. Public water supplies are provided through public funds (Department of Environment, Heritage and Local Government/Local Authority grants) and operated by the local authorities. Group water schemes (GWSs) and private supplies are provided by a combination of funds (DEHLG grants and local funds) and are operated by the owners with the assistance of a state grant and some procedural requirements.

The public water schemes generally cover areas with relatively large populations where it is more economical to provide central water treatment systems. Some public water supply schemes have extended into more rural areas where this has been found to be technically necessary (due to lack of other water resource options) or where it has been proven that extension of the larger scheme is more economical than having a number of smaller schemes.

Some schemes have a number of raw water sources, each with different water treatment requirements. In many urban areas the expansion of the public water supply system is driven by development and is constructed as a consequence of technical considerations rather than with respect to local authority boundaries. As a consequence, it is common for one local authority to purchase water from a neighbouring authority and in some cases to re-export the same water to another local authority.

The distribution of water in the water supply network is a dynamic system and responds to daily variations in pressure, demand and operational problems on an ongoing basis. In the case of the Greater Dublin Area, for example, there are three main sources of water, Roundwood, Ballymore Eustace and Leixlip. The treated water from these sources services consumers in Meath, Wicklow, Kildare, South Dublin, Fingal, Dun Laoghaire and Dublin City Council. While the blend of water being received by a particular consumer will vary slightly on a daily basis (depending on local demand and operational practices) it could be significantly different at times of operational difficulty at a particular plant or during a drought period.

4.3 Treatment

The role of water treatment is to make the water potable i.e. fit for drinking. Depending on the raw water quality, the level of treatment provided at a water supply source can vary from minimal treatment to the provision of very extensive treatment.

The common treatment processes encountered (Hunter, 1997) and how they impact on *Cryptosporidium* are outlined as follows:

(a) *Pre-treatment*

Before raw water is treated it is passed through coarse screens to remove large objects such as plants or animals. The water may then spend time in pre-treatment storage reservoirs where oocyst losses may occur through settlement and ingestion by plankton. It also allows the sun to bleach the water, reducing its colour, and allowing microorganisms to be exposed to the lethal effects of sunlight. Some aeration of the water can also take place. Ground water may need to be further aerated by passing it through a cascade or fountain system. Low oxygen concentrations can adversely affect other treatment processes.

(b) *Coagulation / flocculation / sedimentation*

After pre-treatment small particles, less than 10μm, remain suspended in the water. These particles consist of microorganisms and organic and inorganic matter. These will not settle out by themselves. Coagulant and coagulant aids are used to form flocs that capture fine particles in the raw water. Mixing the water will improve flocculation and allow larger particles to form that will settle more easily. This process of sedimentation is followed by filtration.

(c) *Filtration*

Filtration involves passing water through layers of sand and gravel. Rapid sand filters contain coarse grains of sand through which the water passes quickly. It is not as efficient at removing smaller particles as slow sand filters which use fine grains of sand through which the water passes slowly. It is generally considered that oocysts will be caught by the floc and will be removed at settlement or filtration stage. However, small numbers of oocysts may pass through these treatment stages, especially if the floc is very weak or ruptured.

Particulate matter builds up on filters with use, and would cause them to fail if it was not removed. Cleaning of rapid gravity filters is done by backwashing. This involves passing water through the filters in the opposite direction to normal flow. On completion of the cleaning cycle the filters are brought back into commission. The filters are less efficient for a short period during the early stages of commissioning while they are establishing themselves. This establishment period is called the “ripening period”. The backwash water should be discarded or returned to the start of the treatment process because it contains a large amount of particles, including microorganisms. Some outbreaks have been attributed to ineffective removal of backwash water allowing a bolus of *Cryptosporidium* oocysts to pass through into the distribution system.

(d) *Disinfection*

Disinfection of water supplies by chlorination, at dosage levels normally used, will remove the commonly encountered pathogens. The absence of indicator organisms such as *E. coli* is indicative of the effectiveness of the disinfection. *Cryptosporidium* oocysts however, are resistant to chlorination and, if present, will continue to remain viable and unaffected.

Ozone is another disinfectant that can be used. Unlike chlorine it is effective against *Cryptosporidium* oocysts at normal operational dosages. However, it is more expensive and no residual ozone remains in the water after it leaves the treatment plant. Therefore, it offers no protection against bacterial regrowth or adventitious contamination within the distribution system.

Ultraviolet light at certain wavelengths is also an effective means of treating water but has the same limitation as ozone in that it is ineffective outside the treatment plant.

As a general rule, the larger plants throughout Ireland use coagulation, rapid gravity filtration (or slow sand filtration) and disinfection by chlorination. In most cases these plants are public water supplies under the control of local authorities and their source of raw water is surface water. The smaller plants tend to have less extensive treatment and in some cases there is no treatment. The treatment varies in these plants from:

- Sedimentation and disinfection by chlorination.
- Slow sand filtration and disinfection by chlorination.
- Disinfection by chlorination only.

4.4 Monitoring

Local authorities are required by law to produce wholesome water that is fit for human consumption. To do this they must monitor the water at the various stages from the treatment plant to the consumer's tap. This monitoring is discharged, under the Drinking Water Regulations, by the local authorities themselves and in some areas, on an agency basis, by environmental health officers from the health boards. Private water supplies, including group schemes are also under the supervisory function of the local authorities. Local authorities are obliged to monitor private water supplies, advise owners of such supplies of the results of monitoring, and of any remedial action that may be necessary. Owners are obliged to comply with the remedial action outlined by the local authority.

Until recently, under Statutory Instrument S.I. No. 81 of 1988 – European Communities (Quality of Water Intended for Human Consumption) Regulations, 1988, the quality of drinking water was assessed in relation to various parameters, including bacteriological, chemical and physical. Routine monitoring for *Cryptosporidium* was not included in the regulations. However, new regulations [European Communities (Drinking Water) Regulations 2000 (S.I. No. 439 of 2000) and the Council Directive 98/83/EC] came into effect on 1st January 2004, and introduced radical changes to the monitoring and management of drinking water. The changes include the number of samples, the sampling regime, extent of coverage and the parameters to be monitored. Surface water supplies are to be monitored for *Clostridium perfringens* (including spores). *C. perfringens* is used as an indicator organism i.e. it indicates the presence of faecal contamination and therefore infers that pathogens such as *Cryptosporidium* may be present in the water. In the event of non-compliance with the parametric value (0/100mls water) the supply must be investigated to ensure that 'there is no potential danger to human health arising from the presence of pathogenic micro-organisms, e.g. *Cryptosporidium*'. In order to facilitate compliance with these regulations the DEHLG has appointed consultants to work with all local authorities during 2003 and 2004 towards establishing a Drinking Water National Monitoring Programme. The programme will cover all public and private water schemes that serve 50 persons or more and aims to develop a harmonised system of sampling, testing and reporting.

It is anticipated that with the introduction of these regulations there will be an increased need for public health advice. More resources will be required in public health in order to provide an adequate response when water quality incidents occur.

The local authorities submit their monitoring returns to the Environmental Protection Agency (EPA) which is responsible for producing an annual report on the quality of drinking water in Ireland and for making appropriate recommendations.

In 2001, the EPA estimated that local authorities produced and distributed 92.0% of the sampled drinking water, with 7.9% distributed by GWSs and 0.1% by private water sources (EPA, 2002). While the quality of drinking water produced by the local authorities was found to be high, significant numbers of the GWSs were not fit for human consumption as required by the Drinking Water Regulations.

Samples taken in five local authority areas for *Cl. perfringens* exceeded the guideline of 0/100mls water. However, only one of these local authorities followed up with *Cryptosporidium* monitoring (EPA, 2002). Little *Cryptosporidium* monitoring data are available for Ireland. In 2001, a small number of samples were analysed from public supplies in Ennis, Galway City, Leitrim and Offaly. Most samples were clear. However, one sample contained *Cryptosporidium* at a level 0.11 oocysts per 10 litres of water.

Cryptosporidium monitoring of drinking water has been most extensive in the Dublin Region (Dublin, Kildare and Wicklow). Between October 1995 and the end of 2000, *Cryptosporidium* analysis was carried out on approximately 1200 samples of drinking water supplied in this region. Water production for these areas is about 460 million litres per day, supplying a population of approximately 1.3 million people. The water is abstracted from surface water sources and treated by normal chemical and physical methods, including coagulation, flocculation and filtration, followed by chlorination.

Samples were taken primarily from final waters leaving water production plants, but some were also taken at sites within the distribution systems. Samples taken at plants were usually large volumes (>100 litres) filtered on-site. Samples within the distributions systems were 10 litre bulk water samples.

No oocysts were detected in 98.3% of these samples. Single oocysts or insignificant numbers were detected in a small number of samples and only one sample produced an estimated oocyst abundance above the 1 per 10 litre action limit recommended in the UK Cryptosporidium Regulations (Department of the Environment, Transport and the Regions, 1999).

These results indicate that the quality of drinking water in the Dublin Region with respect to *Cryptosporidium* has been excellent. However, it must be emphasised that this water has principally been produced at very large, well-monitored facilities. Formal *Cryptosporidium* risk assessment at the plants involved confirms the reduced probability of significant oocyst numbers passing the treatment process. It cannot be presumed that similar results will pertain at smaller plants with minimal treatment and more variable raw water sources.

An environmental study conducted by Sligo Regional Technical College found evidence of *C. parvum* in both river water and marine mussels in the Sligo area (Chalmers *et al*, 1997). *Cryptosporidium* was found in five of eleven sites tested on the Owenbeg River. The detection of oocysts in surface water highlights the potential for water-borne outbreaks of cryptosporidiosis to occur, since unfiltered river water may be used for human consumption. *Cryptosporidium* was also found in mussels from one of three shore sites tested in Sligo bay.

4.5 Audit

In 2001, the EPA undertook an audit of a number of local authorities to determine if they were complying with the regulations in relation to drinking water (EPA, 2002). Below are some of their findings:

- There was an absence of documented management systems in most plants visited.
- Some local authorities had no documented procedures for dealing with exceedances of standards, although they noted that a number of local authorities audited the previous year now had documented procedures in place or in preparation for dealing with exceedances of the faecal coliform standard.
- Some had no written procedures for sampling drinking water.
- Documented monitoring programmes were not carried out as specified.
- There were delays in communication of results to health boards.
- There was poor management of treatment plant sludges at some treatment works.
- There was inadequate source protection at some treatment works.

In recent years there have been several developments aimed at improving the quality of water supplied by GWSs. The National Federation of Group Water Schemes (NFGWS) has introduced a quality assurance scheme based on the Hazard Analysis Critical Control Points (HACCP) system used in the food industry. The system sets minimum standards for the supply of drinking water and the schemes that meet these standards are certified under the scheme. These standards do not deal with *Cryptosporidium* specifically. The NFGWS has also undertaken a pilot project for source water protection and will develop a model of best practice in the monitoring and protection of catchment areas. Under the National Development Plan €644 million has been committed to improving water quality supplied by GWSs.

4.6 Conclusion

The new EU regulations on water quality which came into effect on 1st January 2004 will have a significant effect on the way drinking water is monitored and managed particularly in relation to GWSs. All schemes supplying more than 50 people have to comply with drinking water standards, including GWSs. Under the new Water Services Bill which is due out shortly GWS have to be licensed to supply water to consumers and one of the requirements of the license is that they supply water that meets the drinking water standards.

Legislation and Regulatory Standards

5.1 Introduction

While *Cryptosporidium* is global in distribution, and waterborne outbreaks have been documented from many countries, few statutory standards relating specifically to *Cryptosporidium* in potable water supplies have been set.

5.2 Irish standards for *Cryptosporidium* in potable water

In 1998, the Department of the Environment and Local Government requested local authorities to review their action plans and training programmes, to cover the potential risks associated with *Cryptosporidium* (Circular Letter L7/98). The guidelines that were circulated, (Department of the Environment and Local Government, 1998), outline the life history and occurrence of *Cryptosporidium*, and possible sources of contamination. They suggest that routine sampling and analysis for *Cryptosporidium* from all sources is not feasible or practicable, and each local authority should formulate a monitoring strategy having regard to known risks and local circumstances. Where a need for monitoring is indicated, it is proposed that tests for the presence of *Cl. perfringens* (including spores) should be carried out in the first instance. Only if the latter is found to be present in tap water is it suggested that specific testing for *Cryptosporidium* is necessary. No guidance on acceptable levels of oocysts in drinking water is provided.

Cryptosporidium is not included specifically in the revised Drinking Water Directive (98/83/EC) that was transposed into Irish law by European Communities (Drinking Water) Regulations, 2000 (S.I. 439 of 2000), effective from 1st January 2004. However, in order to ensure that water intended for human consumption does not contain parasites such as *Cryptosporidium* in numbers sufficient to constitute a potential danger to human health the new regulations include the indicator organism *Cl. perfringens* (including spores). This parameter must be measured if the water originates from or is influenced by surface water. In addition, there is a note that contains the following requirement, ***"In the event of non-compliance with this parametric value (of 0/100ml) the supply shall be investigated to ensure that there is no potential danger to human health arising from the presence of pathogenic micro-organisms, e.g. Cryptosporidium".***

5.3 Irish infectious disease legislation

The role of public health, and specifically of the medical officer of health (MOH), in relation to outbreak situations and threats to public health has been defined in the Infectious Disease Regulations, 1981 (SI 390, 1981, Section10). These regulations state that the MOH, on becoming aware of a "*case or suspected case of an infectious disease or a probable source of infection…shall make such inquiries and take such steps that are necessary or desirable for investigating the nature and source of such infection, for preventing the spread of infection and for removing the conditions favourable to infection".* These regulations, together with the recent amendment (S.I. No. 707 of 2003) which made cryptosporidiosis a notifiable disease, give the medical officer a statutory role in the prevention and control of infectious disease agents including cryptosporidiosis.

5.4 EU standards

No numerical standard for *Cryptosporidium* is set in the revised Drinking Water Directive (98/83/EC). However, recognising the impracticality of the previous implicit limit value of zero, it states (Article 4, Paragraph 1) "water intended for human consumption shall be wholesome and clean if it is free from any microorganisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health".

In Annex I Part C, the Directive refers to *Clostridium perfringens*. In the attached Note 2 it states that if *Clostridium* is detected, the Member State "must investigate the supply to ensure that there is no potential danger to human health arising from the presence of pathogenic microorganisms e.g. *Cryptosporidium*". Member States must include the results of all such investigations in their summary three-year report.

Given the established relationship between elevated turbidity and the presence of *Cryptosporidium* oocysts, it is noteworthy that in the Revised Directive turbidity is listed as an indicator parameter. The previous MAC of 4 NTU has been replaced by "acceptable to consumers and no abnormal change" with

the following note; “In the case of surface water treatment, Member States should strive for a parametric value not exceeding 1.0 NTU (nephelometric turbidity units) in the water ex treatment works”.

5.5 UK standards

In England and Wales, The Water Supply (Water Quality) (Amendment) Regulations 1999 (Statutory Instrument 1999 No. 1524) came into force in June 1999. These regulations were incorporated as regulations 27, 28 and 29 in new regulations, The Water Supply (Water Quality) Regulations 2000, S.I. No. 3184 which came into effect in England on 1st January 2001 and The Water Supply (Water Quality) Regulations 2001, S.I. No. 3911 (W.323) which came into effect in Wales on 1st January 2002. The regulations make specific provision intended to ensure that water supplied for human consumption is not contaminated with *Cryptosporidium*. They impose a requirement on the Water Industry to carry out a risk assessment for each treatment works to establish whether there is a significant risk from *Cryptosporidium* oocysts in water supplied from the works, and to submit a report to the Secretary of State. ’Significant risk’ is defined in the Regulations as “a significant risk that the average number of *Cryptosporidium* oocysts per 10 litres of water supplied from the works……..would, at any time, be one or more”. Where it is established that there is a significant risk from *Cryptosporidium*, the water undertaker is required to use a treatment process that will ensure that the average number of oocysts per 10 litres of water will be less than one. The effectiveness of treatment must be demonstrated through continuously sampling the final water leaving the works using an approved device and analytical method.

The Drinking Water Inspectorate (DWI) has published guidance on the initial risk assessment procedure that water companies must undertake. It includes a list of factors, which could contribute to increased risk, and pro forma report documentation. The DWI also provides guidance on the sampling and analysis requirements associated with the Regulations by way of *Standard Operating Protocol for the Monitoring of Cryptosporidium Oocysts in Treated Water Supplies to Satisfy The Water Supply (Water Quality) Regulations 2000, SI no. 3184 England and The Water Supply (Water Quality) Regulations 2001, S.I. No. 3911 (W.323) Wales.*

5.6 Scottish standards

The Scottish Executive has recently updated their guidance notes on *Cryptosporidium* in water, The Cryptosporidium (Scottish Water) Directions, 2003. Water authorities are required to test for *Cryptosporidium*, using continuous sampling, where the risk assessment process has indicated a significant risk of *Cryptosporidium* being present in the final water. However, no threshold has been set for the number of oocysts that can be allowable. The final decision on the need for advising customers to boil water lies with the consultant in public health medicine in the local health authority, who should be informed if the water authority detects oocysts in a water sample.

5.7 US standards

The United States Environmental Protection Agency (USEPA) Surface Water Treatment Rule (SWTR) (54 FR 27486, June 29, 1989) set maximum contaminant level goals (MCLG) of zero for *Giardia lamblia*, viruses and *Legionella*. It requires filtration and disinfection of all surface water supplies and groundwater directly impacted by surface water. It specifies a minimum treatment level of 3 $\log_{10}$ removal for *Giardia* and 4 $\log_{10}$ for viruses. In addition, combined filter effluent turbidity should not exceed a maximum of 5 NTU (0.5 NTU for 95% of monthly four hourly samples). These limits were not intended to specifically control *Cryptosporidium* oocysts, and it is not explicitly listed.

During 1995, the USEPA conducted an extensive reassessment of its drinking water protection programme aimed at identifying and implementing high-priority activities that would maximise risk reduction. Among these was the development of new safety standards for high-priority microbial contaminants such as *Cryptosporidium*. Statutory requirements to achieve this, and regulatory deadlines were imposed in the 1996 Safe Drinking Water Act Amendments. In 1998, USEPA established the Interim Enhanced Surface Water Treatment Rule (63 FR 69477, December 16, 1998), which strengthens control over microbial contaminants, including *Cryptosporidium*. Public water systems (serving more than 10,000 people) must have complied with this rule by December 2001. Key provisions of the rule include a MCLG of zero for *Cryptosporidium*; 2 $\log_{10}$ *Cryptosporidium* removal in systems with filtration; a reduction in maximum combined filter effluent turbidity to 1 NTU (0.3 NTU for 95% of monthly four hourly samples); and requirements to monitor individual filter turbidity.

The USEPA presently promotes a voluntary code for *Cryptosporidium* and *Giardia* removal through participation in The Partnership for Safe Water. This seeks to eliminate microbial contaminants through optimisation of existing drinking water treatment systems.

5.8 Recreational water legislation in Ireland

(a) Swimming pools

There is no legislation in Ireland that specifically regulates the use and operation of swimming pools for the purpose of preventing infection. However, whilst there is no specific legislation, the Infectious Disease Regulations 1981 (SI 390 of 1981), including the recent amendment S.I. No. 707 of 2003, can be used by the medical officer (MO) to remedy defects which may have given rise to, or are suspected of having been the probable source of cryptosporidiosis.

Article 19 of the regulations also places an obligation on any person to comply with any requests or direction given by the MO in relation to the above. Article 19 states: "*a person who refuses to comply with a requirement or direction given or a request for information made in pursuance of any of the provisions of these regulations shall be guilty of a contravention of these regulations*." This clearly allows mandatory regulation of a swimming pool for the purposes of controlling cryptosporidiosis. This is a welcome, recent change.

Civil law also places a duty of care on the operator of a swimming pool to his/her customers. This duty of care includes ensuring that the swimming pool is correctly operated and managed (Dadswell, 1996). Damages can be awarded for personal injuries should the swimming pool operators be found to be negligent and have fallen short of their duty of care to the customer.

In order to prevent cases of cryptosporidiosis from being contracted from swimming pools, it is essential that they are operated properly. The infective stages of *Cryptosporidium* are resistant to disinfection. However, the oocysts are in theory capable of being filtered out. Cases of infection are generally associated with failures in the pool's management. A well-run pool should be adequate protection against infection.

Operators of swimming pools have a well-established duty of care to their customers. It is however, a good defence to show compliance with relevant standards/guidance and to have a written system where the parameters of compliance are recorded. The Environmental Health Officers Association (EHOA) in Ireland and the Pool Water Treatment Advisory Group (PWTAG) in the UK have produced guidelines in relation to health standards in swimming pools and other recreational pools (EHOA, 2002; PWTAG, 1999). The guidelines cover the structure of pools, water quality and treatment, cleaning and maintenance and management systems. These guidelines are not mandatory but serve as a useful guide to the leisure industry. A licensing system for all pools would go a long way to ensuring that consistently high standards are met.

The above guidelines should be used in conjunction with the guidelines published in the Morbidity and Mortality Weekly Report (CDC, 2001) which also recommend a multicomponent approach to outbreak prevention in swimming pools, including education of swimmers and pool staff, pool design modifications, and improved operations and maintenance procedures. In particular, people with diarrhoea should not swim, swimmers should avoid swallowing pool water and people should practice good hygiene including showering before swimming, after using the toilet and after changing nappies.

The design and management of pools should be improved by:

- Using separate filtration systems for children's pools and other pools to decrease the risk of cross-contamination.
- Optimising filtration rates of pools for children (without increasing the risk of suction injuries) to decrease the length of time that swimmers would be exposed to pathogens.
- Ensuring that toilets and nappy changing areas are close to the pool and are clean and adequate in number.

Management practices should:

- Reinforce that pool operators regularly maintain and monitor pH and free chlorine levels to help prevent transmission of most waterborne pathogens.
- Develop good policies for pool disinfection following a faecal accident.
- Train staff about prevention of recreational water illness transmission.
- Institute frequent toilet breaks for young swimmers to reduce the potential for faecal accidents.

During a pool-associated or other local outbreak of cryptosporidiosis, extra vigilance is necessary to prevent swimming-related disease transmission.

- Those at risk for serious illness (e.g. immunocompromised persons) should consider not swimming during an outbreak.
- People with diarrhoea should not swim while ill and for 2 weeks after the diarrhoea has ceased.
- Operators of implicated pools should intensify education efforts and consider prohibiting toddlers and children in nappies from swimming during an outbreak.
- Environmental health officers should alert pool operators in the geographic area so that they can undertake intensive education efforts to prevent infected people from swimming in their pools.

(b) Bathing water legislation

In Ireland, monitoring of bathing water quality is undertaken in accordance with the provisions of the European Council Directive (76/160/EEC). The purpose of the Directive is to ensure that bathing water quality is maintained and if necessary improved so that it complies with specified standards designed to protect public health and the environment. Additional standards for various parameters have also been established under Irish legislation. Specific standards for *Cryptosporidium* are not included in the legislation.

Local authorities are responsible for monitoring the bathing sites in their area. Where bathing waters do not comply with the specified standards, local authorities are required to give notice to the public of this fact and to undertake the necessary measures to ensure compliance with standards.

A voluntary scheme, the European Blue Flag Scheme also exists. Participants in the scheme are required to maintain high water quality standards and meet specified objectives regarding the provision of safety services and facilities, environmental management of the beach area and environmental education.

In general the quality of bathing water in Ireland is very high with most of the bathing areas (98.5%) complying with the minimum mandatory standards (EPA, 2001).

Surveillance of Cryptosporidial Infection

6.1 Introduction

The data presented in this section are likely to be an underestimation of the incidence and prevalence of waterborne cryptosporidiosis infection. Not all illness is recognised, investigated or reported. In the case of outbreaks, a high proportion of the population may be affected before the outbreak is detected (MacKenzie *et al*, 1994). In sporadic cases it may be impossible to link a case to a particular source such as water.

6.2 Case definition

In 1998, the European Parliament and Council set up a network for the epidemiological surveillance and control of communicable diseases in the member states (Decision No. 2119/98/EC). Common case definitions were essential for comparison of information between the member states. Decision No. 2000/96/EC obliges member states to apply specific case definitions that have been devised centrally with input from member states. In Ireland, the case definitions were introduced when the new infectious disease regulations came into effect on 1st January 2004.

The following is the European case definition for cryptosporidiosis and should be used in reporting cases:

Clinical description

A clinical picture compatible with cryptosporidiosis, characterised by diarrhoea, abdominal cramps, loss of appetite, nausea and vomiting.

Laboratory criteria for diagnosis

- Demonstration of *Cryptosporidium* oocysts in stool **or**
- Demonstration of *Cryptosporidium* in intestinal fluid or small bowel biopsy specimens **or**
- Demonstration of *Cryptosporidium* antigen in stool.

Case classification

- Possible: N/A.
- Probable: A clinically compatible case with an epidemiological link.*
- Confirmed: A case that is laboratory-confirmed.

*A case with an epidemiological link is a case that has either been exposed to a confirmed case, or has had the same exposure as a confirmed case.

6.3 Cryptosporidiosis surveillance in the United Kingdom

Cryptosporidiosis is not a notifiable disease in the UK. There are an average of 4754 laboratory reported cases each year in England and Wales, 808 in Scotland and 172 in Northern Ireland. In 2000, the rate per 100,000 population was 11.0 in England and Wales, 17.0 in Scotland and 24.9 in Northern Ireland. In England and Wales, and Northern Ireland the highest rates were in the age group 0-4 years, at 57.6, and 189.6 respectively (Public Health Laboratory Service, 2001). These rates are considerably higher than those reported in the USA.

The issue of *Cryptosporidium* in water supplies has been comprehensively addressed by the recent *Cryptosporidium in Water Supplies* document, more commonly known as the Bouchier Report (Bouchier *et al*, 1998). The structures of public health communicable disease control are different to those in the Republic of Ireland, with regional variations between England/Wales, Scotland and Northern Ireland. In addition, the provision of water supplies is in the hands of privatised utilities, rather than under the control of local authorities or private group water schemes as in this country.

The Bouchier Report makes the following recommendations with regard to the surveillance of human cryptosporidiosis:

- Human cryptosporidiosis should be made a laboratory-reportable disease and consideration should be given to making the disease notifiable.

- Water utilities should opportunistically check their water supplies for the presence of *Cryptosporidium* oocysts.

- There is a need for closer liaison between water utilities and health authorities.

- Specifically, the report recommends that health authorities should make available to water utilities postcodes of human cryptosporidiosis cases to enable both organisations identify whether particular water sources are involved or not.

- Health authorities should be informed of any rise in water turbidity that may increase the risk of *Cryptosporidium* contamination of water.

6.4 Cryptosporidiosis surveillance in Europe

As in individual countries, it is difficult to get a true picture of the burden of infection caused by *Cryptosporidium* in Europe. Differences in recording and reporting procedures between countries contribute significantly to this. The World Health Organisation carried out a survey of gastrointestinal disease in European countries from 1986 to 1996 (WHO, 1999).

A total of 2,567,210 cases of gastroenteritis were reported during this period from 17 European countries, 2% of which were linked to drinking water. Cryptosporidiosis, giardiasis and amoebiasis were responsible for 8.6% of these cases and 2.1% of the cases that were linked to drinking water.

6.5 Cryptosporidiosis surveillance in the United States

Cryptosporidiosis became a notifiable disease in the United States in 1997. An average of 2900 cases are reported each year. In 2000, the incidence rate was 1.17/100,000 population, with the highest rate in the 1–4 year age group, at 4.44/100,000 (CDC, 2002). As in other countries the diagnosis is often not considered and laboratories do not routinely test for *Cryptosporidium,* so the disease is under-diagnosed and under-reported.

In 1997, the CDC published a handbook on *Cryptosporidium* in water (CDC, 1997). They made several suggestions on how surveillance of cryptosporidiosis could be improved, including:

1. *Monitoring anti-diarrhoeal medication sales*
   Computerised pharmacies could be asked to provide information on rates of buying of anti-diarrhoeal medications, and changes in these.

2. *Monitoring health maintenance organisations and hospitals for complaints of diarrhoeal illness.*
   A computerised database with postal code numbers would be particularly useful as it might point to a problem in a particular water distribution area.

3. *Monitoring incidence of diarrhoea in nursing homes*
   Rates of illness by source of water supply could be monitored and increases over expected rates could be detected.

4. *Laboratory surveillance of cases*
   Laboratories could be encouraged to test for *Cryptosporidium* in persons who have symptoms compatible with cryptosporidiosis.

6.6 Cryptosporidiosis surveillance in Australia

Cryptosporidiosis became a notifiable disease in Australia in January 2001. There were 1543 cases notified in 2001, giving a notification rate of 8.1/100,000 population. Cryptosporidiosis was the third most common gastrointestinal illness reported after *Campylobacter* and *Salmonella.* The notification rate was highest in the 0-4 year age group at 65.9/100,000 (Communicable Disease Network Australia, 2001). In 2002, there were 3,255 cases of cryptosporidiosis notified giving a crude incidence rate of 16.6/100,000. In 2001, data were not collected for the whole year from all states and this may explain some of the difference in notifications between the two years (personal communication).

6.7 Cryptosporidiosis surveillance in New Zealand

In June 1996, cryptosporidiosis became a notifiable disease in New Zealand. There were 1208 cases reported in 2001, a notification rate of 32.3 per 100,000 population (ESR, 2003).

6.8 Current surveillance activities in Ireland

Very little information is currently available on the incidence of cryptosporidiosis in Ireland. Until recently, cryptosporidiosis was not notifiable except as gastroenteritis in children under 2 years. However, on 1st January 2004 cryptosporidiosis became a notifiable disease under the new infectious disease legislation and there is also a new requirement for laboratory directors to report infectious diseases including cryptosporidiosis. This change will greatly improve the surveillance of cryptosporidiosis and enhance our knowledge of the epidemiology of cryptosporidiosis in Ireland.

For each case reported, a national standard dataset of information (figure 1) will be available including: unique identifier, community care area, health board, date of onset, date of notification, date of birth, age, sex, disease name, and causative pathogen (organism). It is proposed that additional information will shortly be added to the standard dataset including: week number, county (only required if not implicit from CCA provided), specimen type, laboratory diagnosis date, notification source, case classification, outcome, country of birth and country of infection.

National Standard Dataset for Notifiable Infectious Diseases		
Unique identifier:		
Health Board:	**Community Care Area:**	
Date of onset:	**Date of notification:**	
Date of birth:	**Age:**	**Sex:**
Disease name:		
Causative pathogen:		

Figure 1. Standard dataset for notifiable infectious diseases

If a cluster of cases is reported it is recommended that the cryptosporidium questionnaire in Appendix 5 should be used to investigate the potential cause.

Since the late ‘80s/early ‘90s there have been two population based regional laboratory surveillance systems that have reported on laboratory-confirmed cryptosporidiosis: INFOSCAN, which covers a population of 1.2 million persons in the Southern, South Eastern and Mid-Western Health Boards, and LSS, the Laboratory Surveillance System in the Eastern Regional Health Authority (ERHA), covering a population of 1.3 million in Dublin, Kildare and Wicklow. Some useful trend information is available from these systems.

In 1997, the Food Safety Authority of Ireland (FSAI) piloted the introduction of an outbreak surveillance system for foodborne outbreaks. Public health doctors, environmental health officers and microbiologists were asked to notify all outbreaks of gastrointestinal illness to FSAI using a standard form.

The responsibility for outbreak surveillance was transferred to the National Disease Surveillance Centre (NDSC) in July 2001 and the scope of outbreak surveillance was expanded to include waterborne and other outbreaks. Information is gathered on the duration and location of an outbreak, the numbers affected, the aetiological agent, the mode of transmission, and the epidemiological, microbiological and environmental evidence for this (Appendix 3).

6.9 Surveillance data on cryptosporidiosis in Ireland

There have been no reported large-scale outbreaks of cryptosporidiosis in the Republic of Ireland. However, there have been several small outbreaks associated with drinking water (Jennings *et al*, 2002) and in 1995 there was an outbreak associated with a visit to an open farm (Sayers *et al*, 1996). Nine adults and 161 children had visited the farm as part of a summer project. Thirteen children, aged 6 to 15 years, became ill and two were admitted to hospital. *Cryptosporidium* was isolated from the stools in seven of the

13 cases. A cohort study revealed that illness was significantly associated with playing in sand to which animals had access. Direct contact with various animals was not associated with illness.

Several scientific papers have been published detailing the prevalence of *Cryptosporidium* as a cause of gastroenteritis/diarrhoea in children. A study conducted in Cherry Orchard Hospital, Dublin, in 1987 found that out of 1621 admissions for gastroenteritis in children aged under 14 years, 4% were due to *Cryptosporidium* (Carson, 1989). Overall, it was the second most common identified cause of childhood gastroenteritis after *E. coli*. The peak month of cryptosporidial infection was April, and a higher incidence was noted in children from rural areas. The authors relate this higher incidence in April and in rural areas to the lambing and calving season.

A similar study was conducted in the Regional Hospital, Galway (Corbett-Feeney, 1987). Specimens from 1246 children with acute diarrhoea aged 3 weeks to 12 years were tested. *Cryptosporidium* was found in 4.3% of stools. The peak incidence was again noted to be during April and May. The majority (56%) of these patients were from rural backgrounds and 20% came from farms where there had been recent outbreaks of diarrhoea in calves.

A case control study carried out in Cork University Hospital looked at the risk factors for cryptosporidiosis in paediatric patients aged 0-15 years (Corrigan MA, personal communication). During a ten-year period from 1991 to 2000, there were 156 cases of cryptosporidiosis admitted to the paediatric service in Cork. The charts of 122 of these children were examined and compared with the charts of 216 children, randomly selected from children admitted to the same unit with gastroenteritis unrelated to cryptosporidiosis. The children admitted with cryptosporidiosis were more likely to be male, to come from families with three or more children and to come from an agricultural background, with a significantly higher proportion of their mothers being currently employed nurses. They were less likely to have unemployed parents than the children in the control group.

A study of hospital admissions due to cryptosporidiosis in Ireland during the period January 1st 1999 to December 31st 2001, found that there was on average 62 admissions each year. Forty eight percent were male and 52% were female. Seventy five percent of hospitalisations were in children under 5 years of age and 42% were in children under 2 years. This may reflect a higher incidence in these age groups or a greater likelihood of young children rather that older children or adults being admitted to hospital with gastroenteric symptoms. There was a strong seasonal peak in late spring/early summer with almost half (49%) of admissions reported during the period April to June in each year. The Southern Health Board reported the highest rate of hospitalisations due to cryptosporidiosis, followed by the South Eastern Health Board, the North Western Health Board, the Midland Health Board and the Western Health Board. The lowest rates were in the Eastern Regional Health Authority, the Mid-Western Health Board and the North Eastern Health Board. The study used Hospital In-Patient Enquiry (HIPE) data which cover approximately 95% of hospitals in Ireland (Garvey, 2004).

Several health boards have looked at the incidence of cryptosporidiosis in their area. In 2001, there were 70 laboratory-confirmed cases of cryptosporidiosis reported to the South Eastern Health Board, an incidence rate of 18/100,000 population (South Eastern Health Board 2002). The Western Health Board reported a crude incidence rate (CIR) of 18/100,000 population that same year although their rates were higher in 1999 and 2000 at 38/100,000 and 23/100,000 respectively (Western Health Board, 2003). The Mid-Western Health Board reported a CIR of 15.5/100,000 in 2002. The male to female ratio was 1:0.7. The mean age of illness was 8.8 years (median: 4.9 years), with a range from 9 months to 71 years. Most cases (82%) occurred in children under 10 years old, with 51% of cases under 5 years of age. However, it must be noted that in April 2002, the regional laboratory in the Mid-West changed its testing policy on *Cryptosporidium* in faecal specimens from testing on request only to screening all children less than 15 years of age in addition to requests.

Data are available for the Laboratory Surveillance System (LSS) that covers Dublin, Kildare and Wicklow for the years 1994 to 2002 inclusive. During this period, there were 225 laboratory-confirmed cases of human cryptosporidiosis reported to the LSS (figure 2).

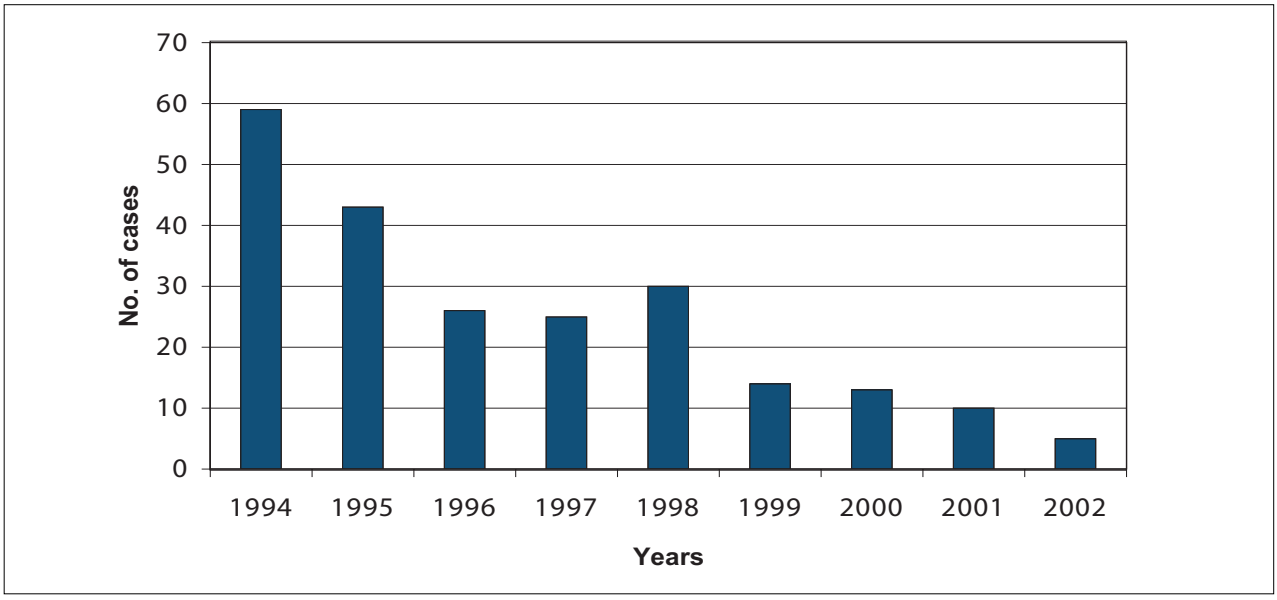


Figure 2: Laboratory cases of human cryptosporidiosis from the Laboratory Surveillance System, 1994 to 2002.

Of these, 115 were female and 110 were male. One hundred and thirteen (50.2%) were in the 0-4 year age group, 52 (23.1%) were aged five to nine years, and 49 (21.8%) were aged ten years or over. There was no age information on 11 (4.9%) cases. In 2001, the incidence rate for cryptosporidiosis was 0.8/100,000 population in the ERHA, with the highest rate in the 0–4 year age group at 5.5/100,000 (figure 3). In 2002, the figures were 0.4/100,000 population in the ERHA, and 2.2/100,000 in the 0-4 year age group.

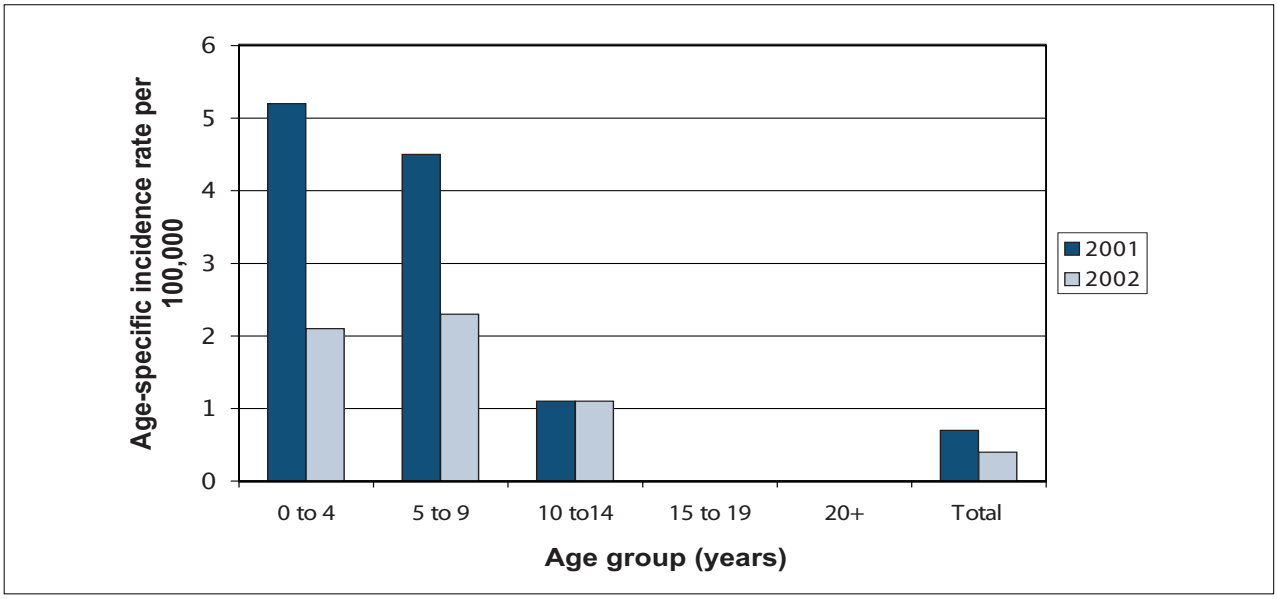


Figure 3. Age-specific incidence rate per 100,000 population of cryptosporidiosis, 2001 and 2002

Data are also available from the INFOSCAN for the years 1989 to 2000 inclusive, which covers the Southern Health Board, the South Eastern Health Board and the Mid-Western Health Board. These figures are shown in figure 4. On average, there were 121 laboratory cases of human cryptosporidiois per annum, between 1989 and 2000, an annual incidence rate of 10/100,000 population.

NDSC receives data on notifiable infectious diseases from around the country. Until recently, cryptosporidiosis was not notifiable in Ireland except as gastroenteritis in children under two years. Cryptosporidiosis accounted for approximately 8% of laboratory-confirmed cases of gastroenteritis in this age group. Information on cryptosporidiosis in other age groups was also received by NDSC but as it was

not a notifiable disease in these age groups, the information was incomplete. Two hundred and forty one cases of cryptosporidiosis were notified in 2001 with 70% in children aged 0-4 years of age. In 2002, there were 333 cases of cryptosporidiosis notified to NDSC with 73% in the 0-4 year age group.

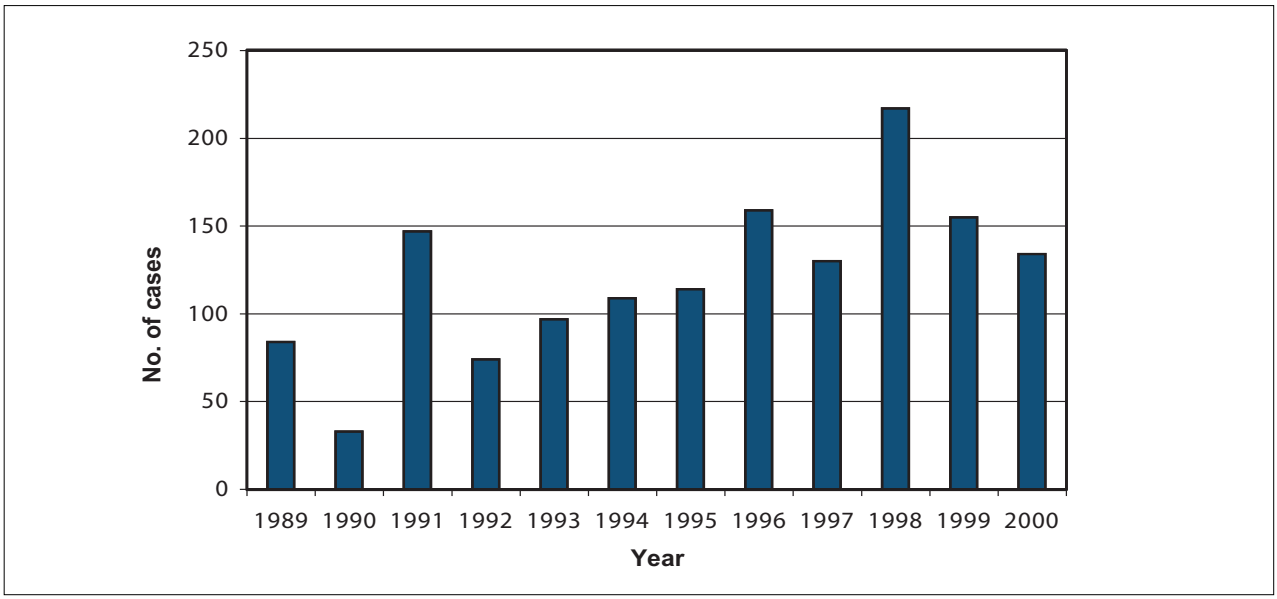


Figure 4: Laboratory cases of human cryptosporidiosis from INFOSCAN, 1989 -2000

On 1st January 2004, cryptosporidiosis became notifiable in Ireland. As of 13th November 2004, 377 cases of cryptosporidiosis were notified to NDSC (provisional data). The peak incidence of infection was in April and May, a pattern noted in other studies. The age-specific incidence rate was highest in the 0-4 year age group at 78.9/100,000 (table 2).

Table 2. Age-specific incidence rate of cryptosporidiosis in Ireland, January-13th November, 2004

Age group (years)	Number of cases	Rate per 100,000
0-4	219	78.9
5-14	75	13.4
15-24	21	3.3
25-34	17	2.8
35-44	18	3.2
45-54	6	1.3
55-64	1	0.3
65+	15	3.4
Total	**372**	**9.5**

The crude incidence rate varied across the health boards from 26.6/100,000 population in the Midland Health Board to 1.6/100,000 in the Eastern Regional Health Authority (table 3).

Table 3. Crude incidence rate per 100,000 population and 95% confidence interval (CI) of cryptosporidiosis, by health board, January-13th November, 2004

Health Board	Number of cases	Rate per 100,000	95% CI
ERHA	23	1.6	(1.0-2.3)
MHB	60	26.6	(19.9-33.4)
MWHB	31	9.1	(5.9-12.3)
NEHB	28	8.1	(5.1-11.1)
NWHB	40	18.1	(12.5-23.6)
SEHB	80	18.9	(14.7-23.0)
SHB	66	11.4	(8.6-14.1)
WHB	49	12.9	(9.3-16.5)
Ireland	**377**	**9.6**	**(8.7-10.6)**

6.11 Conclusions

The size and extent of the problem of cryptosporidiosis in Ireland is not well characterised, as there are no standard laboratory testing procedures for cryptosporidiosis and up until recently it was not notifiable. The new Infectious Disease Regulations which came into effect on 1st January 2004 include cryptosporidiosis as a notifiable disease and mandate laboratory directors to report cases. This will greatly improve surveillance and facilitate a clearer picture of the extent of the problem in Ireland. The higher incidence of cryptosporidiosis reported in children than in adults may reflect a greater susceptibility to infection.
It may, on the other hand, reflect a greater likelihood of a child visiting a GP, having a stool sample taken and laboratories being more likely to routinely test children's stool samples for cryptosporidiosis (Richardson *et al*, 1991).

Health Board and Local Authority Response

7.1 Introduction

The aim of this section is to provide a generic framework of action for health boards, in co-operation with other agencies, in circumstances where there may be a risk to drinking water from *Cryptosporidium*. The recommendations in this chapter are influenced by the document Drinking Water and Public Health (Departments of Public Health, 1998) and the UK Bouchier Report on *Cryptosporidium* in Water Supplies (Bouchier *et al*, 1998). The recommendations in this chapter are also influenced by the Department of the Environment guidelines for dealing with water incidents (Department of the Environment, 1992).

7.2 Health board structure

At present, there are 7 health boards in Ireland, and one regional health authority which comprises three area health boards. This structure is set to change in 2005. However, the recommendations in this report will not be essentially changed by the proposed new structure. Each health board/authority has a director of public health, who is the medical officer with responsibility for surveillance and control of infectious diseases in their area. The term medical officer (MO) has replaced the term medical officer of health, which was introduced in 1981 and meant as appropriate a director of community care and medical officer of health (DCC/MOH), the Dublin Medical Officer of Health, and a senior area medical officer or area medical officer of a health board. In 1998, the post of DCC/MOH was abolished and, under SI 251/1998, medical functions previously vested in or subject to the direction and control of the DCC/MOH were assigned to "*such medical officers as the CEO of each health board may determine*". Chief executive officers in all health boards assigned the MO duties to the relevant director of public health, but also requiring that he/she delegate the day-to-day functions of the MO to senior area medical officers.

The environmental health departments in most health boards carry out local authority functions on an agency basis, including the monitoring of the public water supply. The departments are headed by principal environmental health officers (PEHOs) who are supported by senior environmental health officers (SEHOs) and environmental health officers (EHOs). The PEHOs reports to general managers in the community care areas or assistant chief executive officers of the health boards. They work closely with senior area medical officers and the departments of public health.

7.3 Local authority structure

The local authorities are responsible for an extensive range of services including: planning; roads/transportation; water supply and sewage; development incentives and controls; environmental protection including rivers, lakes, air and noise; recreation facilities and amenities; agriculture, education, health and welfare. Under the Local Government Act 2001, a city or county manager heads the senior management team at local authority level. A director of service is responsible for each of the broad categories of service, including water. The director of service for water is assisted on the technical side by a senior engineer.

7.4 Pre–incident liaison groups

Both national and international guidelines envisage the establishment of pre-incident liaison teams at local level. The purpose of these local liaison groups (LLGs) acting as a support structure to the local authority in fulfilling its statutory obligations, should be as follows:

1. To support the local authority in fulfilling its statutory obligations with regard to local procedures for the monitoring of contamination of water, including contamination with *Cryptosporidium*.

2. To share information across agencies on trends in human gastro-intestinal illness and in cryptosporidiosis, and on the results of water quality sampling.

3. To provide access to maps and other information on water supply zones. The local authorities are using Geographic Information Systems (GIS) to map the public water supply schemes. GIS could also be used for mapping cases of cryptosporidiosis with supply zones.

4. To identify and interpret locally the significance of deviations in water quality indicators such as turbidity.

5. To meet and review water quality anomalies, including the presence of *Cryptosporidium* in the water, and to advise on appropriate actions, using local knowledge.

6. To develop local incident response plans in the event of an incident and to agree joint working procedures.

7. To advise on when the medical officer (MO) should be notified. *In the text when the medical officer (MO) is mentioned it refers to the director of public health or the person s/he has delegated the medical officer of health function to. This would usually be the specialist in public health medicine and/or the senior area medical officer (SAMO).*

8. To review results of risk assessments of water sources.

9. To look at the training needs of all personnel involved with the provision of potable water.

These LLGs should ideally have local authority representation including the sanitary/environmental engineer, environmental health, public health (medical officer) and clinical microbiology input. Other experts can be brought in as the need arises. It is noted that some health boards do not have access to consultant microbiology advice.

LLGs already exist in some areas and are working well. In the South Eastern Health Board a protocol for dealing with microbiological incidents in public water supplies has been agreed and adopted by the health board and all of the local authorities in the region. A Regional Water Liaison Committee has been established in the Southern Health Board (SHB) area. All the local authorities in the region and the SHB are involved with the committee. There are areas where the pre-incident liaison groups may work more effectively at community care/county level, but with the significant reorganisation of the local authority and public health services that have taken place in recent years, and the reorganisation of the health board structures that will take place shortly, a regional liaison group may be more appropriate.

The resources needed to deal with a waterborne outbreak of cryptosporidiosis are significant and should be planned for.

7.5 Action level for *Cryptosporidium* incidents

One of the difficulties in drawing up guidelines for the control of waterborne cryptosporidiosis is that the action level for defining a *Cryptosporidium* incident has not been well established. This is because of uncertainty over what level of *Cryptosporidium* oocysts causes human illness, whether oocysts that are detected are viable or not, differentiating between pathogenic and non-pathogenic cryptosporidia and what the relationship is between indicator organisms such as *Clostridium perfringens* and *Cryptosporidium* contamination.

Only one country to date, the United Kingdom, has put in place a mandatory limit for *Cryptosporidium* oocysts in water. In the United Kingdom, there is a legally enforceable requirement for daily monitoring of water supplies for *Cryptosporidium* oocysts, and a limit of 1 oocyst per 10 litres of water has been set (Department of the Environment, Transport and the Regions, 1999). This limit is not set on health grounds, but rather as a mechanism to allow the UK Drinking Water Inspectorate to ensure that water companies operated treatment plants more efficiently (Fairley, 1999). The regulations make it a criminal offence for the water companies to exceed the cryptosporidial oocyst limit in drinking water.

The costs of implementing a daily monitoring programme and upgrading water treatment plants to meet the requirements of such legislation are very high and may be disproportionate to the potential benefit. Some countries have opted for best-practice programmes appropriate for the circumstances of different water supplies.

In the Irish context, the Department of the Environment guidelines on the *Protection of Water Supplies from Contamination by Cryptosporidum* (Department of the Environment, Circular Letter L7/98) address the issue of monitoring of water supplies for *Cryptosporidium* oocysts. The guidelines state that in the first instance, water supplies should be monitored for *Clostridium perfringens*. If the level of this organism

exceeds 0/100ml, consideration should be given to monitoring for *Cryptosporidium* in raw and treated water. The level of *Cryptosporidium* that constitutes an incident is not specified. However, the guidelines state that the following factors should be taken into account in deciding whether a cryptosporidial incident has occurred:

- History of agricultural pollution of the source water.

.

- Exceptionally heavy rainfall following a dry spell, particularly following recent spreading of slurry.
- Recent operational changes in a water treatment works e.g. the bypassing or severe overloading of filters.

This subcommittee envisages that the LLGs will use local knowledge to aid interpretation of trends in water quality indicators, and determine a level for investigation and action, including notification of the MO, based on careful and thorough risk assessment. Until the LLGs have established these levels, detection of *Cryptosporidium* in water should always be notified to the MO. A risk assessment should be carried out on all water supply schemes. Supplies with minimal treatment facilities should be prioritised. Detection of *Cryptosporidium* oocysts in water should always warrant investigation.

The PHLS Guidelines (Hunter 2000) which list various factors that influence whether an oocyst count is significant or not should aid in this interpretation. The following are the facors that should be considered:

- When and where the sample was taken.
- The number of oocysts detected per 10L of water and the results of any viability testing.
- The species or type of oocysts detected.
- The source and treatment of the affected water supply (groundwater/surface water/full chemical treatment/filtration only/no filtration).
- The distribution area of the water supply and size of the population supplied.
- Whether any problems with the supply, such as treatment failure or high turbidity, have been identified.
- High oocyst counts in consecutive samples.
- Whether there have been any recent changes in the source and/or treatment.
- The history of *Cryptosporidium* sampling for this supply and whether there have been similar detections in the past.
- How fast water travels through the distribution area (is it likely that any of the contaminated water is still in the distribution system).
- Whether waterborne outbreaks of cryptosporidiosis have been associated with the supply in the past.
- The level of immunity in the exposed population.

7.6 General guidelines for the management of cryptosporidial incidents

In a water related incident, it is the responsibility of the local authority to ensure that high quality drinking water reaches the customer, and so the lead organisation in the management of a water contamination incident is the local authority.

It is essential that there is good co-operation and sharing of information between health boards and local authorities. Where it appears that *Cryptosporidium* may have contaminated the water supply source or the distribution system and public health may be at risk, the local authority should inform the MO/PEHO of the health board without delay. The MO will in turn provide advice on the risk to human health. Early notification to the health board is of paramount importance.

The nature and extent of the appropriate response will vary according to the particular circumstances, and will be influenced by detailed knowledge of the history of water quality indicators and local gastro-intestinal illness trends. The expertise of the LLGs will be used in this context.

Local authorities may establish an *Incident Response Team (IRT)* for dealing with an incident. The health board should be members of the IRT and will include the MO who will advise on the human health aspects of the incident, the PEHO and others as appropriate.

The IRT will deal with the overall management of the water incident in terms of finding the source of contamination, preventing the distribution of contaminated water to the public and where necessary providing an alternative water supply. They should:

- Maintain an incident log **including dates, times, key information and details of actions taken.**
- Consider the need for an onsite inspection at the location of the incident.
- Review the nature of the incident: size of water supply zone, number exposed, and any persons ill.

7.7 Check list for local authority members on incident response team

(a) Pollution in the water supply source

Where it appears that there is pollution in the water supply source, and that such pollution would be likely, based on a precautionary assessment of the situation, to represent a danger to the health of consumers the IRT should:

- Shut off the water intake to the treatment plant.
- Arrange for immediate and extensive sampling and analysis of source and distribution system.
- Establish whether there is contamination of the distribution system (including treatment, storage and pipe network).
- If distribution reservoir supplies are uncontaminated, conserve these supplies as much as possible.
- If the contamination is confined to the source, decide on measures to be taken to remedy contamination and implement them.
- Inform the public of the problem.

(b) Pollution in the water distribution system

Where it appears that there is pollution in the water distribution system, and it is likely, based on a precautionary assessment of the situation, to represent a danger to the health of consumers:

- Shut off supply to the affected areas.
- Activate the Public Alert system. Should a 'Boil Water' notice be implemented, the criteria for lifting it should be agreed by the IRT before it is put in place.
- Inform the chief fire officer regarding the flow and pressure limitations.
- Arrange for extensive sampling and analysis of supply throughout the distribution system.
- Decide on measures to be taken to remedy contamination and implement them.
- Use alternative water supply, if available, to clean, flush and disinfect the distribution system (note chlorination does not remove *Cryptosporidium*).
- Provide a safe alternative supply for consumers (tankers if necessary).

(c) Activation of Public Alert

A Public Alert should be activated where it appears that pollution has entered the drinking water distribution system and is likely, based on a precautionary assessment of the situation, to represent a

danger to the health of consumers. This decision should be taken on the advice of the health board representatives on the IRT. The local authority should:

- Provide a communications centre near the area affected.
- Designate a press officer.
- Provide a 24-hour freephone public information service. This service should have quick access to health board expertise.
- Have procedures for saturation leaflet drops to the public (first notice should be printed in advance. Leaflet should be headed PUBLIC ALERT in large bold capitals, and numbered as First Notice, Second Notice etc. (Appendix 4).
- Separate leaflets to be prepared by the MO and the EHO on the IRT or with their agreement, for those users involving services to which the Food Safety Legislation applies, e.g. hospitals, nursing/convalescent homes, restaurants, clubs, hotels, guest houses, shops/supermarkets, schools, crèches/pre-schools, dentists etc.
- Proprietors of swimming pool/leisure complexes should also be notified.
- Liaise with appropriate local bodies/organisations such as civil defence and community associations that can assist in getting advice to consumers as quickly as possible.
- Provide information to the public on cleaning and flushing of internal house systems.

(d) Advice on termination of the Public Alert

When sampling and analysis over an appropriate period shows that the danger to public health has passed, a leaflet terminating the Public Alert should be issued to all consumers in the affected areas. This should be done in consultation with, and on the advice of the MO.
This leaflet should:

- Assure consumers that the supplies have been tested and are safe, and thank them for their cooperation.
- Steps should be taken to reassure the public on the safety of their drinking water for a period after normal supplies have been restored.
- These reassurances should be based on further monitoring, probably by an agency independent of the local authority e.g. the environmental health department of the local health board.

7.8 Check list for health board members on the incident response team

Where a cryptosporidiosis incident occurs, the health board members of the IRT are tasked with managing the public health aspects of incident management. They should:

- Review the nature of the incident: size of water supply zone, number exposed, and any persons ill. Local GP practices should be contacted to assess the level of gastrointestinal infection in the community.
- It is important to be familiar with local laboratory practice as different sampling practices can initially obscure detection of an outbreak.
- Assess the degree of public health risk.
- If the information suggests that persons in the at-risk area(s) have been exposed, the need for case-finding etc. should be considered.
- If cases are found, then an outbreak control team (OCT) should be set up as per health board procedures (e.g. Model Plan for the Management of Communicable Disease Outbreaks. ERHA, 2000). Key members of the OCT are likely to be on the IRT already.

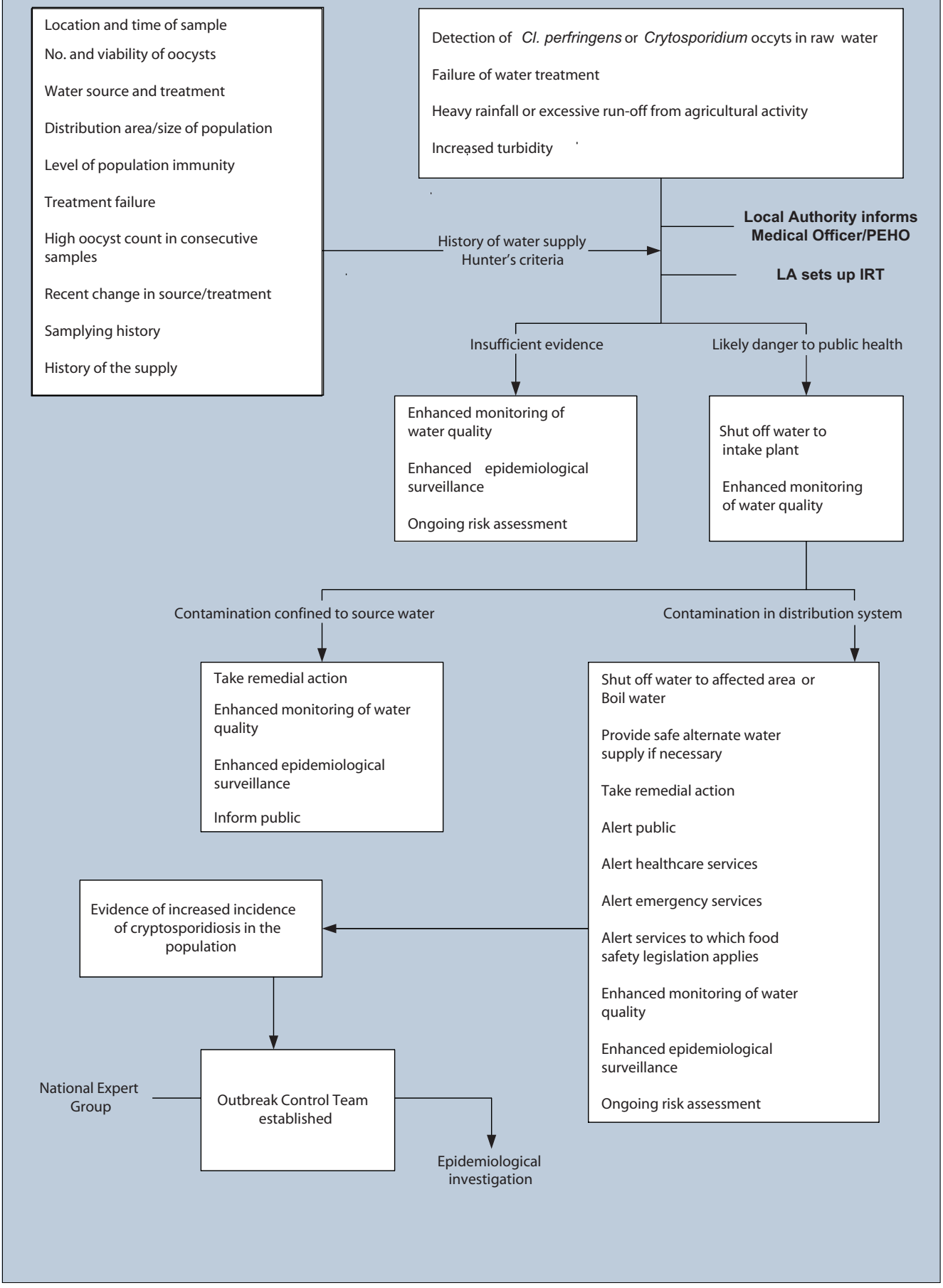
- An epidemiological investigation should be undertaken. The cryptosporidial questionnaire (Appendix 5) has been adapted from one developed by the Midland Health Board and may prove useful.
- Early referral of faecal samples to a reference laboratory for typing may help focus the investigation (genotype 1 indicating a human source, genotype 2 indicating a human or animal source).

In the event of a major outbreak, the OCT should consider seeking advice and assistance from the proposed National Expert Group.

7.9 Role of a national expert group

A national expert group, that can be called on for assistance in any event, should be formed. This group should include epidemiologists, public health doctors, microbiologists, environmental health officers, infection control nurses, vets and water engineers with experience of dealing with water related incidents, and ideally with experience of dealing with cryptosporidiosis outbreaks. Other international experts can be brought in as the need arises. The group should monitor the implementation of this report and review international research on an ongoing basis.

Flow Chart for Management of a *Cryptosporidium* Incident



Prevention of Cryptosporidiosis: Minimising the Risk of *Cryptosporidium* in Water Supplies

8.1 Sources of *Cryptosporidium* contamination of water

Cryptosporidiosis is transmitted by the ingestion of oocysts excreted in the faeces of infected humans or animals. Waterborne transmission can occur through contamination of drinking water or recreational water with *Cryptosporidium* oocysts. Food that is washed with contaminated water and served raw (e.g. lettuce) is another potential source of infection. Outbreaks associated with these forms of transmission have been documented.

The contamination of surface and ground water can occur through a variety of routes:

- Sewage works or septic tank seepage into water sources or entering the distribution through damaged pipes.
- Slurry tank spillage/overflow.
- Cattle yard run-off.
- Penetration of overburden during dry periods (ground fissured).
- Run-off associated with rainfall after manure spreading.
- Wastewater treatment plant effluents discharging into water sources or entering the water distribution system through damaged pipes.
- Water treatment sludge streams.
- In water treatment plants, the backwash waters in particular, are potentially a source of high oocyst concentration as the filters generally retain the bulk of the oocysts.
- Animal slaughtering/meat processing plants upstream of water supply abstraction points may also be a source of contamination.

8.2 Monitoring

Properly operated conventional treatment processes can provide a high level of protection from *Cryptosporidium* contamination. Although experience of *Cryptosporidium* is limited, a number of common features have been identified from the documented waterborne outbreaks to date. The evidence suggests that certain practices may give rise to conditions that favour the passage of oocysts through a treatment plant. In particular, there appears to be a risk of contamination under the following conditions:

- Following agricultural pollution of source water.
- Following exceptionally heavy rainfall after a dry spell, especially when associated with recent spreading of agricultural slurries.
- Following on or associated with major planned changes in operational practices at a treatment works i.e. bypassing of filters or severe overloading of filters.

Clearly the risk is higher for sources with minimal or no treatment.

While it is not feasible or practicable to undertake routine sampling and analysis for *Cryptosporidium* for all sources, each local authority has been asked to formulate a monitoring strategy which clearly sets out how often monitoring will be carried out having regard to the known risks and local circumstances. Where the need for monitoring is indicated, monitoring in the first instance should be for *Cl. perfringens* (including spores). Monitoring should be carried out at the tap, and, where the parametric value of 0/100ml is

exceeded, follow-up monitoring for *Cryptosporidium* should be undertaken on both the raw and treated water. In formulating a monitoring policy the local authority should take into account the following circumstances:

- Following exceptional contamination of water sources by agricultural pollution or sewage.
- For a transitional period when a significant planned change in a water treatment process or distribution network takes place.
- When, for exceptional operational reasons, the water treatment process is operating abnormally.
- When turbidity readings or levels of indicator or other organisms deviate from the normal ranges.
- If an outbreak of cryptosporidiosis in the community is suspected as being linked to a water supply.

8.3 Risk assessment

Risk assessment is a formal procedure wherein a detailed assessment is made of all of the factors that contribute to the potential risk associated with a particular event. The most important function of risk assessment is to identify and prioritise measures for improvement. In relation to *Cryptosporidium,* recent advances have led to the development of two separate risk assessment models in the UK, one for England and Wales and the other for Scotland. A third, the European Model, is currently being developed. These models are discussed in the following sections.

1. European model

As part of a European Commission research project entitled "A risk assessment on *Cryptosporidium parvum*, an emerging pathogen in the food and water chain in Europe," which ran from 2000-2003, a quantitative risk assessment was performed for *C. parvum* in water (EU Commission Report, 2003, QLK1 1999 007750). Microbial Risk Assessment is a specific part of a wider process known as Risk Analysis which has been defined by Codex Alimentarius (1998) (Alinorm 99/13A). Within this framework, risk analysis consists of three elements: risk assessment, risk management and risk communication. Risk assessment is the scientific part of the process in which the hazards and risk factors are identified and the risk posed by the agent is calculated. The risk assessment is based on four main elements:

- *Hazard identification*. In this case the hazard was *C. parvum* in unboiled potable water from a purification plant.
- *Exposure assessment*. Estimates the intake of the hazard by the consumer. In this case exposure to unboiled tap water from a purification plant was assessed and the risk factors taken into account were:
    - ◆ Raw water contamination with *C. parvum* oocysts.
    - ◆ Reduction in viable numbers during storage prior to purification.
    - ◆ Reduction during physical purification.
    - ◆ Reduction during chemical purification.
    - ◆ Amount of consumption.
- *Hazard characterisation*. Relates exposure to a public health effect (illness/death) usually from a dose-response relationship. In this risk model, dose-response relationships described in the literature for *C. parvum* (Haas *et al*, 1999; Teunis *et al*, 1999) were employed. These are based on a human feeding study (DuPont *et al*, 1995).

The initial level of contamination was the most important risk factor. This can be difficult to control but the level of contamination in the raw water and the resultant risk posed can be reduced by limiting the collection of water from areas likely to be contaminated, in particular, unprotected water sources where livestock are kept in the vicinity, or where animal waste or run-off water from agricultural land may

contaminate the water. When water is sourced from areas of high risk for contamination (i.e. unprotected water sources) a more stringent physical treatment of the water should be implemented. Once the oocysts are in the raw water, the most important risk factors are the length of storage of water before purification (physical treatments) and the type of treatment which the water receives.

It is anticipated that this risk assessment model will have considerable benefit to risk managers in the water industry in making decisions on whether current risk is acceptable and whether changes in current practices are necessary. The risk assessment will also be of considerable value in determining the reduction in risk that could be achieved from implementation of specific control/intervention measures and in setting the critical levels of *C. parvum* that are acceptable in water. This is a dynamic based model that can be added to over time as more data become available or can be modified to reflect the risk in a specific region or situation, based on local data. It may also be used in the water industry in carrying out cost benefit analysis.

2.Scottish model

In Scotland under "The Cryptosporidium (Scottish Water) Directions 2003," water authorities are required to carry out a risk assessment for each of their water supplies using a prescribed scoring system that is appended to the Directions (Scotish Executive, 2003). In essence the model is a quantitative assessment of all of the factors that might affect the occurrence of a waterborne outbreak of cryptospoidiosis, including the following:

- The degree of exposure of the catchment to oocysts.
- Agricultural practices.
- Sewage inputs.
- Water source type.
- River and intake management.
- Water treatment.
- Treatment works monitoring.
- Performance and operational factors.
- *Cryptosporidium* monitoring and epidemiology.

The assessment makes every effort to take into account the recommendations of the Third Report of the Group of Experts (Bouchier Report). The methodology is based on a simple scoring system that assesses the risk by identifying the potential for *Cryptosporidium* to be present in the water. A further population-weighting factor is then applied to compute the risk assessment score. The higher the score, the higher the potential risk. Depending on the score the supply is classified as *High Risk*, *Moderate Risk* or *Low Risk*. Each risk classification has an associated "action to be taken by water authorities on completion of a risk assessment." The advantage of this model is that it can be applied with basic local knowledge and will identify factors contributing to high-level scores. This in turn will identify areas where the risk assessment score can be reduced, and so enable the risk classification to be reduced. It is considered that this model is an acceptable model in an Irish context (with adaptations to fit the Irish situation) and should be used for formal assessment of those supplies that are considered to be at significant risk. The EPA have adapted the Scottish risk assessment model for use in the Irish situation (EPA, 2004) and recommend its use by sanitary authorities.

3. English model

The Drinking Water Inspectorate (DWI) has issued a document entitled "Guidance on Assessing Risk for *Cryptosporidium* Oocysts in Treated Water Supplies to Satisfy The Water Supply (Water Quality) (Amendment) Regulations 1999, SI 1524" for England and Wales.

The Water Supply (Water Quality) (Amendment) Regulations require water companies to carry out a risk assessment for each of their treatment works in accordance with guidelines issued by the Secretary of

State, to establish whether there is a significant risk from *Cryptosporidium* oocysts in water supplied from the works. In this model all of the factors contributing to the potential risks are identified (Annex B of guidance). The Water Company must respond to and, where necessary, supply additional information on, each factor that applies to each water supply system and also address any other factors that are important locally. Following this exercise the water authority must then complete an assessment conclusion and submit same to the DWI for acceptance or otherwise. This qualitative model is somewhat subjective and is not considered to be appropriate in an Irish context.

8.4 Risk reduction/minimisation

The potential for risk minimisation arises in two principal areas and these are addressed in the following sections:

1. Catchment

It is generally accepted that *Cryptosporidium* oocysts exist widely in the natural environment as a result of contamination with animal and human faeces. It is clear that a number of measures can be adopted which would proactively manage and minimise the potential risk of a waterborne outbreak. A well-formulated and implemented catchment management plan (Department of the Environment, 1997) can improve the level of protection. To do this effectively, it is important to assess the relative risk from animal and human waste for each water catchment area.

Local authorities have extensive statutory powers available to them under the Water Pollution Acts 1977 and 1990 and the Waste Management Act 1996, to control agricultural activities presenting a threat to water quality including manure and slurry storage and disposal arrangements, e.g. landspreading. These powers should be availed of, as appropriate, to protect water supply sources, including contamination risks arising from direct access by farm animals to rivers and lakes. Attention should also be given to the protection of groundwater sources of supply with restrictions imposed, as necessary, on agricultural practices within the immediate area of the point of abstraction and the zone of contribution to the groundwater resource.

The Department of Agriculture and Food (DAF) have undertaken various initiatives to promote good agricultural practices to protect water quality. The initiatives include The Rural Environmental Protection Scheme (REPS) operated by DAF which rewards farmers for carrying out their farming activities in an environmentally friendly manner, including the protection and maintenance of all watercourses and wells. The Farm Waste Management Scheme that aims to improve waste storage capacity on farms. DAF have also introduced a code of practice - *Good Farming Practice* - for all farmers claiming aid under direct payment and other national schemes operated by them (Department of Agriculture, Food and Rural Development, 2001). Compliance with the code is compulsory for all farmers participating in these schemes.

In 1991, the EU member States adopted The Nitrates Directive (91/676/EEC) which is aimed at protecting waters against pollution caused by nitrates from agricultural sources. The DEHLG and DAF have issued a draft action programme for consultation with interested parties on the further implementation of the Nitrates Directive (DEHLG and DAF, 2003). Following consultation regulations will be drafted which will be legally binding on all farmers. It is hoped that this legislation will be in place by the middle of this year.

The Directive requires Member States to:

- Identify and monitor waters that are polluted or liable to pollution.
- Develop and implement action programmes to reduce and prevent pollution of waters from agricultural sources.
- Monitor the effectiveness of action programmes.

Animal slaughtering/meat processing plants upstream of water supply abstraction points should be investigated and the local authority, or in the case of licensed activities the local authority or the EPA as appropriate, should ensure that a high standard of operation/ maintenance of wastewater treatment in such premises is achieved.

Under the Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 to 2001, local authorities have the power to control the spreading, on agricultural land, of residual sludge from sewage plants treating domestic or urban waste-waters, in order to ensure that the quality of surface water and ground water is not impaired. The EPA has the power to specify and publish criteria and procedures in relation to the operation of sanitary authority water and sewage treatment plants (Environmental Protection Agency Act, 1992).

The EPA has also issued guidance manuals for the siting of on-site wastewater treatment systems for single houses [Wastewater Treatment Manuals: treatment for single houses (EPA, 2000)]; and for small communities, business, leisure centres and hotels [Wastewater Treatment Manuals: treatment systems for small communities, business, leisure centres and hotels (EPA, 1999)]. The local authorities use these guidelines in the planning process.

2. Water treatment plant and distribution networks

In the abstraction and treatment of water careful attention should be paid to the following points:

- In the operation of rapid filters, sudden surges of flow should be avoided which might dislodge retained solids.
- Rapid filters should not be restarted after shutdown without backwashing.
- After cleaning, slow sand filters should not be brought back into use without an adequate "ripening" period.
- Bypassing of part of the water treatment process should be avoided.
- Recycling of backwash water should be avoided as a precaution in times of intense rainfall or after a pollution incident.
- Consideration should be given to the installation of monitors to make it possible to measure the turbidity of each rapid filter to assist early detection of conditions that may favour the breakthrough of oocysts into the treated water.
- The value of coagulant aids should be assessed with a view to optimising flocculation.
- All borehole linings and seals should be maintained to a high standard.
- Local authorities should ensure that the grazing of livestock is not practised on or near grass-covered reservoirs.
- Significant leaks in the distribution system should be repaired promptly.

In addition the following points should always be noted and optimised:

- Coagulant dose and brand/type selection should always be optimal.
- Optimise pH for coagulation.
- The use of flocculant aids should be evaluated.
- Ensure adequate mixing and contact time at flocculation stage.
- The operation of sludge bleeds should be checked regularly.
- Always avoid sludge blanket disturbance by flow variation or by wind effects.
- Downrate plant if possible to maximise particle entrapment.

- Backwash rapid gravity filters as frequently as possible consistent with maintenance of throughput.
- Ensure that depth of media is maintained above the minimum level, particularly on slow sand filters.
- Carefully control filter start-up procedures. Run filters on slow start after they return to service, or preferably run to waste until filtrate turbidity is satisfactory.
- Ensure that part-used filters (both rapid and slow) are never returned to service without cleaning.
- Monitor continuously or regularly turbidity of water from individual filters.
- Achieve consistently lowest possible turbidity, as this will minimise oocyst breakthrough.
- Monitor filter headloss.
- Control filter backwash cycle to ensure maximum allowable headloss or turbidity of filtrate are not exceeded.
- Consider conditioning of water prior to filtration with polyelectrolyte (rapid filter only).
- Consider pre-conditioning of filter bed by addition of polyelectrolyte to final rinse of backwash water (rapid filter only).
- Divert filter backwash water and other process waste waters so that they are not returned to the works without special treatment. Recycling of contaminated backwash water can return a substantial oocyst load to the headworks.
- Make arrangements for the safe disposal of waste process water if it is likely to be contaminated.
- Inspect, clean out, and ensure removal of all sludges from contact tanks.
- With service reservoirs inspect clean out and remove all sludges. Repair all defects (with butyl sheets for example) if rainwater can seep in.
- Introduce program of flushing and/or scouring to remove suspect water and any contaminated mains deposits from the distribution system.

8.5 Point of use devices

There are several point of use devices available which are either intended to produce a physical barrier against impurities or a treatment stage for specific removal of certain substances. Some units are plumbed into mains supplies: others are simply jugs fitted with filters.

- Mechanical filters may be constructed of wound textiles, microporous plastics or porous ceramics and can be effective at removing particulate matter. However, removal of oocysts will depend on pore size. These filters need to be replaced or cleaned regularly and care should be taken in disposing of the used elements.
- Some experimental results reported suggest strongly that ozone, at the concentrations used in water treatment, inactivates oocysts. Inactivation rates of 99% are achievable with contact time values of 5-10 minutes.
- Distillation units are found in hospitals, laboratories but not in domestic properties. These are effective against oocysts but it is not recommended that distilled water be used for drinking purposes as there is very little scientific information on the benefits or hazards of regular consumption of distilled water.

- Reverse osmosis units employ a membrane system and, to be effective, would need to be maintained in accordance with the manufacturer's instructions.
- Activated carbon is commonly used in a cartridge form to improve the organic quality, including taste. Experience would suggest that this is not effective in removing oocysts.
- Ion exchange units employ a cartridge containing resin beads. It is unlikely that these would provide an effective barrier against oocysts.
- Ultraviolet radiation at certain wavelengths can inactivate *Cryptosporidium* oocysts.

8.6 Recommendations

This subcommittee recommends that:

- All providers of water for human consumption should be required to undertake a risk assessment of their water supply.
- The Scottish Risk Assessment model that has been adapted by the EPA should be used in Ireland.
- Sites that might be considered high-risk e.g. minimal treatment surface water supplies should be prioritised for risk assessment.
- Laboratory facilities should be available regionally and nationally for monitoring *Cryptosporidium* in water.
- There should be initiatives to enforce the legislation on the proper disposal of animal waste and on the avoidance of run-off from agricultural land into potable water supplies.
- Education programmes which include information on the risks of cryptosporidial infection/contamination and advice on avoiding or minimising the risks should be targeted at the agricultural industry, and local authority personnel.
- When new private water supplies are being proposed, owners should be made aware of the potential for water contamination and what can be done to reduce the risks.
- There should be initiatives to raise awareness of the EPA guidance manuals for the siting of on-site wastewater treatment systems for single houses; and small communities, business, leisure centres and hotels.

Prevention of Waterborne Cryptosporidiosis In Immunocompromised Individuals

9.1 Introduction

Disease manifestation and duration differ in the immunocompetent and immunocompromised host. In the immunocompetent host, cryptosporidiosis presents as a self-limiting acute diarrhoeal illness lasting 1-2 weeks, which may be accompanied by abdominal cramps, nausea and low-grade fever.

In the immunocompromised host cryptosporidiosis is a common cause of diarrhoea. However, severe and chronic watery diarrhoea is associated with those with markedly impaired immune systems and CD4 cell counts less than 180 cells/mm^3. Until recently, there was no curative antimicrobial treatment for cryptosporidiosis. However, in a recent study in Zambia, nitazoxanide showed promising results in children who were HIV-seronegative but not in those who were HIV-seropositive. The most effective way of dealing with cryptosporidiosis in immunocompromised individuals is the maintenance of immune system function and limiting exposure to *Cryptosporidium*.

The number of cases of cryptosporidiosis has declined dramatically since the routine use of highly active antiretroviral therapy (HAART) for treatment of HIV infection. Treatment results in immune recovery, which is protective against the disease (Manabe *et al*, 1998). If infection does occur in the presence of HAART, the diarrhoeal illness is self-limiting with a clinical and microbiological response similar to immunocompetent hosts. This therapeutic response is sustained over time (Maggi *et al*, 2000). However, the risk from cryptosporidiosis still remains for the small number of HIV patients with lowered CD4 counts who may not be on HAART.

There are different ways of dealing with the problem of waterborne cryptosporidiosis in immunocompromised individuals. The United States and the United Kingdom guidelines are discussed here in turn and are compared and contrasted.

9.2 United Kingdom guidelines

The most recent United Kingdom guidelines for prevention of cryptosporidiosis in immunocompromised individuals are contained in *Cryptosporidium* in Water Supplies: Third Report of the Group of Experts (Bouchier *et al*, 1998).

The guidelines are aimed at immunocompromised individuals, including persons infected with HIV, those with other immune deficiency conditions; hypo- or agammaglobulinemia, hyperimmunoglobulinemia, hyperimmunoglobulin M Syndrome and severe combined immunodeficiency. They are also aimed at persons with immune deficiency due to conditions such as leukaemia, and those on high dose immunosuppressive therapy.

The UK Guidelines make the following recommendations:

- Patients should be educated on the routes of transmission of cryptosporidiosis.
- They should avoid contact with human or animal faeces. They should be advised to wash their hands after nappy changing, after handling pets and after gardening or other contact with soil.
- In relation to household pets, they should avoid bringing animals with diarrhoeal illness into their household, adopting stray animals or purchasing cats and dogs aged less than six months. *C. parvum* is predominately a parasite of neonatal animals. Older animals rarely develop infections.
- Patients should avoid contact with farm animals such as calves and lambs and premises where these animals are raised.
- Patients should avoid swimming in water that may be at risk of contamination, such as river or lake water, and avoid swallowing water during swimming.
- Patients should boil all water, from whatever source, before consuming it. This applies in both outbreak and non-outbreak situations, and also applies to bottled waters.

These UK guidelines have come in for some criticism, particularly in relation to their recommendation that all immunocompromised patients should boil tap water, both in outbreak and in non-outbreak situations. An editorial in the *Journal of Hospital Infection* addressed the issues raised by the Bouchier Report (Cunningham R, 1999). This editorial highlighted the lack of involvement by infectious disease physicians or consultants in communicable disease control in the working group. It questioned the validity of the recommendations covering all patients with immunodeficiency disorders. It noted that the severity of cryptosporidiosis in persons with CD4 counts over 180 cells was not markedly different from immunocompentent persons.

It also noted that the recommendations cover patients who have humoral immunodeficiencies, where the evidence for a significant risk from cryptosporidiosis is lacking. The paper concluded by stating that the Bouchier recommendations may cause anxiety and disruption to immunocompromised persons, and that the report failed to distinguish between recommendations based on expert opinion and recommendations based on clinical evidence.

In response to these concerns a working group chaired by Professor Ian Bouchier met and further clarified which groups of immunocompromised patients are at particular risk of cryptosporidiosis infection and should boil their drinking water. The level of T-cell function and the duration of any immune suppression were considered to be crucial factors in susceptibility to *Cryptosporidium*. People with HIV infection who are immunocompromised, children with severe combined immunodeficiency (SCID) and those with specific T-cell deficiencies such as CD40 ligand deficiency (Hyper IgM Syndrome) should be advised to boil and cool their drinking water from whatever source (Chief Medical Officer, 1999).

9.3 United States guidelines

In 1995, the U.S. Public Health Service (USPHS) and the Infectious Diseases Society of America (IDSA) developed guidelines for preventing opportunistic infections in persons infected with human immunodeficiency virus. These guidelines were updated in 1999 (USPHS/ IDSA, 1999). The guidelines provide ratings indicating the strength of each recommendation and the quality of supporting evidence, and thus readers are able to assess the relative importance of each recommendation.

The 1999 guidelines are similar to the UK Guidelines, in that they make similar recommendations with regard to hand washing following certain household tasks, contact with household pets, contact with certain farm animals and swimming in rivers and lakes. However, they differ from the UK guidelines in the following respects:

- The guidelines only refer to persons with HIV, and not those with other immunodeficiency disorders.
- The US guidelines do not recommend boiling water in non-outbreak situations. They state that the magnitude of risk of acquiring cryptosporidiosis from tap water is uncertain, and conclude that there is currently insufficient data to recommend boiling tap water in non-outbreak situations.
- The US guidelines state that individuals may wish to take independent action to reduce their risk by boiling water or using microfilters that remove oocysts.

The US guidelines make additional suggestions in relation to other risk factors:

- In hospitals, individuals who are severely immunocompromised should not share a room with patients who have cryptosporidiosis.
- Individuals should avoid eating oysters, as oocysts can survive for up to two months in commercial oyster beds.

9.4 Proposed Irish guidelines

The waterborne cryptosporidiosis review group have reviewed the United Kingdom and US guidelines. The group recognize that Ireland differs from these countries in that the majority of water supplies are provided by local authorities rather than private water utilities. In addition, approximately 20% of water supplies originate from private GWSs, where the monitoring of water quality may be more challenging.

The group are broadly in agreement with the US policy of boiling tap water in outbreak situations only, rather than routinely boiling water as recommended in the UK guidelines. However, the group recommend that doctors should carry out an individual assessment of patient risk, particularly those living in areas covered by group water schemes. An information leaflet should be provided to patients and clinicians so that they can make an informed judgement on the issue of boiling of tap water. This advice is dependent on individuals having ready access to information on the source and treatment of their drinking water supply.

The group have made the following recommendations for the prevention of cryptosporidiosis in immunocompromised individuals. The recommendations are rated according to the strength of the recommendation and the quality of the supporting data as set out in Tables 4 and 5:

*Table 4: System used to rate the strength of recommendations.**

Rating	Strength of Recommendation
A	Both strong evidence for efficacy and substantial clinical benefit support recommendation for use. Should always be offered.
B	Moderate evidence for efficacy or strong evidence for efficacy but only limited clinical benefit supports recommendation for use. Should generally be offered.
C	Evidence for efficacy is insufficient to support a recommendation for or against use, or evidence for efficacy might not outweigh adverse consequences (e.g. drug toxicity, drug interactions) or cost of the chemoprophylaxis or alternative approaches. Optional.
D	Moderate evidence for lack of efficacy or for adverse outcome supports a recommendation against use. Should generally not be offered.
E	Good evidence for lack of efficacy or for adverse outcome supports a recommendation against use. Should never be offered.

*Modified from the Infectious Disease Society of America Quality Standards for Infectious Diseases (Gross PA *et al*, 1994).

*Table 5: System used to rate the quality of evidence supporting the recommendation.**

Rating	Quality of evidence supporting the recommendation
1	Evidence from at least one properly randomised controlled trial.
11	Evidence from at least one well-designed clinical trial without randomisation, or from cohort or case-controlled analytic studies (preferably from more than one centre), or from multiple time-series studies, or dramatic results from uncontrolled experiments.
111	Evidence from opinions of respected authorities based on clinical experience, descriptive studies or reports of expert committees.

*Modified from the Infectious Disease Society of America Quality Standards for Infectious Diseases (Gross PA *et al*, 1994).

- Patients should be educated and counselled about the many ways that *Cryptosporidium* can be transmitted (**B111**). Modes of transmission include having direct contact with infected adults, children in nappies, and infected animals; drinking contaminated water; coming into contact with contaminated water during recreational activities; and eating contaminated food.

- Patients should use care in handling human or animal excreta (this includes handling of colostomy bags etc). They should be advised to wash their hands after changing nappies or contact with soil during gardening or after contact with animals (**B111**).

- In relation to household pets, they should avoid bringing animals with diarrhoeal illness into their household, adopting stray animals or purchasing cats and dogs aged less than six months (**B111**).

- Patients should avoid contact with farm animals such as calves and lambs and premises were these animals are raised (**B11**).

- Patients should be aware that many lakes, rivers and some swimming pools might be contaminated with *Cryptosporidium*. They should avoid swimming in water that is likely to be contaminated, particularly during an outbreak (**B111**).

- Avoid drinking water directly from rivers and lakes (**A111**).

- Physicians should make an individual assessment of a patient's risk of waterborne cryptosporidiosis. During outbreak situations, patients should be advised to bring water to the boil to eliminate *Cryptosporidium* spores. (**A1**).

- In hospitals, individuals who are severely immunocompromised should not share a room with patients who have cryptosporidiosis (**C111**).

- Individuals should avoid eating oysters, as oocysts can survive for up to two months in commercial oyster beds (**B111**).

- At risk patients should be provided with the information leaflet (Appendix 6).

References

Alves M, Xiao L, Sulaiman I, Lal AA, Matos O, Antunes F. Subgenotype analysis of *Cryptosporidium* isolates from humans, cattle and zoo ruminants in Portugal. *J Clin Microbiol* 2003; **41** (6): 2744-2747.

Amadi B, Mwiya M, Musuku J, Watuka A, Sianongo S, Ayoub A, Kelly P. Effect of nitazoxanide on morbidity and mortality in Zambian children with cryptosporidiosis: a randomised controlled trial. *Lancet* 2002; **360**: 1375-1380.

Baker M, Russell N, Roseveare C, O'Hallahan J, Palmer S, Bichan A. Outbreak of cryptosporidiosis linked to Hutt Valley swimming pool. *The New Zealand Public Health Report* 1998; **5** (6): 41-45.

Bayer MR, Wright AE. *Cryptosporidium* and water. *Lett Appl Microbiol* 1990; **11**: 272-277.

Bouchier *et al*. *Cryptosporidium* in water supplies. Third Report of the Group of Experts to: Department of the Environment, Transport and the Regions and Department of Health; 1998.

Bridgman SA, Robertson RMP, Syed Q, Speed N, Andrews N, Hunter PR. Outbreak of cryptosporidiosis associated with a disinfected groundwater supply. *Epidemiol Infect* 1995*;* **115**: 555-566.

Carson JWK. Changing patterns in childhood gastroenteritis. *IMJ* 1989; **82** (2): 66–67.

Casemore DP, Roberts C. Guidelines for screening for *Cryptosporidium* in stools: report of a joint working group. *J Clin Pathol* 1993; **46**: 2-4.

Chalmers RM, Hughes S, Thomas AL, Woodhouse S, Thomas PD, Hunter P. Laboratory ascertainment of *Cryptosporidium* and local authority policies for investigating sporadic cases of cryptosporidiosis in two regions of the United Kingdom. *Commun Dis Public Health* 2002; **5**(2): 114-8.

Chalmers RM, Sturdee AP, Mellors P, Nicholson V, Lawlor F, Kenny F, Timpson P. *Cryptosporidium parvum* in environmental samples in the Sligo area, Republic of Ireland: a preliminary report. *Lett Appl Microbiol* 1997; **25**: 380-384.

Chief Medical Officer. *Cryptosporidium* in water: clarification of the advice to the immunocompromised. *CMO's Update 23*; August 1999: 4.

Chin J. Control of Communicable Diseases Manual. Washington: American Public Health Association; 2000.

Clark DP. New insights into human cryptosporidiosis. *Clin Microbiol Rev* 1999; **12** (4): 554-563.

CDC. Working Group on Waterborne Cryptosporidiosis. *Cryptosporidium* and water: a public health handbook. Atlanta: Centers for Disease Control and Prevention; 1997.

CDC. Protracted outbreak of cryptosporidiosis associated with swimming pool use – Ohio and Nebraska, 2000. *MMWR* 2001; **50**(20): 406-410.

CDC. Summary of notifiable diseases – United States, 2002. *MMWR* 2002; **49**(53).

CDC. Fact sheet. Preventing cryptosporidiosis: a guide for people with compromised immune systems. Available at www.cdc.gov/ncidod/dpd/parasites/cryptosporidiosis/factsht_crypto_prevent_ci.htm

Codex Alimentarius Commission. Draft principles and guidelines for the conduct of a microbial risk assessment. WHO, 1998; ALINORM 99/13A.

Communicable Disease Australia. National notifiable disease surveillance system. Available at www1.health.gov.au/cda/Source/Rpt_5.cfm

CDSC. Cryptosporidiosis associated with swimming pools. *Commun Dis Rep CDR Wkly* 1999; **9** (48): 1.

CDSC. Surveillance of waterborne disease and water quality: January to June 2001, and summary of 2000. *Commun Dis Rep CDR Wkly* 2001; **11** (45).

Corbett-Feeney G. *Cryptosporidium* among children with acute diarrhoea in the West of Ireland. *J Infect* 1987; **14**: 79-84.

Crook P, Mayon-White R, Reacher M. Enhancing surveillance of cryptosporidiosis: test all faecal specimens from children. *Commun Dis Public Health* 2002; **5** (2): 112-3.

Cunningham R. The Bouchier Report- a recommendation too far? *J Hosp Infect* 1999; **41**: 261-262.

Current WL, Garcia LS. Cryptosporidiosis. *Clin Microbiol Rev* 1991; **4**(3): 325-358.

Dadswell JV. Managing swimming, spa, and other pools to prevent infection.
Commun Dis Rep CDR Rev 1996; **6** (2): R37-40.

D'Antonio RG, Winn RE, Taylor JP, Gustafson TL, Current WL, Rhodes MM *et al*. A waterborne outbreak of cryptosporidiosis in normal hosts. *Ann Intern Med* 1985; **103** (6): 886-888.

Department of Agriculture, Food and Rural Development, 2001. Good Farming Practice. Available at www.agriculture.gov.ie/publicat/good_farming_b.pdf

Department of the Environment. Protection of drinking water supplies: guidelines for local authorities. Department of the Environment, 1992.

Department of the Environment. Managing Ireland's rivers and lakes – a catchment based strategy against eutrophication. Department of the Environment, 1997.

Department of the Environment and Local Government. Protection of Water Supplies: Guidelines for Local Authorities on minimising the risk of *Cryptosporidium* in water supplies. Circular L7/ 98. Department of the Environment and Local Government; 1998.

Department of the Environment, Heritage and Local Government and Department of Agriculture and Food. Draft action programme under the Nitrates Directive 91/676/EEC. Consultation document, December 2003.

Department of the Environment, Transport and the Regions. The Water Supply (Water Quality) (Amendment) Regulations 1999. Statutory Instrument 1999 No. 1524. London: Stationary Office; 1999.

Departments of Public Health. Drinking Water and Public Health. Joint document produced by Departments of Public Health, 1998.

DuPont HL, Chappell CL, Sterling CR, Okhuysen PC, Rose JB, Jakubowski W. The infectivity of *Cryptosporidium parvum* in healthy volunteers. *N Engl J Med* 1995; **332**(13): 855-9.

Dworkin MS *et al*. *Cryptosporidiosis* in Washington State: an outbreak associated with well water. *J Infect Dis* 1996; **174**(6): 1372-1376.

Eastern Health and Social Services Board, Northern Ireland. Report of an outbreak of cryptosporidiosis in the Eastern Board Area during April and May 2000. Department of Public Health Medicine, 2000.

Eastern Health and Social Services Board, Northern Ireland. Report of an outbreak of cryptosporidiosis during August and September 2000 in the Lisburn, Poleglass and Dunmurry areas of the Eastern Board. Department of Public Health Medicine, 2001.

Environmental Health Officers Association/The Institute of Leisure and Amenity Managers. Environmental health standards for swimming pools, spa pools, hydrotherapy pools and other multi-user pools. 2002. ISBN:0-9537955-1-9.

Environmental Protection Agency. Wastewater treatment manuals: treatment systems for single houses. EPA, 2000.

Environmental Protection Agency. Wastewater treatment manuals: treatment systems for small communities, business, leisure centres and hotels. EPA, 1999.

Environmental Protection Agency. European Communities (Drinking Water) Regulations, 2000 (S.I. 439 of 2000). A handbook on implementation for sanitary authorities. EPA 2004. ISBN 1-84095-141-9.

Environmental Protection Agency. The quality of drinking water in Ireland: a report for the year 2001. Environmental Protection Agency, 2002.

Environmental Protection Agency. The quality of bathing water in Ireland (2000). Environmental Protection Agency 2001.

ESR (Institute of Environmental Science and Research Limited). Infectious diseases in New Zealand: 2002 annual surveillance summary. May 2003. Available at www.esr.cri.nz/frame.html?content=/what_we_do/communicable_disease/

Fairley CK, Sinclair MI, Rizak S. Monitoring not the answer to *Cryptosporidium* in water. *Lancet* 1999; **354**: 967-969.

Fayer R. *Cryptosporidium* and cryptosporidiosis. Boca Raton: CRC Press; 1997.

Fricker CR, and Crabb JH. Waterborne cryptosporidiosis: detection methods and treatment options. *Adv Parasitol* 1998; **40**: 241-278.

Galmes A *et al*. Cryptosporidiosis outbreak in British tourists who stayed at a hotel in Majorca, Spain. *Eurosurveillance Weekly* [Serial online] 2003 [cited, 14 August 2003] **33**. Available at http://www.eurosurveillance.org/ew/2003/030814.asp

Garvey P, McKeown P. Hospitalisations from cryptosporidiosis in Ireland, 1999-2002. *Epi-Insight* 2004; **5**(6).

Glaberman S *et al*. Three drinking-water-associated cryptosporidiosis outbreaks, Northeren Ireland. *Emerg Infect Dis* 2002; **8** (6): 631-633.

Goldstein ST, Juranek DD, Ravenholt O, Hightower AW, Martin DG, Mesnik JL *et al*. Cryptosporidiosis: an outbreak associated with drinking water despite state-of-the-art water treatment. *Ann Intern Med* 1996; **124**: 459-468.

Gross PA, Barrett TL, Dellinger EP, Krause PJ, Martone WJ, McGowan JE *et al*. Infectious Disease Society of America quality standards for infectious diseases: purpose of quality standards for infectious diseases. *Clin Infect Dis* 1994; **18**: 421.

Haas CN, Rose JB, Gerba CP. Quantitative microbial risk assessment. John Wiley and Sons, Inc., 1999; ISBN: 0471183970.

Harp JA, Fayer R, Pesch BA, Jackson GJ. Effect of pasteurisation on infectivity of *Cryptosporidium parvum* oocysts in water and milk. *Appl Environ Microbiol* 1996; **62**(8): 2866-2868.

Hayes EB, Matte TD, O'Brien TR, McKinley TW, Logsdon GS, Rose JB *et al*. Large community outbreak of cryptosporidiosis due to contamination of a filtered public water supply. *N Engl J Med* 1989; **320** (21): 1372-1376.

Hoxie NJ, Davis JP, Vergeront JM, Nashold RD, Blair KA. Cryptosporidiosis-associated mortality following a massive waterborne outbreak in Milwaukee, Wisconsin. *Am J Public Health* 1997; **87**: 2032-35.

Hunter PR. Advice on the response from public health and environmental health to the detection of cryptosporidial oocysts in treated drinking water. *Commun Dis Public Health* 2000; **3**: 24-27.

Hunter PR. Waterborne disease: epidemiology and ecology. Chicester: Wiley; 1997.

Jennings P, Rhatigan A. Cryptopsoridiosis outbreak. *Epi-Insight* 2002; **3**(4): 1.

Jennings P, Rhatigan A. Cryptosporidiosis outbreak in Ireland linked to public water supply. *Eurosurveillance Weekly*, [Serial online] 2002 [cited, 30 May 2002] **22**. Available at www.eurosurveillance.org/ew/2002/020530.asp

Juranek DD, MacKenzie WR. Drinking water turbidity and gastrointestinal illness. *Epidemiology* 1998; **9**(3): 228-31.

Khan OA. A review of cryptosporidiosis. Available at www.cdfound.to.it/HTML/khan.htm

Kao TC, Ungar BL. Comparison of sequential, random and hemacytometer methods for counting *Cryptosporidium* oocysts. *J Parasitol* 1994; **80**(5): 816-19.

Kehl KS, Cicirello H, and Havens PL. Comparison of four different methods for detection of *Cryptosporidium* species. *J Clin Microbiol* 1995; **33**(2): 416-418.

Kosek M, Alcantara C, Lima AAM, Guerrant RL. Cryptosporidiosis: an update. *Lancet. Infectious Diseases* 2001; **1**(4): 262.

Kramer MH, Sorhage FE, Goldstein ST, Dalley E, Wahlquist SP, Herwaldt BL. First reported outbreak in the United States of cryptosporidiosis associated with a recreational lake. *Clin Infect Dis* 1998; **26**: 27-33.

Lisle JT, Rose JB. *Cryptosporidium* contamination of water in the USA and UK: a mini review. *J Water SRT-Aqua* 1995; **44** (3): 103-117.

MacKenzie WR, Hoxie NJ, Proctor ME, Gradus MS, Blair KA, Peterson DE *et al*. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply. *N Engl J Med* 1994; **331** (3): 161-7.

MacPherson DW, McQueen R. Cryptosporidiosis: multiattribute evaluation of six diagnostic methods. *J Clin Microbiol* 1993; **31** (2): 198-202.

Maggi P, Larocca AM, Quarto M, Sergio G, Brandonisio O, Angarano G, Pastore G. Effect of antiretroviral therapy on cryptosporidiosis and microsporidiosis in patients infected with human immunodeficiency virus type 1. *Eur J Clin Microbiol Infect Dis* 2000; **19**(3): 213-7.

Manabe YC, Clark DP, Moore RD, Lumadue JA, Dahlman HR, Belitsos PC *et al*. Cryptosporidiosis in patients with AIDS: correlates of disease and survival. *Clin Infect Dis* 1998; **27** (3): 536-42.

Mandell GL, Douglas JE, Dolin R. Principles and Practice of Infectious Diseases. Fifth Edition. Volume 2. Philadelphia: Churchill Livingston; 2000.

McLauchlin J, Amar C, Pedraza-Diaz S, Nichols GL. Molecular epidemiological analysis of *Cryptosporidium spp*. in the United Kingdom: results of genotyping *Cryptosporidium spp*. in 1,705 fecal samples from humans and 105 fecal samples from livestock animals. *J Clin Microbiol* 2000; **38** (11): 3984-3990.

Meinhardt PL, Casemore DP, Miller KB. Epidemiologic aspects of human cryptosporidiosis and the role of waterborne transmission. *Epidemiol Rev* 1996; **18** (2): 118-136.

Morgan UM, Thompson RCA. PCR detection of *Cryptosporidium*: the way forward? *Parasitol Today* 1998; **14**: 241-6.

Morgan U, Weber R, Xiao L, Sulaiman I, Thompson RCA, Ndiritu W *et al*. Molecular characterisation of *Cryptosporidium* isolates obtained from human immunodeficiency virus-infected individuals living in Switzerland, Kenya, and the United States. *J Clin Microbiol* 2000; **38**(3): 1180-1183.

Morgan-Ryan UM, Fall A, Ward LA, Hijjawi N, Sulaiman I, Fayer R *et al*. *Cryptosporidium hominis* n. sp. (Apicomlexa: Cryptosporidiae) from Homo sapiens. *L Eukaryot Microbiol* 2002; **49** (6): 433-440.

NSW Health. The Sydney water incident: July-September 1998. *NSW Public Health Bulletin* 1998; **9**(8,9): 91-4.

O'Donoghue PJ. *Cryptosporidium* and cryptosporidiosis in man and animals. *Int J Parasitol* 1995; **25**(2): 139-95.

Okhuysen PC, Chappell CL, Crabb JH, Sterling CR, DuPont HL. Virulence of three distinct *Cryptosporidium parvum* isolates for healthy adults. *J Infect Dis* 1999; **180** (4): 1275-81.

Okhuysen PC, Chappell CL, Sterling CR, Jakubowski W, DuPont HL. Susceptibility and serologic response of healthy adults to reinfection with *Cryptosporidium parvum*. *Infect Immun* 1998; **66** (2): 441-3.

Pool Water Treatment Advisory Group. Swimming pool water: treatment and quality standards. BCPublications 1999. ISBN 0 9517007 6 6.

Health Protection Agency. Infectious diseases. Topics A-Z. *Cryptosporidium*. Available at www.hpa.org.uk/infections/topics_az/crypto/data.htm

PHLS. Strength of association between human illness and water: revised definitions for use in outbreak investigations. *CDR Wkly* 1996; **6**(8).

Richardson AJ, Frankenberg RA, Buck AC, Selkon JB, Colbourne JS, Parsons JW, Mayon-White RT. An outbreak of waterborne cryptosporidiosis in Swindon and Oxfordshire. *Epidemiology Infection* 1991; **107**: 485-495.

Sayers GM, Dillon MC, Connolly E, Thornton L, Hyland E, Loughman E *et al*. Cryptosporidiosis in children who visited an open farm. *Commun Dis Rep* 1996; **6**(10): R140-4.

Scottish Executive. The Cryptosporidium (Scottish Water) Directions 2003. Available at www.scotland.gov.uk/library5/health/crypto03.pdf

Smith HV, Patterson WJ, Hardie R, Greene LA, Benton C, Tulloch W *et al*. An outbreak of waterborne cryptosporidiosis caused by post-treatment contamination. *Epidem Inf* 1989; **103**: 703-715.

Smerdom WJ, Nichols T, Chalmers RM, Heine H, Reacher M. Foot and Mouth disease in livestock and reduced cryptosporidiosis in humans, England and Wales. *Emerg Infect Dis* 2003; **9** (1): 22-28.

South Eastern Health Board. Infectious intestinal disease. *Communicable Disease Update* 2002; **1**(1).

Sturdee AP, Bodley-Tickell AT, Archer A, Chalmers RM. Long-term study of *Cryptosporidium* prevalence on a lowland farm in the United Kingdom. *Vet Parasitol* 2003; **116** (2): 97-113.

Teunis PFM, Havelaar AH. *Cryptosporidium* in drinking water: evaluation of the ILSI/RSI quantitative risk assessment framework. RIVM, 1999; Report No.284550006.

CDC. 1999 USPHS/IDSA guidelines for the prevention of opportunistic infections in persons infected with human immunodeficiency virus. *MMWR* 1999; 48(RR10): 1-59.

Valdez LM, Dang H, Okhuysen PC, Chappell CL. Flow cytometric detection of *Cryptosporidium* oocysts in human stool samples. *J Clin Microbiol* 1997; **35**(8): 2013-7.

Veverka F, Shapiro N, Parish MK, York S, Becker W, Smith F *et al*. Protracted outbreaks of cryptosporidiosis associated with swimming pool use – Ohio and Nebraska, 2000. *MMWR* 2001; **50** (20): 406-10.

Western Health Board. Cryptosporidiosis in the Western Health Board. *WESTfile* 2003; **2** (10).

Widmer G. Genetic heterogeneity and PCR detection of *Cryptosporidium parvum*. *Adv Parasitol* 1998; **40**: 223-39.

Widmer G, Lin l, Kapur V, Feng X, Abrahamsen MS. Genomics and genetics of *Cryptosporidium parvum*: the key to understanding cryptosporidiosis. *Microbes Infect* 2002; **4**: 1081-1090.

World Health Organization Regional Office for Europe,1999b. Overview of the environment and health in Europe in the 1990s. Copenhagen.

Xiao L, Morgan UM, Fayer R, Thompson RCA, Lal AA. Cryptosporidium systematics and implications for public health. *Parasitolog Today* 2000; **16** (7): 287-292.

Appendix 1

Laboratory Standard Operating Procedures for the Diagnosis of Cryptosporidial Infection from UK PHLS

Auramine Phenol Stain

(for *Cryptosporidium* species)

1. Prepare a smear on a clean microscope slide.
2. Air dry.
3. Fix in methanol for 3 minutes.
4. Stain with auramine-phenol for 10 minutes.
5. Wash in tap water.
6. Decolourise with 3% acid-alcohol for 5 minutes.
7. Wash in tap water.
8. Counterstain using 0.1% potassium permanganate for 30 seconds.
9. Wash in tap water.
10. Air dry.
11. Examine using a low power objective and an incident-light fluorescence microscope. Morphology may be examined more closely using a high power objective.

Auramine-phenol reagent:	auramine	0.03g
	phenol	3.00g
	distilled water	100mL

Cryptosporidium species (cysts-5μm) fluoresce yellow against a dark background.

Modified cold Ziehl-Neelsen Stain

(for *Cryptosporidium* species, *Isospora* species and *Cyclospora* species)

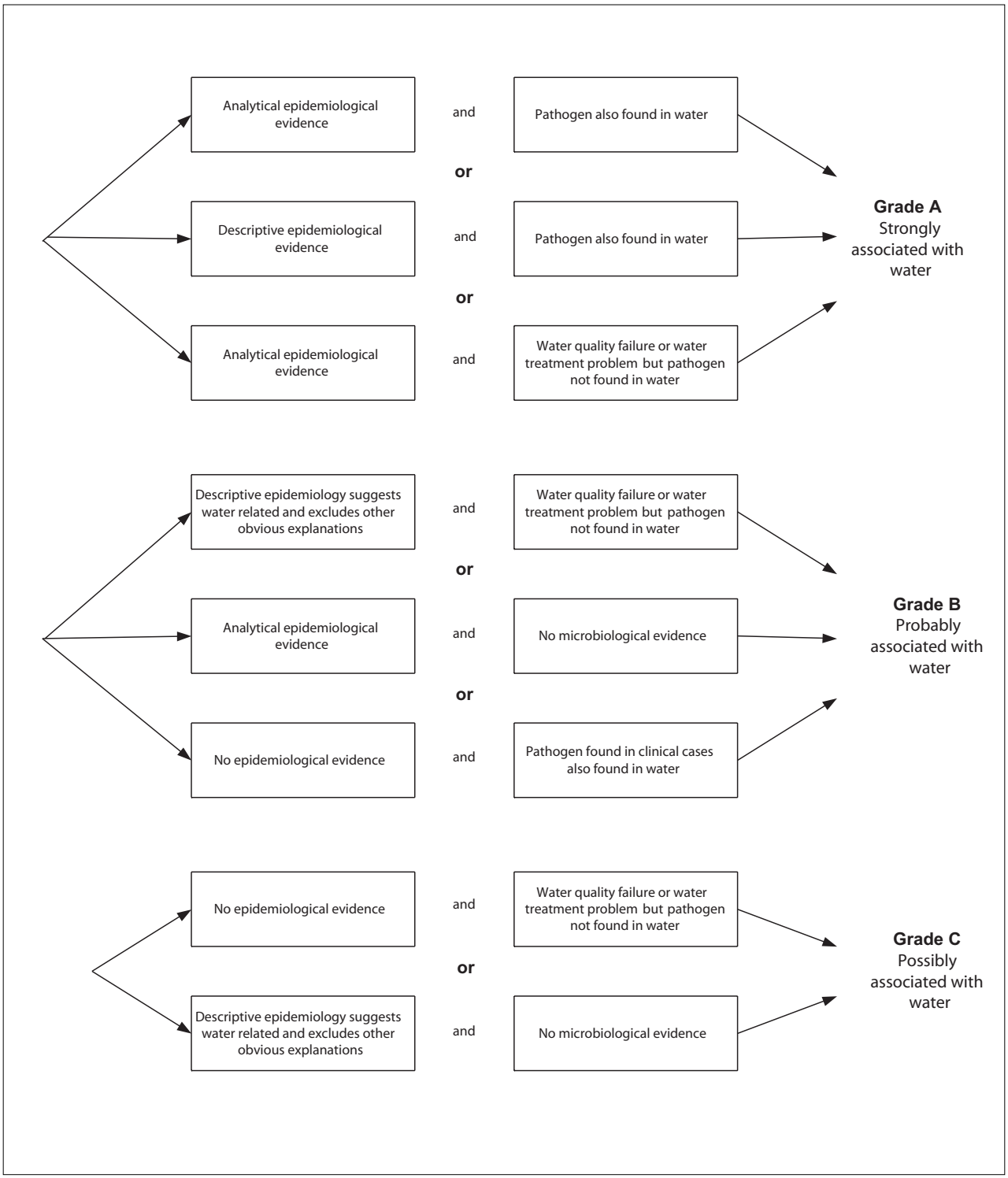
1. Prepare a medium to thick smear (thinner for *Isospora* and *Cyclospora*) on a clean microscope slide.
2. Air dry.
3. Fix in methanol for 3 minutes.
4. Stain with cold carbol fuchsin for 10 minutes.
5. Wash in tap water.
6. Decolourise with 1% HCl (v/v) in methanol for 10 seconds.
7. Wash in tap water.
8. Counterstain using 0.4% malachite green for 30 seconds.
9. Wash in tap water.
10. Air dry.
11. Examine using a low power objective. Morphology may be examined more closely using a high power objective.

Carbol fuchsin reagent:	Basic fuchsin	10.00g
	Ethanol	100mL
	Phenol	50.00g
	Distilled water	1000mL

Cryptospridium species (cysts-5μm), *Isospora* species (cysts-32x16μm), and *Cyclospora* species (cysts-8 to 10μm) all stain red against a green background, some cells of *Cyclospora* and *Cryptosporidium* may appear unstained.

Appendix 2

Association between Human Illness and Water



Source: Adapted from the UK Public Health Laboratory Service Guidelines on the association between human illness and water (PHLS, 1996).

Appendix 3

Enteric, Foodborne & Waterborne Outbreak Report

NDSC

General:

Code for NDSC USE ONLY

Health Board

CCA

Reported by (Name)

Date reported

Position

Telephone

Fax

E-mail

1. How was this outbreak brought to your attention? *Outbreak = 2 or more linked cases*

Public complaint ☐ Laboratory report ☐ General practitioner ☐
Proprietor of food outlet ☐ Other ☐

If other, please specify:

2. Extent of outbreak: *(Tick 1 box only)*

Family outbreak ☐ General outbreak ☐

If general outbreak, tick **1** of the following:

Local ☐ National ☐ International ☐ Across health board ☐ Cross border ☐

3. Principle modes of transmission: *(Tick all that apply)*

Foodborne ☐ Person to person ☐ Animal contact ☐
Waterborne ☐ Airborne ☐ Unknown ☐

If unknown, please specify

4. Main locations of outbreak : *(Tick 1 box only)*

Private house ☐ Hotel ☐ Guest house / B&B ☐ Residential institution ☐
Public house ☐ Restaurant / cafe ☐ Retail outlet ☐ School ☐
Mobile retailer ☐ Staff canteen ☐ Hospital ☐ Crèche ☐
Other ☐ If other, please specify

Describe (Name of premises / type of function etc)

5. Pathogen:

Was the pathogen identified? Yes ☐ No ☐

If YES, please specify: Organism / toxin

Phage type

Antibiogram (if available)

Suspect viral aetiology Yes ☐ No ☐

Appendix 3 continued

Enteric, Foodborne & Waterborne Outbreak Report

6. Laboratory (even if microbiology was negative)

Laboratory where tests were performed:

Reference laboratory:

7. Exposure:

Number ill

Number dead

Number hospitalised

Number exposed / at risk

8. Date:

Onset date of **first** case

Onset date of **last** case

Date suspect function / meal / consumption of food

Median incubation period Days Hours

Please send epidemic curve if available.

9. Number of cases by age group:

< 1 yr	1 - 4 yrs	5 - 19 yrs	20 - 49 yrs	50 - 64 yrs	65 + yrs	Age Unknown

10. Number of cases by sex:

Females Males Sex Unknown

11. Laboratory results relating to the outbreak:

	Ill People		Well People	
	No. of samples **TESTED** (total)	No. Positive	No of samples **TESTED** (total)	No. Positive
Food Handlers (If applicable)				
All other individuals tested during the outbreak				

12. Suspect FOOD vehicle(s) associated with illness:

*Only list specific vehicles for which there is **EVIDENCE** of association with illness.*

Food source

Food unknown

13. Suspect WATER vehicle(s) associated with illness:

DRINKING WATER: *(Tick 1 box only)* Public Private Group scheme Well Bottled Other

TYPE OF WATER TREATMENT : *(Tick all that apply)* None Flocculation / sedimentation Filtration Disinfection Other

RECREATIONAL WATER: *(Tick 1 box only)* Surface **OR** Pool

14. Size of population served: 50 - 500 500 - 5,000 > 5,000 - 50,000 > 50,000 - 500,000 > 500,000

15. Form of evidence: *(Tick all that apply)*

Vehicle(s) Case-control study (statistical) Circumstantial evidence (descriptive evidence)

Microbiological Cohort study (statistical)

Appendix 3 continued

Enteric, Foodborne & Waterborne Outbreak Report

16. Factors contributing to the outbreak as established by the investigation:

FOODBORNE / PERSON TO PERSON TRANSMISSION *(Tick all that apply)*

Grossly contaminated raw ingredients	☐	Inadequate hygiene facilities (toilets, sinks etc.)	☐
Inadequate storage / refrigeration	☐	Gross contamination	☐
Inadequate cooking	☐	Infected food handlers **symptomatic during outbreak**	☐
Poor hygiene conditions in premises	☐	Infected food handlers **symptomatic prior to outbreak**	☐
Inadequately trained / supervised staff	☐	Infected food handlers as **asymptomatic carriers**	☐
Other	☐	If other, please specify:	

WATERBORNE TRANSMISSION *(Tick all that apply)*

Water treatment failure	☐	Inadequate treatment system	☐
Distribution system failure	☐	Other	☐

SOURCE OF CONTAMINATION *(Tick 1 box only)*

Human faeces ☐ Animal faeces ☐ Toxin ☐ Other ☐

If other, please specify:

17. Actions taken:

FOODBORNE OUTBREAK

Product recall	☐	Closure (Voluntary)	☐	Seizure of food / Prohibition Order	☐
Improvement Notice	☐	Closure Order	☐	No action necessary	☐
Improvement Order	☐	Prosecution	☐	Other	☐

If no action was necessary, please describe:

WATERBORNE OUTBREAK *(Please describe the principal control measures put in place)*

Source: Drinking Water

Source: Recreational Water

NOSOCOMIAL OUTBREAK *(Please describe the principal control measures put in place)*

Any additional comments:
(Include actions taken, economic and resource impact, any other aspects not already covered)

18. Will a full report be available? Yes ☐ No ☐ ***If yes, please forward a copy when ready.***

Please send notification to Dr. Paul Mc Keown, NDSC, Fax no: 01 - 87 65 333 or E-mail: paul.mckeown@ndsc.ie

Appendix 4

First Notice

Specimen 'Boil Water' notice and advice for the consumer to accompany 'Boil Water' notice.

IMPORTANT INFORMATION NOTICE

Date as per Postmark

NAME
ADDRESS1
ADDRESS2
ADDRESS3
ADDRESS4

It has come to the attention of _____ City/County Council that the public water supply served by _____ may be contaminated. On the advice of the _____ Health Board/Authority and as a precautionary measure pending further investigation, a boil water notice is being issued. Accordingly, in the interest of public health, it is recommended that all users on the scheme boil the water before use.

- Water should not be used unboiled for
  - Drinking.
  - Drinks made with water.
  - Food preparation.
  - Brushing of teeth.
  - Making of ice.
- Caution should be taken when bathing children to ensure they do not ingest the water.
- Boil water and allow to cool. Cover and store in a refrigerator or cold place. Water from the hot tap is not safe to drink. Domestic water filters will not render water safe to drink.
- Discard icecubes in fridges and freezers and filtered water in fridges. Make ice from cooled boiled water.
- Use water prepared for drinking when preparing foods that will not be cooked (e.g. washing salads).
- Water can be used for personal hygiene, bathing and flushing toilets but not for brushing teeth.

This procedure should continue until further notice.

Issued by _____ City/County Council

What is *Cryptosporidium*?
Cryptosporidium is a microscopic parasite that is found mainly in the faeces of infected humans or animals. Humans are infected when they ingest contaminated water or food, or touch contaminated objects, and then touch their mouth before washing their hands well.

What are the symptoms?
Diarrhoea that lasts 1 to 2 weeks, often accompanied by abdominal cramps, fatigue, nausea, vomiting and low-grade fever. People usually develop symptoms 1 to 12 days after ingesting the parasite. If you are worried contact your local G.P.

What can I do to prevent getting it?

- **Boiled water** to be used for:
  - Drinking.
  - Drinks made with water.
  - Food preparation especially vegetables to be eaten uncooked e.g. salads.
  - Making ice.
  - Brushing teeth.

- Careful hand washing is essential after toileting, changing nappies, before preparing food. Be careful bathing small children to ensure they do not ingest water.

- As *Cryptosporidium* is communicable from animals to humans, good hygiene practice is essential when visiting farms and handling animals.

- Dairy farmers are reminded that the drinking of unpasteurised milk can result in the ingestion of *Cryptosporidium*.

Great care should be taken with boiled water to avoid burns and scalds as accidents can easily happen, especially with children.

Who is most at risk?
Persons with an impaired immune system, young children and older persons are more susceptible to infection.

How long before *the boil water notice* can be lifted and the water is safe to drink?
We do not know, however notification of when the water is safe will be advertised nationally and locally through the media, on our website and on our Freephone update message service _____.

How did it get into the water?

_____
_____
_____

What have we done so far?
1. *Communication*
2. *Actions*
3. *Remedial measures*: short-term and long-term solutions
4. *Ongoing Measures*

How will we keep you informed?
Website
Freephone: _____
Local Radio: _____
Local and national newspapers

Remember to boil water as advised until further notice.
Boil water and allow to cool in a safe place. Cover and store in a refrigerator or cold place.
Water from the hot tap is not safe to drink. Domestic water filters will not render the water safe.

Areas affected:

_____

_____

_____

_____

_____

_____

_____

Source: Adapted from Westmeath County Council's 'Boil Water Notice'

Appendix 5

Cryptosporidium Questionnaire

Patient ID Number _____

INITIATION OF INTERVIEW:

Hello, my name is _____ and I am an AMO/EHO (as appropriate) with the _____ Health Board/Authority.

We have recently been made aware that a number of people in your area have been ill recently.

Would you mind answering a few questions for me? All the information that you provide us with will be kept completely confidential and you have the right to refuse to answer any questions that you do not wish to answer.

PERSONAL DETAILS:

ID Number _____ Case/Control _____

Surname _____ First Name _____

Sex: (Male/Female) _____ DOB _____/_____/_____

Contact number _____

Address _____

_____

_____

_____

Occupation _____

Do you attend a school: Yes ☐ No ☐ Crèche: Yes ☐ No ☐

If yes give details:_____

GP's Name _____ GP's Ph. No. _____

GP's Address _____

INTERVIEWER

Interviewed by _____

Date _____

Title _____

CLINICAL SYMPTOMS

Have you been ill with symptoms of vomiting or diarrhoea in the last month?

Yes ☐ No ☐ Unknown ☐ **(If no skip to Q 10)**

2. When did you first get sick? Date _____/_____/_____ Time _____

3. What was the duration of the illness _____ Days/hours

4. Are you still sick at present? Yes ☐ No ☐ Unknown ☐

5. Did you suffer from the following symptoms?

Diarrhoea	Yes ☐	No ☐	Unknown ☐	No of episodes _____
Vomiting	Yes ☐	No ☐	Unknown ☐	No of episodes _____
Nausea	Yes ☐	No ☐	Unknown ☐	
Stomach Pains	Yes ☐	No ☐	Unknown ☐	
Bloody Stools	Yes ☐	No ☐	Unknown ☐	
Fevers	Yes ☐	No ☐	Unknown ☐	
Headache	Yes ☐	No ☐	Unknown ☐	

Others _____

_____

6. Did you see a doctor? Yes ☐ No ☐ Unknown ☐

7. Has a faecal sample been taken? Yes ☐ No ☐ Unknown ☐

If yes date submitted _____/_____/_____

8. Were you hospitalised? Yes ☐ No ☐ Unknown ☐

If hospitalised for how many days _____

9. Is the case lab confirmed? Yes ☐ No ☐ Unknown ☐

Name of laboratory _____

CONTACT INFORMATION

10. Did you have contact with anyone else who was ill?

Family	Yes ☐	No ☐	Unknown ☐
Neighbours	Yes ☐	No ☐	Unknown ☐
Class mates	Yes ☐	No ☐	Unknown ☐
Work colleagues	Yes ☐	No ☐	Unknown ☐
Other	Yes ☐	No ☐	Unknown ☐

11. Drinks

Do you drink water? Yes ☐ No ☐ Unknown ☐

How much per day? Sip ☐ Half glass ☐ Full glass ☐ Few glasses ☐

Is the water bottled or tap? _____

Do you have any other drinks e.g. diluted squash or juice? Yes ☐ No ☐

Please specify? _____

Please specify quantity per day? _____

Did you have any ice in your drinks? Yes ☐ No ☐ Unknown ☐

Do you drink milk (including in cereal etc)? Yes ☐ No ☐ Unknown ☐

What brand of pasteurised milk do you use? _____

Do you use formulation? Yes ☐ No ☐ Unknown ☐

If yes which brand? _____

Do you drink unpasteurised milk? (Including goats + sheep milk) Yes ☐ No ☐ Unknown ☐

If yes how many glasses per day? _____

WATER SUPPLY

12. What is your usual supply?

Private Well ☐ Group scheme ☐ Public supply ☐

Source _____

Do you drink any other water? e.g. School _____

Crèche _____

Workplace _____

13. Other water sources consumed during last 14 days.

Private Well ☐ Group scheme ☐ Public supply ☐

Details/Other _____

14. Bottled water consumed during last 14 days? Yes ☐ No ☐

If yes brands and date _____

15. Did you consume any untreated spring / river waters during last 14 days.

Yes ☐ No ☐

If yes, give details _____

16. Was there any disruption to the mains supply two weeks prior to illness?

Yes ☐ No ☐

If yes, give details _____

Hobbies and Activities

17. Have you taken part in any of the following activities in the two weeks prior to becoming ill?

Activities	Y / N	Where?	Dates	Others ill?
Swimming				
Paddling				
Boating				
Fishing				
Camping				
Surfing				
Others				

18. Do you live on a farm? Yes ☐ No ☐

If yes have any of the animals had scour in the previous six months?

Yes ☐ No ☐ Unknown ☐

19. Do you have contact with animals (domestic or farm) at home? Yes ☐ No ☐

If yes please give details _____

20. Did you visit any farms or petting zoos in the last month? Yes ☐ No ☐

If so please give details_____

21. Have you been abroad in the last month? Yes ☐ No ☐

If so please give details_____

Read the following when you have finished asking questions
Thank you very much for your time; your help is greatly appreciated. We may need to get additional information from you in the near future. Would you be willing to talk to us again?

Yes ☐ No ☐ Unknown ☐

Thanks again for your time.

Source: Adapted from the cryptosporidium questionnaire used by the Midland Health Board in the April 2002 cryptosporidiosis outbreak.

Appendix 6

Cryptosporidiosis Information Leaflet for Immunocompromised Patients

1. *What is cryptosporidiosis?*

Cryptosporidiosis is a disease caused by a parasite that can live in the intestines of humans and animals. It is often called "crypto". The parasite can cause a diarrhoeal illness in humans known as cryptosporidiosis.

2. *What are the symptoms of crypto?*

Symptoms include diarrhoea, stomach cramps, upset stomach and a mild fever. Some people have no symptoms. Symptoms can appear 1 to 12 days after a person becomes infected. Symptoms usually last about 2 weeks. However, you may continue to pass the parasite in your stool (bowel motion) for up to 2 months. Symptoms may be more severe if you have a weakened immune system.

3. *How does crypto affect you if your immune system is severely weakened?*

In people with AIDS, and in others whose immune system is weakened, crypto can be a serious and long-lasting infection. If you have HIV infection and your CD4 cell count is below 200, crypto can cause severe watery diarrhoea for a long time. If your CD4 cell count is over 200, your illness may only last for 2 weeks. However, you may still carry the parasite and pass it on to others.

4 *How is crypto spread?*

- By accidentally swallowing anything that has come in contact with the stool of a person or animal with crypto.
- By swallowing water contaminated with crypto. This can occur if water from a swimming pool, jacuzzis, lakes, rivers and ponds are contaminated with sewage or faeces from infected humans or animals.
- By eating uncooked contaminated foods.

5. *How is an infection diagnosed?*

You doctor will ask you to submit one or more stool samples to see if you are infected. The doctor will specifically ask for this test to be done since many laboratories do not routinely perform this test.

6. *Can crypto be treated?*

Most people with a healthy immune system will recover themselves. However, people with weakened immune systems are at greater risk of a more severe illness. Until recently, there was no curative antimicrobial treatment for cryptosporidiosis. However, in a recent study in Zambia, nitazoxanide showed promising results in children who were HIV-seronegative but not in those who were HIV-seropositive. If you have diarrhoea, drink plenty of fluids to prevent dehydration. Anti-diarrhoeal medications may help slow the diarrhoea. However, these should only be taken after consulting with your doctor.

7. *How can I protect myself from crypto?*

These following actions can help to protect you from getting crypto:

- **Wash your hands.** This is probably the single most important step you can take to prevent crypto and certain other infections. Always wash your hands before eating and preparing food, after using the toilet, after changing nappies, after gardening, and after touching pets or farm animals.
- **Boil water**. During outbreaks in your community water supply, boil drinking water to kill the crypto parasite and to make the water safe for drinking once it has cooled.
- **Practice safer sex**. Infected people may carry crypto in their anal and genital region. Avoid oral sex and wash your hands after touching your partner's anal area.
- **Avoid touching farm animals**. Crypto is common in young animals, especially calves and lambs. If contact cannot be avoided always wash your hands well with soap and water following contact.
- **Avoid touching the faeces of pets**. Most pets are safe to own. The risk of getting crypto is greatest from pets that are less than 6 months old or stray animals. If you must clean up after a pet, use disposable gloves and wash your hands afterwards. If any pet gets diarrhoea, have it tested for crypto.
- **Be careful when swimming in lakes, rivers, ocean water and swimming pools**. Avoid swallowing water while swimming.

- **Wash and cook your food**. Proper cooking kills crypto. Do not eat or drink unpasteurised dairy products.
- **Take extra care when travelling**. If you are travelling to developing countries, you may be at greater risk of crypto and other infections because of poorer water treatment and food preparation. Talk to your doctor about guidelines for travel abroad.
- **Drink safe water**. Contact your local authority or water provider to find out about your water supply. Questions you might ask include:

What is the name of the supply?
If you know the name of the supply you can look up the Environmental Protection Agency (EPA) Annual Report at www.epa.ie for an independent assessment of the quality of the supply.

Is it a surface water or ground water supply?
Surface waters (lakes, streams, rivers) are more vulnerable to contamination with crypto than groundwater (springs, wells).

Does the source ever change?
Sources may change for operational reasons and the alternative source may differ in quality.

Has there been any monitoring of the supply for the presence of crypto and what are the results?
Previous known occurrences of crypto suggests significant risk.

What is the history of the supply?
Even if there has been no monitoring for crypto, have there been any incidents involving crypto, or has there been an outbreak of cryptosporidiosis associated with the supply?

Has there been a formal assessment of the risk of contamination of the supply with crypto, and what are the results?
If the risk of crypto occurring in the supply is significant or high, then what actions have been taken?

How often has the supply been tested for faecal coliforms/*E. coli* in the past year, and how many samples were positive?
Very few samples (less than 12), or any positive samples, suggest poor monitoring and/or dubious quality.

What sort of treatment does the water get?
Disinfection with chlorine will not kill crypto, but ozone and ultraviolet light will. Slow sand filtration, or coagulation followed by rapid gravity filtration can remove any crypto from the water at the treatment plant. However, such systems must be operated properly and efficiently. What evidence is there for this (quality assurance/documentation/audits)?

- **Avoid drinking water from lakes, rivers, springs, ponds or streams** unless it has been filtered and chemically treated.
- **If the local authority in your area advises boiling water in the event of a community outbreak of crypto, do not drink tap water unless you boil it**. Boiling water: boiling is the best extra measure to ensure that your water is free from crypto and other infections. After boiling the water, put it in a clean bottle with a lid and store it in the fridge. Use this water for drinking, washing teeth, cooking or making ice.

Based on the CDC Fact Sheet. Preventing Cryptosporidiosis: A guide for people with compromised immune systems.

Appendix 7

List of Submissions and Acknowledgements

We would like to thank the following people for their considered and helpful responses to the draft consultation document:

Mr Micheal O'Mahony, Faculty of Veterinary Medicine, University College Dublin

Mr Darragh Page, Environmental Protection Agency

Dr Brian Smyth, Communicable Disease Surveillance Centre, Northern Ireland

Ms Mary Keane, Environmental Health, South Western Area Health Board

Dr Patricia Prendiville, Department of Public Health and Mr Frank Menton, Environmental Health, South Eastern Health Board

Ms Jane Murphy, Infection Control Nurses Association

Dr Tom Donnelly, Health and Safety Authority

Mr Noel Shanaghy/Dr Anne Moloney, Microbiology Department, Waterford Regional Hospital

Mr Frank Gleeson/Lorcan O'Brien, Environmental Health, Mid-Western Health Board

Dr Suzanne Cotter, Department of Public Health, Mid-Western Health Board

Professor Hilary Humphries, Microbiology Department, Beaumont Hospital

Mr Donal Connolly, County and City Managers Association

Dr Margaret O'Sullivan, Faculty of Public Health Medicine, Royal College of Physicians of Ireland

Dr Patrick Wall, Food Safety Authority of Ireland

Dr Margaret O'Sullivan, Southern Health Board

Dr Karina Butler, Faculty of Paediatrics, Royal College of Physicians of Ireland

Ms Aideen McGuinness, Irish Nutrition and Dietetic Institute

Ms Mary Falvey, Environmental Health, Southern Health Board

Dr Delia Skan, Faculty of Occupational Medicine, Royal College of Physicians of Ireland

Ms Mary Gillooly/Ms Mari Greene, Environmental Health, Midland Health Board

Dr Colm Bergin, Irish Infection Society

Mr Sean O'Laoide, Westmeath County Council

Glossary of Terms

Abstraction – The removal of water from surface water or groundwater, often by pumping.

Antibody – a specific substance produced by the body's immune system in response to a particular infection.

Aquifer – a permeable geological formation that is capable of both storing and transmitting water in significant amounts.

Backwash – cleaning water treatment filters by reversing the water flow.

Catchment – the area of land that drains into a watercourse.

CD4 – a group of lymphocytes which are important in mediating the immune response; counting CD4 cells provides a guide to the potential for mounting an immune response to foreign substances and organisms.

Clostridium – an anaerobic spore-forming bacterium.

Coagulant – a substance added in water treatment to cause coagulation of particles.

C. parvum – a species within the genus *Cryptosporidium*.

Cryptosporidiosis – the illness produced by infection with *Cryptosporidium.*

Cytokines – biologically active, soluble fractions secreted by lymphocytes and other cells.

Epidemiology – a study of factors affecting health and disease in a population.

Flocculation – the aggregation of very fine organic or inorganic particles to form larger particles (floc) which can be moved by separation purposes, such as sedimentation, flotation or filtration, as part of the treatment of drinking water. Flocs are generally produced by the addition of chemicals.

Flow lines – lines indicating the direction of groundwater movement.

Giardia – a protozoan parasite capable of infecting man and causing diarrhoea.

Groundwater – naturally occurring sub-surface water in the saturated zone of a rock.

Group Water Scheme – any supplies of water provided otherwise than by a statutorily appointed local authority.

Groundwater vulnerability – the tendency or likelihood for contaminants to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer.

HAART – Highly active anti-retroviral therapy.

Hazard – a property or situation that in particular circumstances could lead to harm.

High transmissivity – capable of transmitting a large amount of water.

HIV – Human Immunodeficiency Virus.

Immunocompromised – individuals with an impaired or inefficient immune response.

Immunoglobulins – immune response.

Monoclonal antibody – an antibody produced in a laboratory which recognises one specific part of a specific micro-organism.

Oocyst – the environmentally resistant transmissable form of Cryptosporidium excreted in the faeces of an infected person or animal.

Outbreak – two or more linked cases of the same illness, or the situation where the observed number of cases exceeds the expected number, or a single case of disease caused by a significant pathogen (e.g. diphtheria or viral haemorrhagic fever).

Pathogen – a microorganism capable of causing disease.

PEHO – Principal Environmental Health Officer.

Phenotype – the sum of the observable characteristics of an organism.

Recycling – the return of water which cannot enter the supply system, for example the initial filtrate after backwashing, to the treatment plant inlet.

Risk – a combination of the probability, or frequency, of occurrence of a defined hazard and the magnitude of the consequences of the occurrence.

Risk estimation - is concerned with the outcome or consequences of an intention, taking account of the probability of occurrence; risk evaluation is concerned with determining the significance of the estimated risks for those affected, it therefore includes the element of risk perception; risk perception is the overall view of risk held by a person or group and includes both feeling and judgment; risk assessment consists of risk estimation and risk evaluation.

SPHM – Specialist in Public Health Medicine.

Sporozoite – the motile stage of Cryptosporidium which is released after excystation.

Surveillance – the process of monitoring the number of cases of disease in the community.

Zoonosis – a disease transmitted naturally from animals to man.