

CRYPTOSPORIDIUM
in
WATER SUPPLIES

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Review of Current Knowledge

This review is one of a series of reviews of current knowledge (ROCKs) produced by FWR. They focus on topics related to water supply, wastewater disposal and water environments, which may be the subject of debate and inquiry. The objective of each review is to produce concise, independent scientific and technical information on the subject to facilitate a wider understanding of the issues involved and to promote informed opinion.

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Review of Current Knowledge

***CRYPTOSPORIDIUM* in WATER SUPPLIES**

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1 Introduction

Most developed countries have regulations which specify a minimum quality for public and private drinking water supplies. This is to ensure that the water is both pleasant and safe to drink.

In the European Union (EU) the quality required in member states for public supplies of drinking water was first specified in 1980 by the 'Drinking Water' Directive. The Directive defined limits for the chemical and microbiological content of the drinking water. A revised EU Directive was approved in 1998 (EU Council Directive 98/83/EC) which has been implemented in the UK by means of Statutory Instruments (SI) which define drinking water regulations. The overall requirement for drinking water is that it shall be "Wholesome". This is defined in the regulations as "water which does not contain any micro-organism or parasite or any substance at a concentration or value which would constitute a danger to human health". Further information is available from the website of the Drinking Water Inspectorate (for England & Wales) at www.dwi.gov.uk.



Small water reservoir below Malvern Hills. © *R G Ainsworth*

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The UK is unique in that it has introduced additional regulations (SI 1999 No. 1524) for the specific purpose of controlling the presence of one particular protozoal parasite in public drinking water supplies, namely *Cryptosporidium*. These regulations required water companies to carry out risk assessments to establish whether there is a significant risk from *Cryptosporidium* in water supplied from each of their treatment works. Where there is a risk, water companies must design and operate the facilities for treating the water to ensure that the average number of oocysts is less than 1 per 10 litres of water, and to check this using a standard monitoring procedure. An oocyst is the infective form of the parasite *Cryptosporidium* and is described later in this review. Other potential parasites are found in surface waters, most notably *Giardia*, but are not specifically mentioned in the UK regulations.

A wide range of parasites can cause disease (for example malaria is caused by the parasite *Plasmodium* and sleeping sickness is caused by the parasite *Trypanosoma*). A number of parasites (or their infective form) are found in lakes, rivers, and groundwaters and if they are ingested when the water is drunk illness can follow. *Entamoeba histolytica*, which is principally a tropical parasite causing amoebic dysentery, is the third largest cause of parasitic death in human beings after malaria and schistosomiasis. The American Water Works Association Manual on Waterborne Pathogens (AWWA, 1999) lists 18 different waterborne parasites most of which are found principally in tropical climates.

The waterborne parasites of greatest concern in countries with temperate climates are *Cryptosporidium* and *Giardia*. This review provides specific information on *Cryptosporidium*, a parasite which causes an unpleasant illness and which is well known for its resistance to drug therapy in infected animals and human beings and its resistance to the normal methods used to disinfect drinking water. Another review in this series addresses *Giardia* (FWR, 2006).

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2 What is *Cryptosporidium* and Cryptosporidiosis?

Cryptosporidium is a waterborne parasite found widely distributed around the world including Europe. When ingested it can cause an unpleasant illness called **cryptosporidiosis**. Infection is transmitted by tiny spore- or egg-like cells called oocysts. These oocysts are small, roughly spherical in shape and about 4 to 6 μm in diameter; a μm is a micrometre, one millionth of a metre.



Surface of the small intestine infected with *Cryptosporidium parvum* parasites.

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The symptoms of cryptosporidiosis are diarrhoea (92% of patients), mild abdominal pain (45% of patients), nausea and vomiting (51% of patients), mild fever (63% of patients) and fatigue. The incubation period of the disease is between 4 and 28 days with an average of 7 days. No drug has been shown to be effective against *Cryptosporidium* infection and recovery from the illness is dependent on the body's immune system. As a consequence cryptosporidiosis may be very serious in people whose immune system is

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weakened or less effective such as the very young, the elderly, AIDS sufferers and those on immuno-suppressant drugs. Although the disease is not usually fatal it can be life-threatening for individuals with weakened immune systems.

3 *Cryptosporidium* in the environment

Cryptosporidium is found in man and many other mammals and also in birds, reptiles and fish. It is principally an infection of new-born and young animals except in man in which it can readily infect all ages. Although known as a cause of sickness in farm animals it was not recognised as a causative agent of illness in man until 1976 (Casemore *et al*, 1985). Oocysts are passed in the faeces of infected animals, including humans. Typically, an infected calf can excrete ten thousand million oocysts daily for up to 10 days. Infection occurs either by zoonosis (animal-person contact), by ingestion of contaminated food and drink, or by inhalation of droplets contaminated with oocysts (e.g. from farm animals).

A UK survey (Carrington & Smith, 1995) found that between 37% and 74% of samples of treated sewage from 14 plants in the UK contained oocysts. Rivers into which treated sewage is discharged are thus likely to contain oocysts. Groundwater can also become contaminated with oocysts. In 1993 an outbreak of cryptosporidiosis in the UK was associated with a borehole supply (Morgan, 1995) and other studies have also shown that groundwaters can be contaminated by both *Cryptosporidium* and *Giardia* (Hancock *et al*, 1997). Swimming pools are also potential sources of oocysts and infection (DWI, 2000; Puech *et al*, 2001).

There are many different species of *Cryptosporidium* found in animals (DWI, 2004). Some species are adapted to infecting several hosts - for example *Cryptosporidium parvum* infects both human beings and ruminant animals (Chalmers *et al*, 1995). Other species are more host specific, for example *Cryptosporidium hominus* is largely confined to human beings.

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The oocysts of *Cryptosporidium* are passed in huge quantities in the faeces of infected people and animals (which is why oocysts are found in sewage effluent and sewage sludge). When animal slurry is spread on farmland oocysts may well be present, and as a consequence runoff from rain can carry oocysts into streams, rivers, lakes and reservoirs. It has been reported that many waterborne outbreaks of cryptosporidiosis occur during and after heavy rainfall (Atherholt *et al*, 1998; Curriero *et al*, 2001).



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4 The life-cycle of *Cryptosporidium*

The life cycle of *Cryptosporidium* is very complex and consists of a number of stages which may take 1-8 days to complete. The cycle is continually repeated so that the host re-infects itself. The oocyst is ingested; in the gut it excystates (or hatches out) releasing four sporozoites which attach themselves to the lining of the small intestine. The sporozoite then enters a surface cell and develops into a spherical trophozoite which subdivides forming a meront which eventually releases merozoites. These then form either macrogametes or microgametes; the microgametes fertilise the macrogametes which become zygotes which then form oocysts. The oocyst is the infective stage which then either passes out with the faeces, or excysts and starts another cycle.

Oocysts have thick protective walls which ensure their survival in the environment and which are also highly resistant to the disinfectants used to treat drinking water (disinfection and removal are discussed later).

5 Cryptosporidiosis in the community

In England and Wales, the Centre for Infections (CfI) which is part of the Health Protection Agency (HPA) produces routine reports on the levels of "notifiable diseases". Regulations (SI 1988 No. 1546) require that the CfI is informed when certain diseases are identified. Although cryptosporidiosis is not itself a notifiable disease its symptoms are very similar to those of food poisoning which is notifiable, and as a consequence data on *Cryptosporidium* are collected and published by the CfI. In England and Wales, in the region of 5000 cases are identified annually. In Scotland there are between 600 and 900 cases identified annually. These figures underestimate the actual cases to a large extent because those infected may not visit a doctor and because those that do visit may not provide a sample for analysis. However, the collected data indicate that *Cryptosporidium* is the third leading cause of non-viral gastro-intestinal illness in the UK.

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Studies have shown that between 21% and 49% of the UK population might have been infected at some time by *Cryptosporidium* (Wheeler *et al*, 1999; Hunter, 1999). Prior infection with *Cryptosporidium* can confer immunity against re-infection (Chappell *et al*, 1999).

6 Outbreaks of Cryptosporidiosis

An 'outbreak' of cryptosporidiosis or intestinal disease is defined as a level of disease above the normal background level (Badenoch, 1990). The first recorded outbreak of cryptosporidiosis associated with a public drinking water supply was in Bexar County, Texas, in 1984 which affected 79 people. The first identified outbreak in the UK was in Ayrshire in 1988, affecting 27 people. In 1989 there was a major outbreak in the Swindon area which affected over 500 people. It was this outbreak which led to the establishment of the Group of Experts under the chairmanship of Sir John Badenoch which produced two reports (Badenoch, 1990; Badenoch, 1995). After the death of Sir John Badenoch in 1996 Professor Ian Bouchier was appointed chairman of the Group of Experts which produced its third report in 1998 (Bouchier, 1998). The third report identified 25 outbreaks of cryptosporidiosis in the UK between 1988 and 1998 that had been associated with the consumption of public drinking water supplies.

The largest recorded outbreak of cryptosporidiosis was in Milwaukee in the USA in 1993 (MacKenzie *et al*, 1994) when approximately 54 people (85% of whom were immuno-deficient) died as a consequence (Hoxie *et al*, 1997).

Most outbreaks of cryptosporidiosis in the UK appear to be associated with swimming pools. In the period January 1999 to December 2000 there was a total of 18 outbreaks of cryptosporidiosis of which 2 were attributed to public water supplies, 1 to a private water supply, 1 uncertain and 14 were attributed to swimming pools. The total number of people infected in these outbreaks was 667, of whom 405 were infected by the public water supply, whereas the total number of individual cases notified to the CfI for the same period in

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England & Wales was 10,037. This indicates that the great majority of infections of cryptosporidiosis (i.e. about 96%) are not from the drinking water supply but from other sources such as contact with infected pets and farm animals, contaminated food and person to person contact in families and nurseries.

7 Can all oocysts cause an infection?

There is usually a so-called "infective dose" with many infective agents. An infective dose depends on the physical condition of the person who is infected and the state of their immune system so the size of an "infective dose" will vary. In the case of *Cryptosporidium* oocysts the infective dose may be between 30 and 1 million viable oocysts. However, not all oocysts are viable (viable means that they are able to "hatch out" and start the reproductive cycle of the parasite).

Available analytical methods for detecting viable oocysts in the environment are not very reliable (although they are improving all the time). An infective dose of 30 oocysts is quoted by the American Water Works Association Manual on Waterborne Pathogens (AWWA, 1999). A study on healthy volunteers showed that the infective dose can vary between 30 and 1 million oocysts with a mean dose of 132 oocysts (DuPont *et al*, 1995). In this study only 20% of the volunteers became infected after ingesting 30 oocysts, 88% became infected after ingesting 300 oocysts whereas all those ingesting 1 million oocysts developed the disease. However, no data are available on how many of these oocysts were viable, so there is still considerable uncertainty on the levels of infective dose.

8 How are oocysts detected in water supplies?

The analysis of a water sample for the presence of oocysts consists of three stages: - concentration, separation and detection. There is therefore ample opportunity for oocysts to be missed during the collection and analysis of a

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water sample and there is a wide variation in the results of analyses (Nahrstedt and Gimbel, 1996). Recovery of oocysts can vary by as much as 30% to 60%. The Drinking Water Inspectorate in the UK has produced detailed protocols for the approved methods of analysis for *Cryptosporidium* oocysts (Standard Operating Protocols, 1999).

The current UK regulations which require not more than one oocyst in 10 litres (see the Introduction) takes no account of whether the oocysts are viable or not; at the present time a sample would fail even if the oocyst were non-viable. However, these regulations are not a health standard but an operational standard to ensure that the processes for physical removal of particles (including oocysts) are working efficiently at the supplier's treatment works. The regulation is based on an analysis of waterborne outbreaks of cryptosporidiosis (Bouchier, 2000) which showed that in all cases there was either some failure in the effective operation of the treatment plant or inadequate physical barriers in place. It was concluded that it was important to have a monitoring system which checked on the efficacy of treatment for sites at risk of contamination. The treatment standard is that there should be less than 1 oocyst in 10 litres with a sample flow-rate of at least 40 litres per hour taken over a day. This means in practice, a sample of around 1000 litres a day passed through a continuous sampling cartridge.

9 How do we prevent *Cryptosporidium* entering water supplies?

Preventing pathogenic micro-organisms entering a drinking water supply depends firstly on catchment control measures to minimise pollution risks, secondly physical removal in a well-operated treatment plant, and thirdly by disinfection or inactivation of the organisms.

A well-operated water treatment plant using conventional coagulation and filtration can reduce oocysts by as much as 99% or even 99.8% (Hall, 1994). Contrary to received opinion, oocysts, although small (4 - 6 μm), can be

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removed by well-operated sand filters. However, sudden changes in flow rates dislodge some of the solids retained within the filters, including oocysts (Badenoch, 1995; Glasgow, 1998), so the careful operation of the filters is of great importance. This fact is recognised in the UK by the adoption of the treatment regulation summarised in the above section on detection.

In the last decade or so the use of polymeric membranes for water treatment has increased significantly. Membranes are effectively impervious to particulate matter of the size of oocysts and, in theory, can provide an effective barrier. However, membranes and the seals can occasionally leak so even a membrane process cannot be regarded as 100% effective.

Since membrane plants and well-run conventional treatment plants may have occasional problems it is prudent to have additional measures to combat the potential break-through of *Cryptosporidium* oocysts into the drinking water supply. Some sort of disinfection or inactivation method is therefore desirable. Furthermore, disinfection is, of course, also required for the inactivation of pathogenic viruses and bacteria.

The traditional techniques available for disinfecting drinking water consist of chemical dosing with chlorine, chloramines, chlorine dioxide and/or ozone. An emerging technology is irradiation with ultra-violet (UV) light.

Oocysts are protected by a thick wall which is highly resistant to chlorine. Free chlorine is effective against bacteria and viruses but ineffective against *Cryptosporidium* oocysts because it requires impracticably large concentrations that would create undesirable chemical by-products. Unfortunately, the evaluation of the performance of all disinfectants is strongly dependent on the method used for determination of the degree of oocyst inactivation and the different methods give inconsistent results. Most of the work carried out in the UK has used viability measurements which suggested that the disinfectants used in water treatment, at practicable dose levels, are ineffective as a means of reducing risk from *Cryptosporidium*.

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Irradiation with UV light is claimed to be an effective form of disinfection - or inactivation - for *Cryptosporidium*. The UV damages DNA in cells, disrupting their replication thereby preventing new cells being created. Although early work on UV light suggested that it was not very effective against *Cryptosporidium* a number of recent studies using different techniques to measure inactivation have claimed reductions in oocyst viability of 99% to 99.99% (Dyksen, 1998; EPA, 1999; Leech, 2000). A detailed description of the use of UV light for disinfection can be found in the EPA Manual on Alternative Disinfectants (EPA, 1999). The use of UV light for disinfection of water and inactivation of oocysts is becoming increasingly widely used, especially on waters taken from sources which are known (or suspected) to be susceptible to contamination by *Cryptosporidium* and *Giardia*.



UV disinfection equipment. *Photograph courtesy of Hanovia Ltd.*

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However, in the UK there are concerns that the available data on UV effectiveness are mainly derived from laboratory experiments, frequently under static conditions. Where studies have addressed the effects of natural water quality the conditions have not been representative of actual high-risk conditions. Studies have also used unrealistically high spiking levels of oocysts which bear little relation to the high risk situation in drinking water treatment where much lower concentrations can be associated with particulate matter that could protect oocysts from the UV light.

10 Summary

Cryptosporidium is a parasite which can produce an unpleasant gastric illness known as cryptosporidiosis. The parasite is transmitted in an encysted form known as an oocyst. At the present time there is nothing to treat cryptosporidiosis other than the body's defence systems. Cryptosporidiosis can, therefore, be a serious problem in people with weak immune systems such as young children, the elderly, people on cytotoxic drugs and those suffering from AIDS. *Cryptosporidium* is the third leading cause of non-viral gastro-intestinal illness in the UK

There are a number of different species and strains of the parasite, but those which can infect human beings are also capable of infecting some animals, and vice versa.

Cryptosporidium is frequently waterborne in natural waters and infections have occurred from drinking contaminated water supplies. However, there are many other possible sources of infection such as zoonosis (animal-person contact), contaminated food and contaminated swimming pools and other recreational waters (rivers and lakes), or foreign travel.

A well-operated drinking water treatment plant can physically remove over 99.99% of oocysts from an affected raw water. Traditional processes such as coagulation, clarification and filtration remain the best defence against this parasite entering supplies.

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The effectiveness of chemical disinfectants is very limited as revealed by the available measures of oocyst viability. However there are indications that UV light may be effective.

In the UK there are regulations to control the risk of pathogens getting into the drinking water supply. There are also additional regulations which are aimed specifically at the control of *Cryptosporidium* oocysts in the water supply which specify that there must be no more than 1 oocyst per 10 litres of water, regardless of whether the oocyst is viable or not. This regulation is intended as an operational standard for the performance of treatment works. The rationale is to ensure that the processes of physical removal are continuously capable of removing oocysts when challenged with their presence in raw water sources.

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References

- Atherholt, T. B., LeChevalier, M. W., Norton, W. D. and Rosen, J. S. (1998) "Effect of rainfall on *Giardia* and *Cryptosporidium*", J Amer. Water Works Assn. **90**(9), 66-80.
- AWWA, (1999). Waterborne Pathogens: Manual of Water Supply Practice, Manual M48, ISBN 1 58321 022 9.
- Badenoch, J. (1990) *Cryptosporidium* in water supplies; report of the Group of Experts. HMSO, ISBN 0 11 752322 4
- Badenoch, J. (1995) *Cryptosporidium* in water supplies: second report of the Group of Experts. HMSO, ISBN 0 11 753136 7
- Bouchier, I. (1998) *Cryptosporidium* in water supplies: third report of the Group of Experts. HMSO, ISBN 1 85112 131 5
- Carrington, E. G. and Smith, H. V., (1995). The occurrence of *Cryptosporidium* oocysts in surface waters and factors influencing their levels, with particular reference to the United Kingdom. Protozoan parasites and water, pp.57-62, Royal Society of Chemistry, ISBN 0 85404 755 7.
- Casemore D. P., Sands, R. L. and Curry, A. (1985) "*Cryptosporidium* species a "new" human pathogen". *J Clin Pathol.* **38**, 1321-1336.
- Chalmers, R. M., Sturdee, A. P., Bull, S. A. and Miller, A., (1995) "Rodent reservoir of *Cryptosporidium*", in Protozoan Parasites and Water, pp. 63-66, Ed. Betts, W. B., Casemore, D. P., Fricker, C. R., Smith, H. V. and Watkins, J., pub. Royal Society of Chemistry, ISBN 0 85404 755 7.
- Chappell, C. I., Okhuysen, P. C., Sterling, C. R., Wang, C, Jakubowski, W. and DuPont, H. L., (1999) "Infectivity of *Cryptosporidium parvum* in healthy adults with pre-existing anti-*C. parvum* serum immunoglobulin G." *Am J Trop Med Hyg*, **60**(1), 157-164.

Review of Current Knowledge

Curriero, F. C., Patz, J., Rose, J. B. and Subhash, L. (2001) "The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948-1994". *Am J Public Health*, **91** (August), 1164-1199.

DuPont, H. L., Chappell, C. L., Sterling, C. R., Okhuysen, P. C, Rose, J. B. and Jaku, W. (1995) "The infectivity of *Cryptosporidium parvum* in healthy volunteers." *New Engl J Med*, **332**(13), 855-859.

DWI (2000). "Review of outbreaks of cryptosporidiosis in swimming pools", Ref. No. DWI 0812. Available from FWR, Allen House, The Listons, Marlow, Bucks., SL7 1FD, UK.

DWI (2004). "Workshop on the application of genetic fingerprinting for the monitoring of *Cryptosporidium* in humans, animals and the environment. (Boulder, Colorado, USA 3rd-5th August 2003)". ISBN: 09521712 5 2 Reference No. DWI/B2003 Available from FWR, Allen House, The Listons, Marlow, Bucks., SL7 1FD, UK. www.fwr.org

Dyksen, J. E. 1998. "Cost of advanced UV for inactivating *Cryptosporidium*." *J Amer. Water Works Assn.*, **90**(9), 103-111.

EPA (1999). "Alternative Disinfectants and Oxidants Guidance Manual: section 8. Ultraviolet radiation." published by the US Environmental Protection Agency, Office of Water, Washington, DC 20460. EPA 815-R-99-014, April 1999.

EU Council Directive 98/83/EC (OJ No. L330, 5.12.98 p32) on the quality of water intended for human consumption.

FWR, 2006. *Giardia* in Water Supplies. Ref. No. FR/R0006. Available from FWR, Allen House, The Listons, Marlow, Bucks., SL7 1FD, UK. www.fwr.org

Glasgow, G. D. E. and Wheatley, A. D. (1998) "The effect of surges on the performance of rapid gravity filtration". *Water Sc. & Techn.* **37**(2), 75-81.

Review of Current Knowledge

Hall, T., Presdee, J., and Carrington, C. (1994) "Removal of *Cryptosporidium* oocysts by water treatment processes", Ref. No. FR 0457. Available from FWR, Allen House, The Listons, Marlow, Bucks., SL7 1FD.

Hancock, C. M., Rose, J. B. and Callahan, M., (1997) "The prevalence of *Cryptosporidium* and *Giardia* in US groundwaters". International Symposium on Waterborne *Cryptosporidium*, Newport Beach, California.

Hoxie, N. J., Davies, J. P., Vergeront, J. M., Nashold, R. D., Blair, K. A. (1997) "Cryptosporidiosis-associated mortality following a massive waterborne outbreak in Milwaukee, Wisconsin". *Am J Public Health*, **87**(December), 2032-2035.

Hunter P. B, (1999) Letter re. Community study of infectious intestinal disease in England by Wheeler *et al.* *BMJ*, **319**, 258.

Jacangelo, G., Adham, S. S. & Lainé, J-M. (1995) "Mechanism of *Cryptosporidium*, *Giardia* and MS2 virus removal by MF and UF." *J Amer. Water Works Assn.*, **87**(9), 107-121.

Leech, J. 2000. "Advances in ultraviolet treatment of wastewater". *Water & Waste Treatment*, April, p21.

MacKenzie, W. R, Hoxie, N. J., Proctor, M. E., Gradus, M. S., Blair, K. A., Peterson, D. E., Kazmierczak, J. J., Addiss, D. G., Fox, K. R., Rose, J. B., Davies, J. P. (1994) "A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through the public water supply". *New England J Med.*, **331**(3), 161-167.

Morgan, D., Allaby, M., Crook, S., Casemore, D., Healing, T. D., Soltanpoor, N., Hill, S. and Hooper, W. (1995) "Waterborne cryptosporidiosis associated with a borehole supply". *CDR Review*, 5(7), 23 June, R93-R97. ISSN 1350 9349

Nahrstedt, A. and Gimbel, R. (1996) "A statistical method for determining the reliability of the analytical results in the detection of *Cryptosporidium* and *Giardia* in water" *J Water SRT - Aqua*, **45**(3), 101-111.

Review of Current Knowledge

Puech, M. C., McAnulty, J. M., Lesjal, M., Shaw, N., Heron, L. and Watson, J. M. (2001) "A statewide outbreak of cryptosporidiosis in New South Wales associated with swimming in public pools", *Epidemiol Infect*, **126**(3), 389-396.

SI 1988 No. 1546. The Public Health (Infectious Diseases) Regulations 1988.

SI 1999. No. 1524. The Water Supply (Water Quality) (Amendment) Regulations 1999 (These are the "*Cryptosporidium* Regulations").

Standard Operating Protocols for the Monitoring of *Cryptosporidium* Oocysts in Treated Water Supplies to Satisfy Water Supply (Water Quality) (Amendment) Regulations 1999, SI 1999 No. 1524. (Available from www.dwi.gov.uk/regs/index.htm)

Wheeler J. G., Sehti, D., Cowden, J. M., Wall, P. G., Rodrigues, L. C., Tomkins, D. S., Hudson, M. J. & Roderick, P. J. (1999) "Study of infectious intestinal disease in England: rates in the community, presenting to general practice, and reporting to national surveillance", *BMJ*, **318**, 1046-1050.