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Guidance for the investigation of *Cryptosporidium* linked to swimming pools

Agencies: Public Health Wales, Public Health England, Local Authorities, the Chartered Institute of Environmental Health, the Pool Water Treatment Advisory Group and the Chartered Institute for the Management of Sport and Physical Activity.

Ownership:
Head of national *Cryptosporidium* Reference Unit, Public Health Wales.

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Purpose of Document:

This document was drawn up by a task and finish group to provide guidance to public health professionals on the prevention and investigation of cases of cryptosporidiosis linked to swimming pools in England and Wales. This guidance concentrates on conventional swimming pools i.e. rectangular, indoor pools used by people of all ages and with no extra features. Although the recommendations hold good for most pools, they may need to be varied to apply to non-conventional or specialist pools.

It is intended for use alongside the Pool Water Treatment Advisory Group's (PWTAG) publication Swimming Pool Water Treatment and Quality Standards for Pools and Spas, Third Edition 2017 (ISBN 978-1-5272-1666-2), the PWTAG Code of Practice and Technical Notes available at www.pwtag.org

Information about risks and prevention from interactive water features and paddling pools is provided in PWTAG Technical Note 13.

A separate document is available on controlling infection risks in spa pools, although these are rarely linked to *Cryptosporidium* because head immersion, and therefore ingestion of water, is rare in these settings. If needed, see Control of legionella and other infectious agents in spa-pool systems at http://www.hse.gov.uk/pubns/books/hsg282.htm

Summary of document:

Infection with the protozoan parasite *Cryptosporidium* is characterised by watery diarrhoea, abdominal pain, and nausea and/or vomiting. For most people, it is an unpleasant but self-limiting illness lasting up to 3 weeks, but in some very immuno-compromised individuals, infection may cause severe, possibly life-threatening illness.

Transmission is via the oocyst life cycle stage, during close contact with an infected person, animal, or their faeces, or through consumption of contaminated food, drinking water or recreational waters.

Oocysts are shed in high numbers (10^6 – 10^7 per gram stool) during acute illness. There is a high probability of infection from a single oocyst.

Oocysts may continue being shed for two weeks after symptoms have ceased, with long-term asymptomatic carriage also reported.

Since 2001, swimming pools have been the most common setting for outbreaks of waterborne infectious intestinal disease in England and Wales, with *Cryptosporidium* as the leading cause.

Cryptosporidium presents specific infection control difficulties because unlike most other pathogens it is resistant to normal chlorine levels used for pool disinfection. Oocysts can survive for months in moist environments with ambient temperature and will therefore survive in pool water and present an infection risk unless removed.

Removal of oocysts from pool water relies on good circulation with optimal filtration and coagulation/flocculation. Secondary disinfection using ozone and more practically UV light plays an important role in *Cryptosporidium* disinfection. UV light is recommended by PWTAG, both for its capacity to reduce chloramines and inactivate microorganisms.

Despite these measures, bathers in the vicinity of faecal contamination by someone infected with *Cryptosporidium* will be at risk if they ingest the pool water. Risks to public health can be minimised by 1. ensuring swimming pool construction, engineering, management, procedures and pool water circulation, treatment and disinfection are optimal and in accordance with current guidelines, and 2. healthy swimming messages are promoted and followed by pool users. Both approaches are detailed by PWTAG in the CoP and posters are available to inform bathers (www.pwtag.org).

The guidance outlines:

- The problems of *Cryptosporidium* and swimming pools
- The legal framework
- Normal pool water treatment, operating parameters and standards
- How *Cryptosporidium* evades pool water treatment and disinfection
- Establishing and investigating a link between cases and pools
- Emergency actions for public health protection
- Public health messages
- Independent sources of advice
- Inspection of swimming pools.

The key public health messages are:

- People with diarrhoea should not use swimming pools whilst symptomatic, or for 48 hours after symptoms have completely ceased
- People diagnosed with cryptosporidiosis should not use swimming pools for 14 days after symptoms have resolved
- Encourage frequent toilet breaks and always wash hands after using

the toilet
- Babies and toddlers must wear special, double-wrap swim nappies
- Thorough pre-swim hygiene including showering reduces risk of pool water contamination
- Do not swallow pool water.
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Work Plan reference: Cryptosporidium Reference Unit 2010/11

Document Amendment:

Date	Section No.	Page No.	Version No.	Description
06/02/14	All	All	2	Review of complete document and appendices Reflect organisational changes Clarification of key points Improved cross referencing to PWTAG Technical Notes Updated information from outbreaks Updated legal framework Updated references Revised backwash water sample volume from 1-10 L to 1 L Improved checklist layout and interpretation
15/07/16	5 5 6		3	Updated source of cleaning guidance in 5.2.2 Section 5.2.5 Removal of sentence "Sampling and testing can also be accessed through the *Cryptosporidium* Reference Unit". Appendix 2 withdrawn Email address for comments changed to Swansea.crypto@wales.nhs.uk
January 2020	All		4	Updated cross references, legislation and organisations Included healthy swimming by bathers as a critical control point Included a transmission pathway Key defences simplified Updated epidemiological data Improved advice notes Improved terminology to differentiate filter velocity and pool water circulation rate

Contents

The Appendices are available as separate documents, downloadable from www.publichealthwales.org/cryptopoolguidance/

Appendix 1. *Cryptosporidium* risk assessment checklist.
(Appendix 2. WITHDRAWN: Sampling swimming pools for *Cryptosporidium*)
Appendix 3. Sources of independent advice regarding swimming pools.
Appendix 4. Example of letter to GPs/Hospital Trusts/NHS Direct.
Appendix 5. Example enhanced questionnaire for the investigation of cases linked to a swimming pool.
Appendix 6. Example cryptosporidiosis advice notes.

ABBREVIATIONS

A&E	Accident and Emergency
BCDMH	Bromochlorodimethylhydantoin
BDCM	Bomodichloromethane
CCDC	Consultant in Communicable Disease Control
cfu	Colony-forming unit
CPH	Consultant in Health Protection
CIEH	Chartered Institute of Environmental Health
CIMSPA	Chartered Institute for the Management of Sport and Physical Activity
Ct	Contact time for disinfection value
eFOSS	Outbreak Electronic Foodborne and Non-Foodborne Gastrointestinal Outbreak Surveillance System
EAP	Emergency action plan
GP	General Practitioner
ICT	Incident control team
JP	Justice of the Peace
MPN	Most probable number
NIS	National Infection Service
NOP	Normal operating procedure
NTU	Nephelometric turbidity unit
OCT	Outbreak control team
ORP	Oxidation reduction potential
PCT	Primary Care Trust
PHE	Public Health England

PWTAG	Pool Water Treatment Advisory Group
UV	Ultraviolet
WHO	World Health Organization

1 Introduction

Since 2001, swimming pools have been the most common setting for outbreaks of waterborne infectious intestinal disease in England and Wales, with *Cryptosporidium* as the leading cause (Smith et al., 2006; Nichols et al., 2006). The need for guidance was identified as a result of an increased number of investigations, particularly during 2009 (Anon, 2009a).

The protozoan parasite *Cryptosporidium* causes an acute gastroenteritis, often lasting up to two weeks, sometimes more, and presents specific infection control difficulties in swimming pools (Kebabjiam, 1995; Ryan et al., 2017). This is because, unlike most other pathogens, it is resistant to normal chlorine disinfection (Korich et al., 1990) which provides the residual disinfectant in the majority of swimming pools. Removal of *Cryptosporidium* from swimming pool water by filtration is possible over time but only if there is good circulation and optimal filtration incorporating coagulation (Wood et al., 2019) (see Section 3 for explanation of pool water treatment). Pools with supplementary disinfection by ozone or ultra violet (UV) light may offer increased disinfection of *Cryptosporidium* as the water passes though the treatment plant if the dose and contact time are sufficient. However, bathers in the vicinity of faecal contamination by someone infected with *Cryptosporidium* will be at risk if they ingest the pool water. Despite this, risks to the public health can be minimised by making sure swimming pool design, construction, engineering, management, procedures, and pool water circulation, treatment and disinfection are optimal and in accordance with current guidelines. A critical control point is the adoption of healthy swimming practices by pool users to minimise the introduction of Cryptosporidium into swimming pools (Chalmers and Johnston, 2018).

1 Background to the problem of *Cryptosporidium* and swimming pools

1.1 *Cryptosporidium* and cryptosporidiosis

Cryptosporidium is a protozoan parasite that causes an acute gastroenteritis (Davies and Chalmers, 2009). Transmission is by the oocyst life cycle stage, via the faecal-oral route.

The incubation period is 3 to 12 days, usually 5 to 7 days.

The main symptoms are watery diarrhoea, often of sudden onset, abdominal pain, low grade fever, nausea and/or vomiting. Symptoms can range from mild to severe and usually last for up to 2 weeks, sometimes longer, with about one third of patients experiencing relapse (Hunter et al., 2004a). Patients may continue to shed oocysts for two weeks after symptoms have ceased. Asymptomatic carriage can also occur.

Illness is usually self limiting but in patients with certain T-cell related immuno-deficiencies, it can be severe and sometimes life threatening (Hunter and Nichols, 2002). Long term sequelae have been reported but require further investigation (Hunter et al., 2004b; Davies and Chalmers 2009; Stiff et al., 2017; Carter et al., 2019).

All ages can be affected but more cases are reported among children, especially the under five year olds, than adults.

Oocysts, which are about 5 µm in diameter, are shed in the stools in high numbers (10^6 to 10^7 per gram stool) during acute illness, and are infective immediately. They can survive in moist environments at ambient temperatures for months; survival is longer under cool conditions.

Ingestion of fewer than 10 oocysts may be sufficient to cause infection and disease.

There is no specific drug treatment licensed in the European Union.

Cryptosporidium is widespread in all countries and in addition to human infection, causes disease in animals, mainly neonatal livestock. Transmission is by close contact with an infected person or animal, or their faeces, or through the consumption of contaminated drinking water or recreational waters. Cases and outbreaks have also been associated with contaminated foods including salad items, fresh-pressed apple juice and unpasteurised milk and dairy products.

Outbreak settings have included:

- Treated recreational water venues (communal swimming or splash venues).
- Untreated recreational water venues (lakes, rivers).
- Institutions (day care centres and nurseries, schools, hospitals, prisons).
- Farms (open farms, commercial farm open days, residential farm centres).
- Households.
- Community.

Outbreaks have been linked to:

- Swimming pools.
- Water parks.
- Interactive water features (splash zones).
- Paddling pools.
- Decorative fountains.
- Mains water supplies.
- Private water supplies.
- Person-to-person spread.
- Animal contact.
- Surface water contact.
- Environmental contact.
- Food consumption.

Two *Cryptosporidium* species account for >96% of cases in the UK: *Cryptosporidium parvum* can be acquired from animals (mainly young ruminants) or humans, and *Cryptosporidium hominis* is acquired from humans. Infection with either species has been linked to swimming pools, although *C. hominis* is more common in this setting (Chalmers et al., 2019). Species identification (typing) is a reference test undertaken by the Cryptosporidium Reference Unit in Swansea. There is no standardised sub-typing scheme for *Cryptosporidium*, although sequencing the gp60 gene is helpful for investigating clusters of cases and in outbreaks (Chalmers et al., 2019).

In some outbreaks and especially in sporadic cases, the source of the infection may be difficult to ascertain, and recuperating patients, asymptomatic carriers or people with only mild symptoms may be involved in transmission as substantial numbers of oocysts may still be shed. Routine diagnostic tests may fail to detect the parasite in stools because the threshold of detection is high. Similarly, testing of suspected sources or vehicles may yield false negative results. Because the infectious dose is very low, even low numbers of oocysts can amount to a substantial infection risk.

1.2 *Cryptosporidium* and survival of pool water treatment

Swimming pool water treatment is a re-circulating system (in contrast to drinking water treatment which is a once-through system), comprising two main steps: filtration and disinfection. Filtration maintains a physically clean, clear and safe environment. Disinfection is needed to prevent cross-infection between bathers and the growth of infectious agents in the water and on the surfaces of the swimming pool system.

If *Cryptosporidium* contaminates a swimming pool, bathers are at risk of infection (Chalmers and Johnston, 2018). The size of that risk will depend on the design and construction of the pool, effectiveness of the treatment, management and operation of the pool, and the actions taken following incidents such as faecal accidents. Well-designed, modern pools should have treatment that is capable of removing *Cryptosporidium* oocysts. However, even modern pools can be mismanaged in a way that allows water to become contaminated.

The main problems with *Cryptosporidium* and swimming pool water treatment are that:

- *Cryptosporidium* oocysts are resistant to the levels of chlorine normally present in pool water.
- There is no routinely used residual disinfectant that inactivates *Cryptosporidium* oocysts in pool water.
- Additional disinfection that may be effective (e.g. UV, ozone) is plant-room based.
- Swimming pool filters were not designed to remove *Cryptosporidium*; medium rate filters (<25 m/h) are more effective than high rate, and their efficiency is greatly improved with flocculation/coagulation.
- Filters can allow breakthrough of *Cryptosporidium* oocysts if they are not backwashed frequently enough.
- Filter backwashing can disrupt filter integrity and allow *Cryptosporidium* oocysts to break through so needs to be carried out properly.
- Backwashing just before or during pool use may re-contaminate the pool water with *Cryptosporidium* oocysts and expose swimmers.

A pathway has been produced for transmission in an indoor swimming pool (see below).

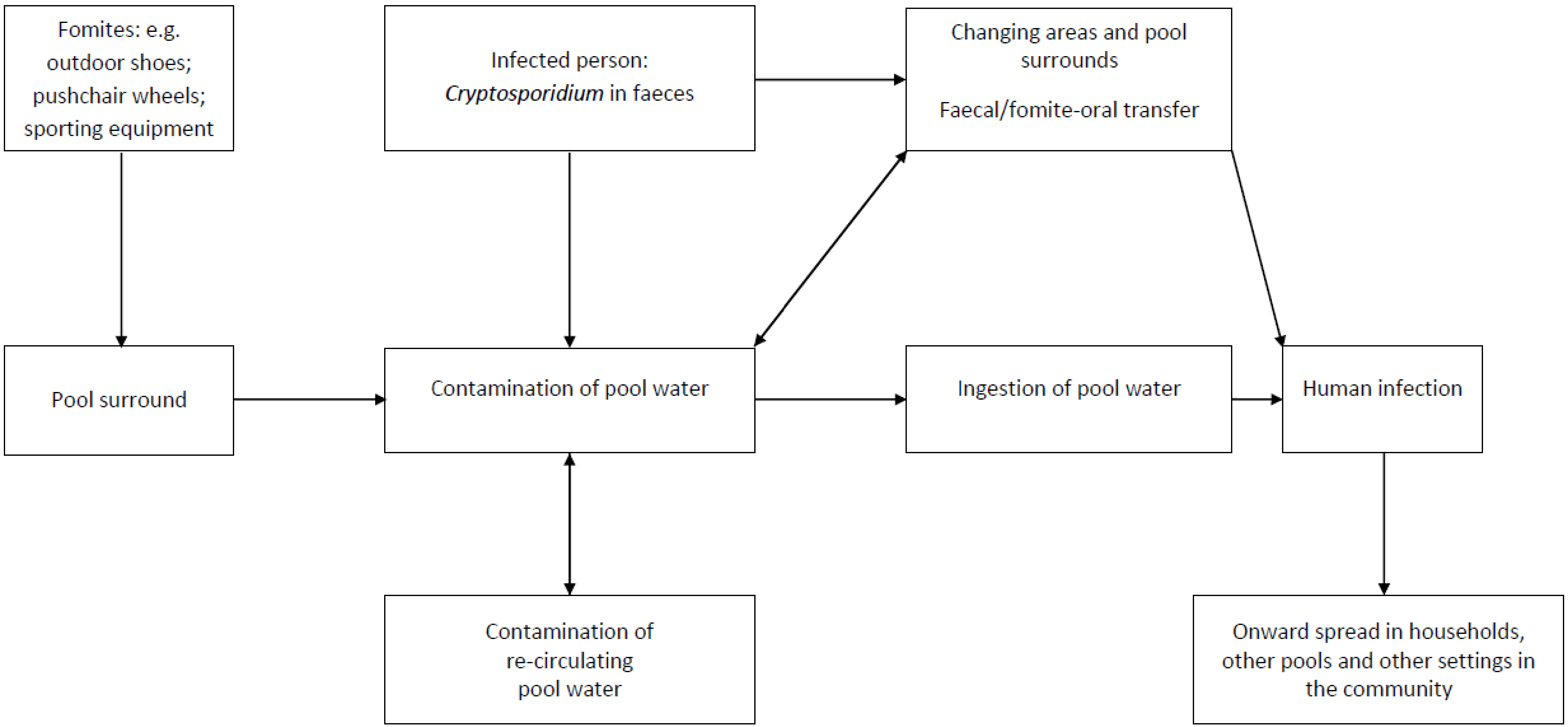

Figure 1. Transmission of Cryptosporidium in an indoor pool.

Reproduced from Chalmers R, Johnston R. Understanding the public health risks of Cryptosporidium in swimming pools: a transmission pathway approach. Perspect Public Health. 2018 Sep;138(5):238-240. doi: 10.1177/1757913918772795.

Mitigation can reduce the risk. Key defences supported by good pool management are essential and are outlined in the textbox below.

The key defences against *Cryptosporidium* are:

- Keep *Cryptosporidium* out of the pool through the promotion of healthy swimming behaviours.
- Deal with contamination promptly and appropriately.
- Adequate pool water circulation, coagulation and filtration to remove contaminants.
- Good filter backwashing practice and procedures.
- Adequate pool design and construction to prevent cross connections and spread of contamination.
- Circulation, filtration and treatment for learner pools that is separate from the main pool.
- Additional treatment with UV light.

1.3 Information from outbreaks

Outbreaks of cryptosporidiosis linked to swimming pools were first recognised in the United States of America in 1988 (CDC, 1990; Sorvillo et al., 1992) and in the UK in Doncaster the same year (Joce et al., 1991). Increased awareness and recognition of the risks from swimming pools have led to an apparent increase in the number of recognised outbreaks and since 1999, swimming pools have been the most frequently identified setting for outbreaks of cryptosporidiosis in England and Wales (Smith et al., 2006; Nichols et al., 2006; Chalmers et al., 2019).

1.4 National outbreak surveillance

National outbreak surveillance for general outbreaks of infectious intestinal disease in England and Wales is based on voluntary reporting; data are collated by PHE using the Outbreak Electronic Foodborne and Non-Foodborne Gastrointestinal Outbreak Surveillance System (eFOSS). Between 1992 and the end of 2017, there were 116 reported outbreaks of cryptosporidiosis linked to swimming pools. Not all outbreaks are reported to eFOSS and additional outbreaks came to the attention of the national Cryptosporidium Reference Unit for investigation and species identification. Analysis of a combined dataset from 2009 to 2017 (Chalmers et al., 2019) showed that there were a total of 178 outbreaks of cryptosporidiosis of which 82 (46%) were linked to recreational waters, mainly swimming pools, involving a median of 5 (2–70) confirmed cases per outbreak (Table 1).

Genotyping data was available for 59 (72 %) outbreaks and showed that most were caused by *C. hominis* (n=52 outbreaks) although *C. parvum* (n=6 outbreaks) was also involved and there was one outbreak caused by both species (Table 1). Not all case isolates are genotyped but those that are have been shown to be representative of cases in general (Chalmers et al., 2009; Chalmers et al., 2010).

Table 1. Recreational water outbreaks and *Cryptosporidium* species identified in cases in England and Wales, 2009–2017 (PHE eFOSS and CRU data).

Setting	**Number of outbreaks**				
	Total	**No. geno-typed (%)**	***C. parvum***	***C. hominis***	**Both species**
All recreational waters	82	59 (72%)	6	52	1
Swimming pool	72	55	6	48	1
Hydrotherapy pool	5	1	0	1	0
Baby swimming pool	4	2	0	2	0
Paddling pool (outdoor)	1	1	0	1	0

The number of outbreaks linked to recreational waters varied each year, median nine (range three to fifteen) (Figure 2).

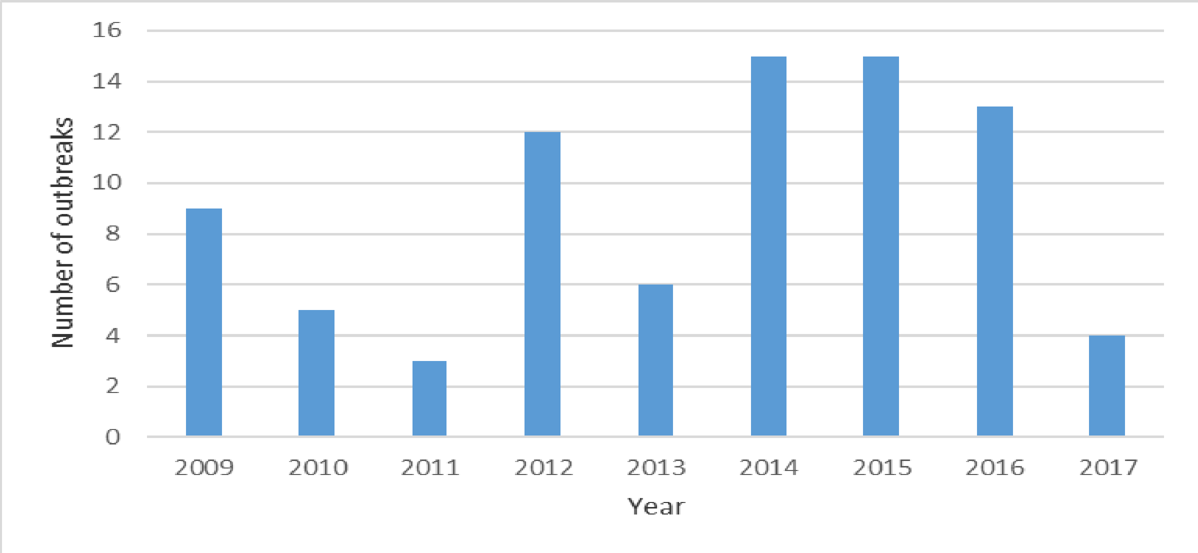

Figure 2. Annual distribution of outbreaks of cryptosporidiosis linked to recreational waters reported to national surveillance and CRU 2009-2017 (PHE eFOSS and CRU data).

Although outbreaks occurred at any time of the year, there was a seasonal distribution with most occurring in the second half of the year, especially in August and September (Figure 3).

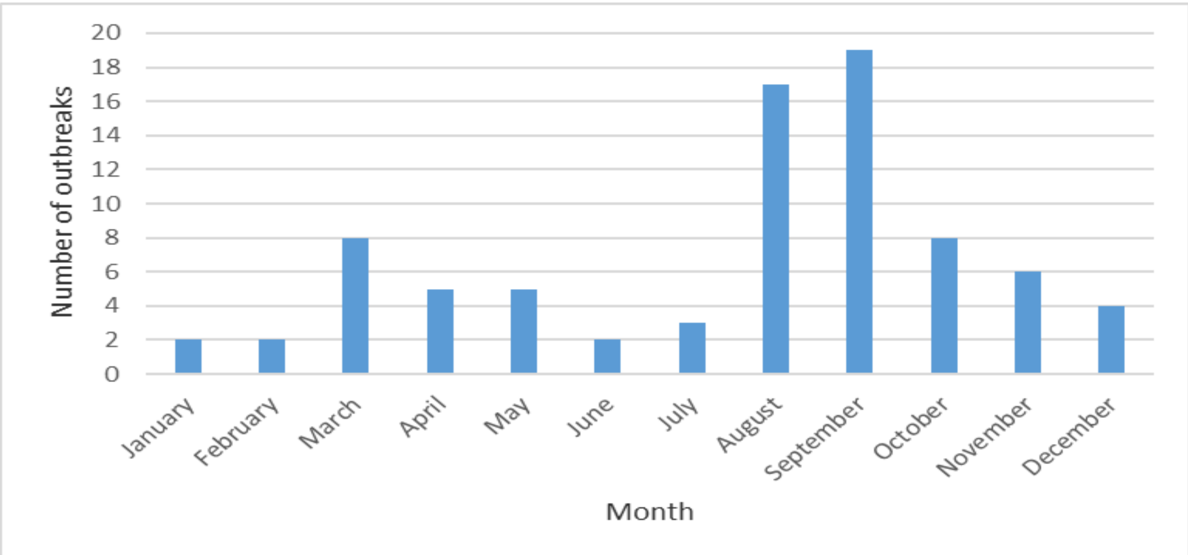

Figure 3. Monthly distribution of outbreaks of cryptosporidiosis linked to swimming pools reported to national surveillance 2009-2017 (PHE eFOSS and CRU data).

Outbreaks were reported in all regions, with most in the South West (Table 2).

Table 2. Regional reports of outbreaks of cryptosporidiosis linked to swimming pools reported to national surveillance 2009-2017 (PHE eFOSS and CRU data).

Region	**Number of reported outbreaks**
South East	16
South West	15
North West	13
East of England	7
East Midlands	7
Yorkshire & the Humber	6
Wales	6
North East	5
London	4
West Midlands	3

Most recreational water outbreaks were linked to swimming pools at leisure centres but other settings were also involved (Table 3).

Table 3. Settings of outbreaks of cryptosporidiosis linked to swimming pools reported to national surveillance 2009-2017 (PHE eFOSS and CRU data)

Recreational water setting	**Number of reported outbreaks**
Leisure centre pools	24
Unspecified pools	21
Holiday/caravan/water parks	19
Health care, hydrotherapy pools	5
School and college pools	4
Private clubs and hotels	4
Dedicated baby swimming pools	4
Outdoor paddling pool	1

1.5 Review of 18 outbreaks followed up for pool details, 1990-1998

Following a peak in the number of reported swimming pool-related outbreaks identified in England and Wales in 1999, a review was undertaken in 2000 of the 18 outbreaks in the preceding 10 years (Chalmers et al., 2000), providing additional information about the nature of such outbreaks that is still of relevance.

Most (n=14) of the outbreaks were associated with swimming pools on the basis of descriptive epidemiology, with analytical epidemiological evidence in only four outbreaks. This was often limited to identifying the swimming pool as a possible common factor among cases, although head immersion was significantly associated with illness in the Doncaster outbreak in 1988 (Joce et al., 1991).

In some outbreaks the evidence for association with the pool was not strong and there could be other exposure risks at the pool facility such as food consumption or changing room/toilet hygiene which should also be considered during outbreak investigations.

While good descriptive epidemiology may itself identify a link with a swimming pool without the need for more complex epidemiological investigation, analytical studies may be required to provide epidemiological evidence for a common source of disease or specified risk factor which would enable appropriate action to protect the health of the public. In addition, analytical studies may provide information about transmission or particular risk factors in such settings leading to general improvements at these facilities. Because many pool related outbreaks involve only a small number of cases the power of a study may not be sufficient to show statistical significance. This can be important in deciding whether such a study is warranted.

Sampling pool water or filter samples for *Cryptosporidium* revealed oocysts in six incidents, but approaches to sampling were variable. Sampling and testing for *Cryptosporidium* is discussed in Section 5.

The pools involved included those disinfected with chlorine or with additional ozone facilities, but the latter were often reported to be failing. Outbreaks occurred at pools considered by the investigating team to range from poorly- to well-managed, indicating the vulnerability of swimming pools to *Cryptosporidium* contamination. However, details of pool water treatment and bacteriological monitoring were often sparse.

Outbreaks were more frequently reported in learner or toddler pools than main pools, reflecting the vulnerability of the key user group (young children) who could also be the source of infection. Two thirds of the cases who swam were children, and one quarter were under five years old. Diarrhoea is more likely to be investigated in this age group than adults, and outbreaks of illness may be more readily noticed amongst groups of children. However, young children are more susceptible to infection. The distribution may also reflect the risk activities and behaviours of this particular age group.

Recognised faecal accidents at the pool were reported prior to only four outbreaks although such contamination was suspected in a further five outbreaks. Reporting systems for faecal accidents were often lacking at the pools.

A global analyses of all waterborne disease outbreaks associated with protozoa has also been published (Karanis et al., 2007; Baldursson and Karanis, 2011).

1.6 Keeping *Cryptosporidium* out of the pool

Because of the resistance of *Cryptosporidium* to chlorine disinfection, keeping the parasite out of the pool, and removal from the water through effective treatment remain key control measures. The source of *Cryptosporidium* contamination in swimming pools is usually directly from bathers, either as an overt faecal accident or residual faecal matter on bathers' bodies (CDC 2001). Although they are relatively rare in the UK, outdoor pools or pools with outdoor features, for example river rapids, could be contaminated by pets and wildlife.

Cryptosporidium infections are common in young children who may contaminate the pool water either through faecal incontinence, accidents or from contamination on their skin. A double wrap swim nappy system is recommended for young children, but does not retain liquid stools and so are not appropriate for use on a child with infectious diarrhoea; no-one with diarrhoea should swim. Recognised faecal releases in swimming pools are reported to occur especially frequently in pools used by young children; one published paper indicates these occur a couple of times a month (Schets *et al.,* 2004). Some pool operators report them two or three times a week, others rarely (personal communication from pool managers).

A liquid stool is more likely than a formed stool to contaminate hands and the environment, and presents a greater risk of spreading faecal pathogens. All faecal accidents should be reported, recorded and handled appropriately, in accordance with the latest PWTAG guidelines (see www.pwtag.org).

Even asymptomatic carriage, or recovered individuals shedding lower numbers of oocysts in smaller volumes of faeces, or having residual matter after inadequate cleaning, may contribute substantially to contamination.

Although a study in USA failed to detect *Cryptosporidium* oocysts in 293 formed faeces recovered from non–outbreak-related pools, a diagnostic immunofluorescence microscopy (IFM) assay (Anon 2001) had been used which may underestimate the presence of oocysts in such samples. In a study of asymptomatic carriage in children in nurseries in the UK the prevalence was 1.3% (95% confidence interval 0.3% to 3.8%) using a more sensitive test. This test, which combines immuno-magnetic separation of oocysts with IFM, detected oocyst concentrations of between 56 and 13367 oocysts per gram formed stool, which may have been missed by IFM alone (Davies et al., 2009). Formed stools may therefore pose a risk of *Cryptosporidium* contamination, but are generally considered less likely to transmit infection if they are reported and dealt with appropriately (see section 5.2.2).

Documented procedures for recording the time and place of faecal releases, the actions taken and the names of the operators/life guards are part of good pool management (see section 4), and will be essential in investigating contributing factors in outbreaks.

The problem of people continuing to swim while they are symptomatic has been identified during outbreak investigations and has been identified as a cause of the propagation of outbreaks (Karanis et al., 2007). The need to exclude symptomatic people from swimming pools has been highlighted (McCann et al., 2013).

Experimental infection and dose response models suggest that ingestion of single numbers of *Cryptosporidium* oocysts could cause infection (DuPont et al., 1995; Chappell et al., 2006). Symptomatic individuals can shed over 10^6 oocysts per gram of faeces. A release of faeces, of say 100 ml, by a symptomatic person could yield as many as 100 million oocysts, which, even with dilution factors at the pool, can result in an infectious dose for many other bathers. One study has estimated that during 45 minutes of active swimming, children ingested 37 ml and adults 16 ml pool water (Dufour et al., 2006). It is suspected that very young children, who were not part of that study, may consume more. It is also likely that interractive water features may facilitate consumption of pool water.

Although *Cryptosporidium* does not multiply outside of a host under natural conditions, large numbers of oocysts can be shed in faeces. In only a very few documented outbreaks has cross linkage from sewers been identified, most notably the outbreak in Doncaster in 1988 (Joce et al., 1991). Significant plumbing defects allowed sewage that had backed up from the main sewer into the circulating pool water. Oocysts were detected in the pool water, and there was a significant association between head immersion and illness among bathers.

Knowing where the pool water is coming from and where it goes is vital, as short circuits in the system may mean pool water fails to achieve adequate treatment which could propagate contamination. Dead-legs created either by retention of water in infrequently used circuits (e.g. flume supply or hydro-jet loop), plumbing dead-ends or pool shape can result in lack of circulation and inadequate treatment. Study of the as-built schematic diagram of the pool and water treatment plant is essential.

Although faeces present the usual contamination risk for *Cryptosporidium*, oocysts have been detected in vomit and reported from a childhood case with severe vomiting and diarrhoea (Casemore et al., 1985). Vomiting is reported by 65% cryptosporidiosis cases seeking medical help and is more frequent in children than adults (Hunter et al., 2004a). Vomit is an unevaluated risk for the contamination of swimming pools with *Cryptosporidium*. However, gag reflex induced vomiting is a frequent event in swimming pools, often as a result of swallowing pool water. Current PWTAG guidance for dealing with vomit in swimming pools assumes infectious causes will be dealt with by the residual disinfectant, although the WHO guideline is to deal with vomit in the same way as a liquid stool (WHO, 2006).

Problems that have contributed to outbreaks of cryptosporidiosis:

- Inadequate pool design and construction, including water features.
- Sewage cross-connection.
- Faecal release or contamination from bathers.
- Excessively high bather loads
- Inappropriate handling and disposal of stools.
- Inappropriate response to faecal accidents.
- Inadequate pool water circulation, coagulation and filtration.
- Filter backwashing problems.
- Inappropriate backwashing procedures.
- Ozone or UV treatment not working properly.

2 The legal framework

2.1 Regulation of swimming pools and advisory guidelines

2.1.1 Health and safety law for swimming pools

There are no swimming pool specific health and safety laws. However, swimming pool operators must comply with their general duties under the Health and Safety at Work etc Act 1974 and the associated regulations.

Operators must make a suitable and sufficient assessment of the health and safety risks to workers and users to help decide what they must do to make their pool safe. This is known as risk assessment.

The law does not state what safety measures an operator must put in place. Such judgements must be made by each operator, based on the particular risks in their pool. More information on the law, the duties of swimming pool operators, and conducting a risk assessment are detailed in the Health & Safety Executive (HSE) guidance, HSG179 Managing Health and Safety in Swimming Pools, HSE, 2018.

2.1.2 Guidance and advice

Managing Health and Safety in Swimming Pools has been produced to help pool operators comply with health and safety law and is relevant to swimming pools used by the public, and segregated areas of rivers, lakes, the sea and other non-standard swimming facilities. It applies anywhere swimming is actively encouraged, but it does not apply to swimming in open water which is not maintained as a swimming facility. The guidance may also apply to paddling pools, depending on the particular circumstances.

The Pool Water Treatment Advisory Group (PWTAG) has produced detailed guidance on swimming pool water quality and treatment, that is recognised by HSE as a useful resource for pool operators when drawing up their operating procedures. Enforcing bodies (HSE and local authorities) consider the PWTAG guidance as the standard to be achieved in effectively managed swimming pools.

Advisory guidelines for swimming pools that are brought together in the PWTAG book Swimming Pool Water (PWTAG 2017) are:

The Health & Safety Executive (HSE) guidance, HSG179 Managing Health and Safety in Swimming Pools (HSE 2018) covers both worker and bather safety. Following the advice will help prevent or reduce accidents and ill health. The document gives management advice and technical information on health and safety in swimming pool design and pool water treatment. The information on swimming pool design and pool water treatment is only an introduction to these topics. For more in-depth technical information, refer to the specific industry guidance listed below and the PWTAG book.

The Control of Substances Hazardous to Health Regulations 2002 (COSHH) apply to employers whose business involves 'substances hazardous to health' – which includes all disinfectants and other chemicals used in and around a swimming pool. COSHH regulations also include microorganisms, by-products and any substances creating the sort of hazard to health that a classified chemical might. So pool operators should include in their COSHH assessment specific consideration of bacteria, viruses and protozoa, other pollutants, disinfection by-products etc. As COSHH applies to microbiological safety, pool operators have a clear responsibility to assess the exposure and deal with it through disinfection. This demands chemical as well as microbiological testing.

The Management of Health and Safety at Work Regulations and the COSHH process includes the need for staff involved in the handling and use of chemicals to receive appropriate training and instruction. Managers should check that staff understand and follow all procedures and are aware of their responsibilities. Monitoring and review of the arrangements and their effectiveness must then follow. Actual training sessions need to be recorded and reviewed.

British Standards. In the UK, the body responsible for standards is the British Standards Institution (BSI). The standards are not mandatory, but in the event of an incident, they will be used as evidence, so any deviation from the standards should be documented and reasons given for any variation. The relevant British Standards European Norm (BS EN) for swimming pools are:

British Standard BS EN 15288-1:2018/A1 Swimming pools Part 1:2018 Safety Requirements for Design, provides safety requirements relevant to the design and construction of public pools. It is intended for those who are concerned with construction, planning and operation of swimming pools. It provides guidance about the risks associated by identifying the design characteristics required for a safe environment. The requirements of this standard are applicable to all new classified pools and, as appropriate, to specific refurbishments of classified existing pools. There are no standards for the effectiveness of filters at removing *Cryptosporidium* oocysts.

BS EN 15288-2:2018/Swimming pools Part 2:2018 Safety Requirements for Operation, provides safety requirements for the operation of public swimming pools. It is intended for those concerned with the operation and management of swimming pools. It provides guidance about the risks for staff and users associated with public swimming pools, by identifying the precautions needed to achieve safety. The requirements for safe working methods and supervision shall be followed insofar as they are relevant.

BS EN 13451 Swimming pool equipment (Parts 1–11) includes general safety requirements and test methods thereof.

BS EN 15031 Swimming pool and spa chemicals covers chemicals used for the treatment of pool water.

Sport England Design Guidance Notes for Swimming Pools (www.sportengland.org) outline the basic principles and concepts of good swimming pool design. They are aimed at all those involved in developing swimming provision, point to further information and give a number of best practice examples. This guidance deals with those aspects of building design not directly connected with the water treatment plant – but important nevertheless for the safe, comfortable and efficient running of a swimming pool. That includes ventilation and heating. Good design and system engineering is, however, critical for the reduction of the risks associated with water systems and for safe management and maintenance. Overall, the design should conform to the appropriate guidelines for maintaining safety and the chemical and microbiological quality of the water.

The World Health Organization (WHO) Guidelines for Safe Recreational Waters Volume 2: Swimming Pools and Similar Water Environments (2006) is intended to provide a basis for standard swimming pool settings, and represents a consensus view among experts on the risk to health represented by various media and activities and on the effectiveness of control measures in protecting health. It provides an authoritative referenced review and assessment of the health hazards associated with swimming pools and spas, their monitoring and assessment, and activities available for their control through education of users, good design and construction, and good operation and management. It addresses a wide range of types of hazard, including water quality, physical hazards (leading to drowning and injury), contamination of associated facilities and air quality.

The PWTAG Code of Practice 2016 (being updated in 2019) provides pool operators with a structured plan for the technical operation of their pool. The Code ensures that the technical operation of a pool meets quality standards that provide a healthy experience for swimmers using recognised and established practices, techniques, engineering and design. For this reason all UK pools are encouraged to follow it. The Code provides a model of operation based on the authority of PWTAG good practice. Following the Code gives an assurance to operators and to the public that the pool meets essential healthy pool operational standards. The Code is designed, among other things, to meet the health challenge of *Cryptosporidium*.

The Code is based on the PWTAG book, *Swimming Pool Water: treatment and quality standards for pools and spas*. It does not replace the book. Operators should still refer to it, and it provides some of the basis for PWTAG's training material.

Pools that follow and achieve PWTAG standards through Pool Mark assessment are awarded a plaque and certificate to show their achievement. They also become associate members of PWTAG and receive technical updates, emergency notices and have access to designated areas of the PWTAG website

PWTAG technical notes are updates or new material for the standards and guidance given in the PWTAG book, Swimming Pool Water and in the PWTAG Code of Practice and should be read in association with these publications.

2.2 Local authorities: roles and enforcement powers

The Health and Safety at Work etc. Act 1974, Section 3(1), imposes a requirement on employers to conduct their undertaking in such a way to ensure, so far as is reasonably practicable, that persons not in their employment are not exposed to risk to their health and safety, and this requirement will be enforced by either the Health and Safety Executive or the local authority environmental health departments, depending on the premises where the pool is located as defined within the Health and Safety Enforcing Authority Regulations 1998 (i.e. local authority run leisure centres & special schools are enforced by the HSE, privately owned leisure facilities, hotels etc. are enforced by the local authority).

All workplaces are subject to the provisions of the Health and Safety at Work etc. Act 1974, and will be subject to periodic interventions or inspections by the enforcing authorities. However, there are no regulatory inspection requirements for swimming pools. Frequent inspections will only be undertaken for the highest risk premises and those with swimming pools may not routinely fall into this risk category unless there is a previous history of poor health and safety management.

When a pool becomes implicated in an outbreak of cryptosporidiosis, the enforcing authority for the premises can use their powers in *ss* 20, 21 and 22 of the Act to take such action as is considered appropriate, being proportional to the risk of infection. These powers include the power to enter premises at any reasonable time, to take with them any other duly authorised person, and to make all necessary examinations and investigations including taking measurements, photographs and samples.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR) 2013 do not currently include *Cryptosporidium* as a specified notifiable disease, hence infection due to ingestion of water from a swimming pool operated by a local authority is unlikely to be subject to investigation by the Health and Safety Executive. It is therefore recommended that Local Authorities should, in the interests of public health, adopt the same investigatory procedure as would be used in investigation of a privately owned facility working with the Corporate Health and Safety Department or Leisure Services Directorate as appropriate.

The Public Health (Control of Disease) Act 1984 was amended in 2010 to provide new regulations taking forward the modernisation of health protection law:

- **The Health Protection (Notification) (Part 2A Orders) Regulations and Health Protection (Notification) (Part 2A Orders (Wales) Regulations 2010** include *Cryptosporidium* in the Schedule 2 list of causative agents for which detection is notifiable by laboratories since October 2010. Notification is likely to require urgent response when the notification forms part of known cluster of cases, is known to be a food handler or there is evidence of increase above expected numbers of cases.

- **The Health Protection (Local Authority Powers) Regulations and the Health Protection (Local Authority Powers) (Wales) Regulations 2010** update the powers and duties of local authorities relating to their health protection role, where judicial oversight of a JP is not necessary. These Regulations enable Local Authorities to make formal requests for cooperation of an individual person, or a group of people, to take, or refrain from taking, any action to protect human health. The request must be for the purpose of preventing, protecting against, controlling, or providing a public health response to infection or contamination that presents, or could present, a significant harm to human health.

In the context of cryptosporidiosis associated with the use of pools, dependent on specific circumstances it may be pertinent to use this power to request:

- that cases of cryptosporidiosis refrain from using swimming pools until 14 days after their last symptoms[1].
- pool operators to undertake remedial works to the pool water treatment or filtration system.
- closure of a pool.

2.3 Certification of pool operators

There is no legal requirement for pool operators to be certificated or registered with certain bodies, but only trained, competent people should operate plant and handle chemicals. In meeting this requirement, the training for the safe operation and use of equipment and chemicals will need to:

➢ Be related specifically to the design, operation and maintenance of the particular plant, hazards associated with it, and substances used. Employees' attention should be drawn to any manufacturers' instructions, and copies made conveniently available (e.g. secured to the plant itself)

➢ Be given to enough employees to ensure that plant need never be operated by untrained, unqualified staff

➢ Be given to all employees whose actions or responsibilities may impact upon water quality or safety

➢ Include pool managers, to ensure they understand the functioning of the pool water system, including the plant and associated hazards, sufficiently to supervise safe operation

➢ Include the use, care and maintenance of personal protective equipment

➢ Include the use of clearly defined procedures based upon normal operating procedures (NOPs), emergency action plans (EAPs), Safety Data Sheets and safe systems of work for all processes involved

➢ Require those who have been trained to demonstrate that they can operate and maintain the plant safely.

[1] To reduce risk of further spread, ALL cases of gastroenteritis should be regarded as potentially infectious and no-one should swim when symptomatic with diarrhoea. At least 48 hours should elapse after the person is free from diarrhoea and/or vomiting before swimming. People with diagnosed cryptosporidiosis should not use swimming pools for two weeks after the first normal stool (Anon 2019).

One requirement of the PWTAG Code of Practice is that pool technical staff shall be appropriately trained and qualified. PWTAG have defined what the training and assessment criteria shall be in a model syllabus that is available to all pools and can be delivered and assessed by PWTAG Accredited Training Organisations. There are other organisations which provide training courses, the course content should ideally be checked to ensure that it is in line with those recommended as being necessary by PWTAG.

3 Swimming pool water treatment and quality

3.1 Basic principles of swimming pool water treatment, disinfection and efficacy against *Cryptosporidium*

This section provides simplified guidance on the principles and practices for maintaining the water in swimming pools in acceptable condition. It is included to enable greater understanding of the issues that may be encountered during investigation of swimming pools. Full details can be found in the PWTAG book and updates on their website (www.pwtag.org). Effectiveness of pool water treatment and disinfection against *Cryptosporidium* is also described.

3.2 Bathers and bather numbers

Each swimming pool plant is designed to accommodate a specific bathing load and a designed bather number should be provided for each pool. All bathers, regardless of age or size, should be counted as one bather.

To minimise bather pollution it is essential to encourage good hygienic standards. Before swimming, bathers should be strongly encouraged to:

- visit the toilets and wash their hands
- wash or shower before use of the pool. Nude showering, with soap, is the ideal standard, with particular attention to young children.
- provide frequent toilet breaks for young children.

Nappy changing facilities should be provided. The facilities must have washbasins and special containers for nappy disposal. Swim nappies for children who are not yet potty trained should be used only to guard against unforeseen accidents: they are not a substitute for frequent toileting breaks nor are they designed as leak-proof. While some stools may be retained, these items leak and must not be used to enable a child with infectious diarrhoea to enter the pool (Amburgey et al., 2009). No-one with diarrhoea (or who has had diarrhoea in the past 48 hours) should swim.

3.3 Swimming pool design and circulation

Swimming pools should be designed to enable dilution of pool water with fresh water to limit accumulation of pollutants from bathers, disinfection by-products and other dissolved chemicals. Pool water replacement should be part of the water treatment regime.

To ensure that the whole pool is adequately served by filtered, disinfected water, good circulation and hydraulics are essential. These should be designed specifically for each pool and the flows modified to obtain satisfactory pool water circulation. Dye testing can be used to demonstrate circulation in the pool. Treated water must continually get to all parts of the pool, including all water features, and water must be removed to prevent the build-up of contaminants, especially from areas most used and most polluted by bathers. It is recommended that 75% to 80% of water replaced is taken from the surface (where the pollution is greatest), with the remainder taken from the bottom of the pool.

3.4 Filtration

Swimming pool filters are designed to maintain a physically clean, clear and safe environment. This is important for the physical safety of bathers and to enable uncompromised disinfection. For adequate filtration, pool water circulation must be good enough to collect all the water in the pool, without dead-spaces. Filtration should run continually.

Swimming pool water filtration is a re-circulating system and successive passes through the filter contribute to *Cryptosporidium* removal from the pool water. Like all plant room treatments, filtration relies on good circulation and turnover. Optimal filtration by sand filters is achieved by the continual fine dosing of a coagulant.

Issues linked to poor circulation and turn-over may contribute to reduction in *Cryptosporidium* removal:

- Some pools have movable floors and this can restrict water flow.
- Poor water turnover may be a problem, especially in some older pools.
- Water replacement may be inadequate to prevent the build-up of contaminants.

Sand is the most common and generally most suitable filter medium for swimming pools. It must be specifically for use in filters – beach and builder’s sand are not suitable.

In general, filtration efficiency reduces as filtration velocity increases and low or medium velocity filters are more desirable (Wood et al., 2019).

High velocity filters are only suitable for small domestic pools with a low bather load. Filter ratings are based on sand filtration velocity:

- Low velocity, up to 10 m/h.
- Medium velocity, 10-25 m/h.
- High velocity, >25 m/h.

Filtration occurs through five mechanisms, of which the first three are of relevance for *Cryptosporidium* (Wood et al., 2019)

1. Mechanical straining.
2. Sedimentation.
3. Adsorption.
4. Chemical activity.
5. Biological activity.

1. Mechanical straining.

Particles suspended in the water will become trapped in the pores between the sand grains, mainly on the surface of the sand bed. Most swimming pool sand beds have a 1:2 ratio of grain sizes of 0.5 to 1 mm and 1 to 2 mm, with 0.5 mm offering a pore size of 77 µm. This is too large to retain *Cryptosporidium* oocysts which are about 5 µm in diameter. However, interstitial straining occurs due to the converging spaces between sand grains, and as particles become trapped, the pore sizes are reduced further, resulting in increased straining which will trap some oocysts. Particles that become part of a larger floc (for example, where coagulants are used) are much more likely to be retained by the filters.

2. Sedimentation.

If particulate matter has a settling velocity greater than that of the water sedimentation will occur over the large surface area provided by the upward facing surface of the sand grains. The settling velocity of *Cryptosporidium* oocysts at 23 °C has been estimated at 0.35 µm sec^{-1} but is affected by attachment to particles e.g. organic matter (Medema et al., 1998).

3. Adsorption.

This is the attachment of particulate matter to the surface of the sand grains. Adsorption is enabled by transport mechanisms to bring matter sufficiently close to the sand grains, and is promoted by adherence and electrostatic attraction. Electrostatic attraction is measured by the zeta potential, which for *Cryptosporidium* oocysts is about -25mV (Kim et al., 2010). Particles typically become destabilised in the range of -10 mV to +10 mV and more attractive to each other. Outside of this range, particles tend to repel like-charged particles and surfaces. Pool coagulants can significantly decrease the zeta potential of particles by binding to the surface thus enhancing and facilitating removal by filtration (Shaw et al., 2000).

Daily records of circulation rates, pressure differentials and backwash procedures should be kept.

Filters should be inspected internally at least once a year, with attention being paid to the sand bed, under-drains and corrosion.

There is no prescribed time period for filter sand replacement, but it may need to be replaced every 5 to 10 years.

Filter backwashing

To ensure good filtration and to prevent breakthrough of *Cryptosporidium* oocysts, filters should be backwashed regularly. Backwashing of medium velocity filters should be undertaken a minimum of once a week or more frequently as the filter pressure differential dictates and according to the Manufacturer's literature for the filters installed. High velocity filters may need to be backwashed more frequently as the pressure difference dictates but this should never be more than once per day.

Backwashing should ideally be done at the end of the day, whenever loss of pressure across the filter reaches that recommended by the manufacturer. It should not be done while to pool is in use. This is because backwashing can disrupt filter integrity and may allow *Cryptosporidium* oocysts to pass through the filter bed and expose swimmers if undertaken just before or during pool use. Filters need time to settle and re-compact or "ripen" after backwashing, before they are running effectively again. It also allows for the water to turnover through the filters multiple times before bathers use the pool again.

Backwashing can be monitored visually by a sight glass on the filter outlet pipe and should continue until the backwash water runs clear. Backwash water is classified as industrial effluent and must be sent to waste, as should the first few minutes of filter re-start (commonly known as rinse) water. The time will depend on the system in place. There are no controls on the effectiveness of the backwashing processes in different pools.

3.5 Coagulation/flocculation

Coagulation (sometimes called flocculation) must be present for sand filters[2] to allow the removal of small particles (dissolved, colloidal or

[2] Note that coagulants are not used with diatomaceous earth or cartridge filters, often present in small pools (e.g. at hotels or fitness clubs) and spa pools, or on activated

suspended) by clumping them together before they are introduced into the filter. Coagulant dosing should be ideally achieved by fully automated, continual fine dosing. Coagulant efficiency is pH dependent, and should be <pH7.5. Commonly used coagulants are:

- Alum.
- Polyaluminium chloride (PAC).
- Iron chlorides and iron sulphates.
- Cationic polyelectrolytes[3].

Without coagulation, oocyst removal in medium velocity filters has been estimated at substantially less than 90%, and may be negligible (Croll 2004).

Because only a proportion of swimming pool water passes though the filters at any one time, and flow characteristics are highly variable, conservative estimates show that as long as the filters are capable of >90% reduction in oocyst numbers with each pass, then 6 turnovers will remove sufficient oocysts to substantially reduce the risk from a faecal accident (Croll, 2004). This forms the basis of the PWTAG advice for dealing with faecal accidents (Technical Note Faecal Contamination, www.pwtag.org). But even in a "best case" scenario (best mixing, best filtration) a 99.3% reduction in oocyst numbers has been estimated after 6 turnovers, and if filter efficiency is reduced (lack of coagulation; higher velocity filtration) the numbers of oocysts remaining in the pool could expose pool users to a greater infection risk (Wood et al., 2019).

Some smaller pools use high velocity filters that are significantly less efficient at removing *Cryptosporidium* oocysts, and PWTAG recommends superchlorination for dealing with faecal contamination of swimming pools using these filters (Technical Note Faecal Contamination, www.pwtag.org).

3.6 Circulation rate and turnover period

The circulation rate and turnover period are related and form the basis for sizing new water treatment plants, and for checking the capacity of existing water treatment plants.

The circulation rate is the flow of water in m^3/h to and from the pool, through the pipework and water treatment system.

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carbon filters mainly fitted for ozone reduction. Sometimes ozone-carbon filters are combined with sand filtration in multi-layer filters, although ozone works best on water that has already been coagulated and filtered.

[3] Used on high rate filters.

The turnover period is the theoretical length of time taken for the equivalent of the entire pool water volume to pass through the water treatment plant and back to the pool. The shorter the turnover period, the better the water treatment.

It is important to find out the circulation rate and turnover period of the pool as this will be utilised when establishing the remedial action to be taken in the event of a liquid faecal accident in the pool water.

Indications for adequate filter maintenance and filtration:

- Separate filtration systems for each pool at a facility, especially toddler pools.
- Backwashing should be a minimum of weekly and more frequently if pressure dictates or if the bather load is high.
- Filter pressure differentials over and above the clean filter pressure of greater than 5 psi, 3.6 kg/m^2, or 3 to 5 metres head for medium velocity filters only, are indicative of a dirty filter and the need for backwashing.
- Backwashing duration should be specified by the installer/manufacturer and the duration should be as specified or until the backwash water runs clear, whichever is the longer.
- All filters for each pool should be backwashed on the same day, after the last swim session, once no further use is due to take place. This is to ensure the overnight removal of any particulate breakthrough resulting from backwashing that might include *Cryptosporidium* oocysts.
- Make up of the pool water volume with fresh water should only occur upon completion of the backwash procedure.
- Annual filter inspections should be undertaken to establish the condition of the filter media and filter shell.

Chemical or physical disinfection is needed to prevent cross infection between bathers and the growth of infectious agents in the water and on the surfaces of the swimming pool and its associated water and air circulation system. The most common swimming pool water disinfectant is chlorine but some pools are disinfected with bromine. Dosing of disinfectant and pH control chemicals should be fully automated.

The disinfection residuals achieved and maintained during normal swimming pool operation (Table 3) will be dependent on the design of the plant and its capability to maintain a satisfactory bacteriological quality. Additional (secondary) disinfection may be provided by UV light or ozone.

3.8 Disinfection efficacy

Efficiency depends on initial disinfectant concentration, residual disinfectant concentration and contact time. This can be expressed as exposure value or contact time for disinfection (Ct) values where:

Exposure value or Ct = contact time x disinfection residual

Table 3. Guideline operating ranges of commonly used swimming pool water disinfectants

Disinfection type	**Free chlorine**	**Combined chlorine**	**Total bromine**	**pH**
		mg/L ideal (range)		
Bromochlorodimethyl-hydantoin (BCDMH)	N/A	N/A	4-6 (4-10)	7.2-8.0
Sodium bromide plus sodium hypochlorite			1.5-3.5	7.2-8.2
Sodium or calcium hypochlorites	<1 (0.5 - 2)*	0 (<50% of free chlorine to 1.0 max)	N/A	7.2-7.4**
Chlorine gas	<1 (0.5 - 2)*	0 (<50% of free chlorine to 1.0 max)	N/A	7.2-7.4**

N/A = not applicable

*the minimum level of 0.5 mg/L may be used where the pool is designed, engineered and operated to PWTAG standards and/or when used in combination with UV or ozone, provided satisfactory bacteriological quality can be achieved and maintained.

**may be below 7.2 where conditions and pool fabric allow

3.9 Chlorine

Chlorine is an oxidant that reacts with water to produce hypochlorous acid and hypochlorite ions which create the free chlorine residual. Different chlorine donors are used, including chlorine gas, sodium hypochlorite, calcium hypochlorite, and chlorinated isocyanurates. Trichloroisocyanuric acid (trichlor) may be more appropriate for less demanding pools and outdoor pools as the cyanuric acid helps to prevent depletion of chlorine by solar UV sunlight.

Chlorine is ineffective for rapid inactivation of *Cryptosporidium* at the doses used in normal pool water treatment (Korich et al., 1990; Lykins et al., 1990). This means that, unlike for most other gastro-intestinal pathogens, there is no effective residual disinfection in the swimming pool against this parasite. There is some evidence that inactivation of oocysts with chlorine is increased when ozone, chlorine dioxide or UV is also used (Gregory, 2002). However, these assessments were made under laboratory (i.e. ideal) conditions, and used oxidant demand-free water (i.e. they were not performed in simulated recreational water where additional organic material is present). Carpenter et al. (1999) found that the presence of faecal material increased the contact time (Ct) value needed to disinfect swimming pools. The survival time of *Cryptosporidium* has been re-assessed under chlorinated recreational water conditions in bench-scale tests (Shields et al., 2008) and comparative data are available for other pathogens (Table 4). These data show that there is no residual disinfection in the swimming pool against *Cryptosporidium* oocysts.

Table 4. Survival of gastro-intestinal pathogens in chlorinated (1mg/l free chlorine) swimming pool water at pH 7.5 and 25°C
Source http://www.cdc.gov/healthywater/swimming/pools/chlorine-disinfection-timetable.html Accessed 5th April 2019

Pathogen	Disinfectant Times for Faecal Contaminants in Chlorinated Water (3 log inactivation)
E. coli O157	Less than 1 minute
Hepatitis A	Approximately 16 minutes
Giardia	Approximately 45 minutes
Cryptosporidium	Approximately 15,300 minutes (10.6 days)
Note: These disinfectant times are only for pools that do not use chlorine stabilizers such as cyanuric acid. Disinfection times would be expected to be longer in the presence of a chlorine stabilizer.	

3.10 Bromine

Bromine is an oxidant that disinfects with a free bromine residual. However, unlike chlorine, the bromamines, primarily monobromamine, formed by reaction with ammonia, disinfect almost as effectively as free bromine and there is no need to differentiate when measuring disinfectant activity and therefore total bromine concentrations are recorded. Bromine-based disinfection is applied in two systems in the UK: bromochlorodimethylhydantoin (BCDMH) and sodium bromide plus sodium hypochlorite. Although bromine-based disinfection is not as common as chlorine in the UK, BCDMH may be used in some small pools and spas and sodium bromide plus hypochlorite in large leisure pools. BCDMH has been linked to skin irritation.

Integral to effective disinfection is pH adjustment, as pH affects the disinfection efficiency of chlorine and, to a lesser extent, bromine. pH corrector dosing should be fully automated, monitored and adjusted as required.

Bromine is ineffective for *Cryptosporidium* inactivation at the doses used in normal pool water treatment (Korich et al., 1990). This means that, unlike for other gastro-intestinal pathogens, there is no rapidly effective residual disinfection in the swimming pool against this parasite.

3.11 Chlorine dioxide.

Chlorine dioxide is not classed as a chlorine-based disinfectant as it acts in a different way, and does not produce free chlorine. It breaks down to chlorite and chlorate which have guideline standards for drinking water. Although not in wide use in pools in the UK, it is used against biofilm, usually in combination with residual disinfectants (i.e. chlorine- or bromine- based). There is growing evidence for efficacy against Cryptosporidium, although further studies are needed to evaluate safety constraints for use as a primary pool water disinfectant (Murphy et al., 2014) as there is potential for a build-up of chlorite/chlorate in recirculating pool water (WHO 2006).

3.12 Additional disinfection: ozone and UV

Additional, secondary, disinfection may also be provided by UV or ozone. These are used to complement chlorination. Both are plant-room treatments and neither provides a residual disinfection capability in the pool tank but they are efficacious against Cryptosporidium if the dose/Ct is adequate.

Ozone gas is a plant-room treatment, which purifies the circulating water, making subsequent disinfection easier, but without leaving a residual in the pool water. As a result of the purification process, a lower-than-usual level of free chlorine residual (from chlorine gas or hypochlorite) can disinfect the pool water.

Ozone is especially susceptible to depletion by organic materials leading to depletion of the residual and is highly temperature dependent, efficacy increasing with temperature.

Ozone is toxic and therefore needs to be removed, either by activated carbon filtration or UV within the treatment system before returning to the pool. Some ozone treated pools have conventional sand filtration prior to ozonisation, mixing, contact and deodorisation, but others apply the ozone prior to filtration and have combined activated charcoal and sand filters. The chemistry of the relation between ozone and pool contaminants is complex. There are significant reactions which allow subsequent filtration of the organic molecules by a process of microflocculation. This effect will not occur if the ozone fails or is switched off.

Where ozone treatment has been retro-fitted to a pool, only a proportion of the water flow through the treatment plant might be ozone treated, called side- or slip-stream ozonation. At least 20% of the flow rate should be treated. This is inherently less effective than full ozonation for inactivating *Cryptosporidium* oocysts.

In the absence of data relating directly to *Cryptosporidium* in swimming pool water, the efficacy of ozone is indicated from drinking water and bench-scale studies. Swimming pool systems employing full ozonisation are designed to operate with a minimum dose of 0.4 mg/L ozone with a contact time of 2 to 2.5 minutes minimum depending on the design of the system (BEWA, 1990). This would offer a Ct of 0.8 mg.min/L. However, most ozone-treated pools have a typical dose of 0.8 to 1mg/L with a typical minimum contact time of 2 minutes offering Ct of 1.6 to 2 mg.min/l and the kill can be estimated at 90 to 99%.

Ultra violet (UV) light is a plant-room treatment used to inactivate microorganisms. UV is a highly effective physical disinfectant, but has no residual effect, so free chlorine is still required for residual disinfection within the pool tank. However, given that the UV inactivates microorganisms that are passed through it, the amount of free chlorine that is then needed in the pool itself is lower than that required with no UV treatment. UV also helps to remove trace organic chemicals and so may be installed to control by-products of chemical disinfection.

The most effective germicidal wavelength of UV light is 254nm. This is supplied by one or more low mercury pressure (monochromatic) or medium mercury or xenon pressure (polychromatic) lamps. Quartz glass sleeves protect the lamps, which must be kept clean by either manual or automatic procedures as the efficacy of UV light emission is impacted the growth of biofilms. Particulate matter impedes transmission of UV rays and so turbidity should be low.

Monitoring is provided by UV sensors which measure the dose transmitted through the water as it passes the lamps. UV lamps degrade over time so have a limited working life.

In the absence of data relating directly to *Cryptosporidium* in swimming pool water, the efficacy of UV is indicated from drinking water and bench scale studies that have shown that *Cryptosporidium* oocysts are irreversibly inactivated by UV treatment (Rochelle et al., 2005). Typically, doses of >60mJ/cm^2 (0.06 J/cm^2) are used in swimming pools. In side-stream applications the actual dose may be lower. UV is particularly efficacious against *Cryptosporidium* and 10mJ/cm^2 can achieve 4 log inactivation (Clancy and Hargy, 2008).

The total log-reduction in either numbers or viability of *Cryptosporidium* oocysts will be as a result of a combination of any efficacious treatments. For example, where optimal circulation, filtration and UV or ozone are in place, the overall log reduction will be increased (Gregory, 2002).

3.13 Pool water quality and testing parameters

3.14 Chemical quality

Poolside testing and recording of residual disinfectant and pH levels should be undertaken before the swimming pool is used each day. Testing frequency thereafter will be dependent on the type of pool and its usage levels but as a minimum should be 3 times a day and for heavily used pools every 2 hours. Appearance (visual assessment of colour and clarity) should be recorded at the same time. Automatic systems should be checked against calibrated standards. Disinfectant concentration should be also checked and adjusted after closing.

The daily on-site chemical tests required and recommended values (PWTAG 2017) are:

- Temperature 27-30 ^{O}C except: children’s teaching (up to 31 ^{o}C) or baby/ toddler (up to 32 ^{o}C), hydrotherapy (up to 35 ^{o}C) and spa (up to 40 ^{o}C) pools
- Residual disinfectant level (see Table 3).
- pH (see Table 3).

Operational parameters, including total alkalinity, calcium hardness, total dissolved solids, water balance index should be recorded weekly. If measured, turbidity should be <0.5 nephelometric units (NTU). The oxidation reduction potential (ORP) value may be measured, and that to be achieved will be dependent on the incoming water quality characteristics and the disinfectant utilised, but typically values in excess of 650 mV would be expected.

Results should be recorded in a log book, which should state the acceptable limits for parameters tested, together with any remedial action to be taken in the event of a test result being out of specification. Where remedial action has been taken, records should be continued until they demonstrate that that it has been effective and operating conditions have been returned to normal. Records should be kept for a minimum of 5 years (COSHH 2002).

3.15 Bacteriological quality

It is the pool manager's responsibility to arrange regular microbiological testing by a UKAS accredited laboratory. Monthly sampling for bacteriological quality is advocated by PWTAG and HSE. Samples should also be taken before the pool is used for the first time and before it is back into use following shut down for whatever reason. Additional testing may be required when there is contamination or as part of investigations into possible adverse effects on bathers.

Routine bacteriological parameters (see Table 5 for operational guideline standards):

- Aerobic colony count at 37^{O}C 24 hours. This gives valuable information about the general quality of the pool water and whether the filtration and disinfection systems are operating satisfactorily.

- Coliforms. Their presence indicates potential faecal pollution or environmental contamination.

- *Escherichia coli* indicate faecal contamination and failure of the water treatment to remove the contamination.

- *Pseudomonas aeruginosa* indicates colonisation of the pool system and indicates inadequate disinfection and/or backwashing.

If a bacteriological test result is unsatisfactory (Table 5), the operator should take a repeat sample as soon as possible. If this is also unsatisfactory, the pool's management and operation should be investigated and the test repeated. Following a third unsatisfactory result, immediate remedial action is required which may mean closing the pool. The pool should also be closed if any test indicates gross contamination.

If there is chemical or physical evidence of unsatisfactory treatment or disinfection, the pool should be closed and the appropriate remedial action taken.

3.16 Interpretation of results in the context of *Cryptosporidium*

Because *Cryptosporidium* is resistant to chlorine and bromine disinfection, which control other pathogens and indicator organisms, normal bacterial indicators of water quality are not directly applicable (Chalmers et al., in preparation). Problems with cryptosporidiosis may still arise even when chlorine levels are adequate and bacterial counts are within acceptable limits. However, inspection of bacteriological results is essential because if they are unsatisfactory this may provide evidence that there could be problems with the operation of the pool. See Section 4 for issues regarding *Cryptosporidium* sampling and testing, as it is not a routine parameter.

Table 5. Bacteriological Parameters, Operational Guidelines (PWTAG, 2017) and Action on Failure for Swimming Pools*

<table>
<tr><th>Bacteriological parameter</th><th>Operational guideline</th><th>Action</th><th>Public Health</th></tr>
<tr><td>Aerobic colony count
at 37 °C, 24 h expressed as colony forming units (cfu)</td><td>≤10 cfu/ml</td><td>If disinfection and pH are within normal range, re-test.
If consistently raised 10-100 cfu/ml, investigate.
If >100 cfu/ml, operating conditions are clearly unsatisfactory.
If coliforms are also present, serious defect in disinfection / chemical balance / filtration is indicated.</td><td rowspan="4">Close the pool if there is evidence of gross contamination.</td></tr>
<tr><td>Coliforms
Expressed as most probable number (MPN)</td><td>Absent in 100 ml</td><td>1-9 100 ml and absence of E. coli and normal colony count may be acceptable if residual disinfectant and pH values are satisfactory.
Should not be found in consecutive samples.</td></tr>
<tr><td>E. coli
Expressed as MPN</td><td>Absent in 100 ml</td><td>A single positive may arise from single contamination and a re-test should be done.
>10 per 100 ml and either an aerobic colony count > 10 cfu/ml or P. aeruginosa >10 per 100ml, or both, indicates gross contamination.</td></tr>
<tr><td>P. aeruginosa
Expressed as MPN</td><td>Absent in 100 ml</td><td>If >10 per 100 ml, repeat testing should be undertaken.
If present in repeated samples, the circulation, filtration and disinfection processes should be investigated.
If >50 per 100 ml pool and colony count >100 per ml, gross contamination is indicated.</td></tr>
</table>

*interpretation of results for non-conventional pools will need to be undertaken on a pool-by-pool basis taking into account variants such as operating temperatures, bather profile etc.

4 Key indicators of good pool management

4.1 An appropriate management structure

The actual management structure will vary according to the type of facility from a small team of multi-skilled staff trained in the plant room techniques required to maintain water quality, under the guidance of a pool manager qualified both professionally and by experience, perhaps backed up by locally available engineers. But as the size and complexity of the pool increases, it becomes more appropriate to specialise. In a large, multi-facility site, with major capital investment in engineering plant and controls, the services of a full-time qualified and experienced engineer or plant technician are indispensable.

4.2 An effective management system

4.3 Policy

The pool management should define and document its policy for the general operation and safety of swimming pool water treatment systems including the Pool Safety Operating Procedures (PSOP), Normal Operational Procedures (NOP) and Emergency Action Plan (EAP). This policy should be communicated, implemented and maintained throughout the organization.

4.4 Management review

The pool management should review the swimming pool water treatment system at least annually, to ensure its continuing suitability, adequacy and effectiveness. Inputs to the management reviews should include:

- Feedback from bathers or other users of the pool, suppliers, regulators, regulatory authorities or other external parties.
- Performance of the water treatment systems.
- Status of preventive and corrective actions.
- Information on any incidents or emergencies and lessons learned.
- Follow-up actions from previous management reviews.
- Compliance with Health and Safety and COSHH regulations and guidance detailed in Section 2.
- Changes that could affect the swimming pool water treatment system, including any changes in regulations or national standards.
- Records from management reviews should be maintained.

4.5 Measuring, monitoring, analysis and improvement

The effectiveness of the procedures and the operation of the water treatment and management system should be measured, monitored and analysed on a regular basis, to identify opportunities for improvement. As a minimum, pool management should monitor the safe and effective performance of their pool operation through:

- bacteriological monitoring
- chemical monitoring
- plant and treatment systems monitoring
- feedback from regulatory authorities and users of the pool
- actions taken or required to ensure compliance with operational plans and procedures, including cleaning; also performance requirements
- any corrective and preventive actions
- responding to incidents and other emergencies.

4.6 Qualification, training, awareness and competence

The management of the swimming pool should identify all training needs. It should require that all personnel, whose work is concerned with the swimming pool water treatment system have received appropriate training. The management should establish and maintain procedures to make its employees or members at each relevant function and level aware of:

- The importance of conformance with the swimming pool management system policy and procedures, and with the requirements of the swimming pool management system.
- The significant operational or safety impacts, actual or potential, of their work activities and the benefits of improved personal performance.
- Their roles and responsibilities in achieving conformance with the policy and procedures and with the requirements of the swimming pool management system, including emergency preparedness and response requirements.
- The potential consequences of departure from specified operating procedures.
- Personnel performing tasks with significant operational or safety impacts should be competent on the basis of education, appropriate training and/or experience.

4.7 Emergency preparedness and response

The pool management should establish and maintain procedures (EAP) to identify potential for, and response to, accidents and emergencies, and for preventing and mitigating any possible operational and safety impacts.

Management should, where necessary, review and revise its emergency preparedness and response procedures, in particular, after accidents, near misses, and emergencies. Where practicable, the emergency procedures should be tested periodically.

4.8 Non-conformance and corrective and preventive action

The pool management should establish and maintain procedures for defining responsibility and authority for handling and investigating non-conformance; taking action to mitigate any impacts; and initiating and completing corrective and preventive action. The organization should implement and record any changes in the documented procedures resulting from corrective and preventive action.

4.9 Documentation

The management system should contain or refer to the following documentation:

- an organization chart showing lines of authority, responsibility and allocation of functions stemming from senior management.
- the policy.
- procedures covering the operation and safety of the swimming pool water treatment systems.
- procedures covering the identification of non-conformances and action to be taken to resolve such non-conformances.
- emergency procedures, including a faecal accident plan.
- An as-built schematic diagram of the swimming pool and pool water treatment plant.

It is imperative that senior management ensures the effective implementation of all documented procedures and instructions.

4.10 Records

A record system should be established. It is important that records:

- demonstrate that procedures have been effectively used and implemented.
- demonstrate that risk analysis methods have been applied to determine the safety of the system.
- demonstrate that appropriate means have been applied to ensure identified risks have been minimised and are within legally established safety limits.
- demonstrate that relevant and adequate training has been provided for all staff involved in the safety and operation of swimming pool water treatment systems.
- be kept for a period of time so that continued confidence may be demonstrated for a period of at least five years.

5 Public Health Actions and Interventions

5.1 Protecting the public when something goes wrong

Cryptosporidium affects all ages but certain groups of swimming pool users may be more predisposed to exposure than others. For example, children may spend long periods in the pool and are more likely than adults to intentionally or accidentally swallow water (Dufour et al., 2006). A quantitative microbial risk assessment identified that both the average infection risk per swim event and the annual infection risk were higher for children than for adults (Suppes et al., 2016). Children and immunocompromised individuals are at higher risk from infection.

5.2 Action during water quality warning advice

When contamination or adverse incidents occur to mains water supplies, notices regarding these supplies may be issued by the water provider (Anon 2009, being revised in 2019). There are three types of warning message:

1. Boil before use for drinking or food preparation.
2. Do not use for drinking or cooking.
3. Do not use for drinking, cooking or washing.

These notices may also be issued for reasons other than *Cryptosporidium* contamination.

During boil water advisory notices for *Cryptosporidium*, it is possible that a swimming pool could be replenished by contaminated mains water. Generally, it is highly unlikely that, following dilution, filtration and turnover of the pool water, sufficient oocysts would be present to cause an outbreak. However, each situation must be assessed on an incident-specific basis, and include consideration of the oocyst counts from the mains water testing, through liaison with the incident control team and water company.

5.3 Action during a community *Cryptosporidium* outbreak

During a community outbreak there will be more people than normal shedding *Cryptosporidium* oocysts, whether they have been diagnosed or not. There will be a need for heightened awareness not only among public health professionals but also among swimming pool operators in the locality, emphasising exclusion criteria and vigilance for faecal contamination incidents. Pro-active public health actions (see section 5.4.3) may be relevant in these circumstances.

5.4 Action when cases of gastrointestinal illness are linked to a swimming pool

If there is evidence that there is a **cluster of illness** linked to the pool water, the Local Authority Environmental Health Officers and a Consultant in Communicable Disease Control (CCDC) / Consultant in Health Protection (CHP) will be involved. These should jointly consider the facts (in consultation with a microbiologist) and decide whether to declare an outbreak and convene a multiagency Incident or Outbreak Control Team (ICT / OCT). It will be the responsibility of the ICT / OCT to advise on the closure of the pool and agree criteria for re-opening.

In Wales, all outbreaks are managed under the Communicable Disease Outbreak Plan for Wales (The Wales Outbreak Plan) (Welsh Government, 2014 being updated in 2019)[4], and in England, under the Communicable Disease Outbreak Plan: Operational Guidance (PHE, 2014)[5]. If an outbreak is declared, it should be recorded and reported according to each organisation's protocols.

In England additional support and advice, which should be sought early in the investigation, can be provided by the NIS scientists in the Field Service (site visits, environmental investigations), and the Field Epidemiology Service (data management and interpretation, case definitions).

Suggested membership of a swimming pool Incident or Outbreak Control Team

Core Membership		**Potential Co-optees**
Consultant in Communicable Disease Control / Consultant in Health Protection		Pool Operating Staff Representative
Environmental Health		Pool Senior Management
Microbiologist (Food, Water and Environmental Microbiologist may also be invited)		Others as appropriate depending on nature of individual incident/outbreak e.g. school staff if school pool; infection control team if hospital pool
Director of Public Health		Infection Control Nurse from Primary Care Trust / Health Board
And in significant outbreaks: Epidemiologist		

4 http://www.wales.nhs.uk/sitesplus/888/page/88948
5 https://www.gov.uk/government/publications/communicable-disease-outbreak-management-operational-guidance

Public Relations Officers Health and Safety Executive Local Authority Secretariat Cryptosporidium Reference Unit		

Given that many Local Authorities own swimming pools, it is possible that there might be a conflict of interest, in that Environmental Health Officers may be investigating pools in their own organisation. The following suggestions may be helpful in minimising this conflict of interest:

- The OCT should be chaired by a core member not in the same organisation.
- OCT members with conflicts of interest should declare this at the first OCT.
- Any core member of the OCT who declares a conflict of interest should attend as a member of the OCT and not as a duty holder of the premises.
- EHOs from other local authorities could be asked to carry out / audit the investigation of the pool. Whilst we recognise that they would not legally have any enforcement powers outside of their usual geographical area, they could report their findings to the CCDC and OCT and thus provide an independent source of information, evidence and/or advice to be considered by the outbreak control team.
- The HSE may assist in the investigation of a major outbreak.

For *Cryptosporidium* it will be prudent to eliminate the possibility that the water supply had been contaminated, by requesting water quality data from the water company.

5.5 Guidance for pool closure and re-opening

Adverse bacteriological test results indicating gross contamination are reasons for closing pools (Table 5). Where the water quality and treatment remain suspect, the pool should be closed.

Prior to closing a pool, the OCT should establish agreed criteria for re-opening. However, the situation is usually not so clear-cut, and here we provide guidance to assist the decision making process.

Outbreaks of *Cryptosporidium* can take two main forms, a point source outbreak or a continuing outbreak. The latter can begin as a point source but viable oocysts can remain in the water for many reasons including inadequate coagulation/flocculation and filtration, aberrant pool plumbing features, unsuspected dead legs and poor pool operation.

In a pure point source outbreak, by the time the outbreak is detected, it is most likely that *Cryptosporidium* contamination will have been removed from the pool water. Therefore pool closure will be unnecessary.

The only way to try and initially distinguish between a point source outbreak and a continuing outbreak when cases first present is through:

1) Active case finding.
2) Careful review of exposure history (plot epidemic curves of exposure dates and illness onset dates).
3) A thorough review of the pool schematics and plant operation, policies and procedures.

In a point source outbreak no cases should present with a date of exposure to the pool water greater than 48 hours after the postulated contamination incident.

In practice however, it can be extremely difficult to distinguish between the two in the early stages of an outbreak. This is because of:

- the long and variable incubation period,
- the delay in the presentation of cases,
- the fact that many cases don't seek medical help and
- the difficulty in ascribing the illness to exposure to the swimming pool waters (many cases have multiple *Cryptosporidium* risk factor exposures).

So, when should a pool be closed in an outbreak? Each outbreak or incident requires individual assessment, however a number of factors may indicate that there is the potential for continuing exposure to *Cryptosporidium* oocysts and prompt an OCT to consider closing the pool (see text box below).

Pool closure will certainly lead to swimmers going to other pools: precautions must be taken so that this does not expand the outbreak e.g. provide clear public health messages (see section 5.4).

At the time of deciding to close the pool, the OCT should establish a draft set of criteria for when the pool can re-open. In practice these may be very simple for example one or more of:

1) After obtaining and reviewing the as-built schematic.
2) After receiving and reviewing the report of an independent advisor.
3) After the appropriate remedial structural repairs have been undertaken.
4) After remedial staff training has been undertaken or policies and procedures amended.
5) After seeking advice from the *Cryptosporidium* Reference Unit.

Whenever a pool has been closed, in addition to remedial actions, chemical and bacteriological parameters must be checked and satisfactory before the pool is re-opened.

Factors that may prompt an OCT investigating *Cryptosporidium* cases to close a swimming pool

Two or more cases of cryptosporidiosis linked to the pool, and one or more of:

1) Evidence that cases may still be occurring.
2) Evidence that the pool may pose an imminent risk to its customers (e.g. an obvious defect in treatment is identified).
3) New cases are presenting with swimming pool exposure dates more than 48 hours after the identified faecal contamination incident (where swimming pool exposure is the most likely cause of the case’s illness).
4) Absence of as-built pool schematics being readily available (as there may be unidentified/aberrant plumbing or deadlegs allowing oocysts to persist) and evidence of an imminent risk to bathers.
5) Absence of adequate pool operation and maintenance policies and procedures.
6) Evidence of poor practices in faecal disposal, backwashing, or pool operation by pool staff (as this increases the likelihood of greater exposure at time of incidence and the persistence of contamination)
7) Evidence of structural defects.
8) Lack of confidence in the senior pool management (this could include failure to engage with OCT, lack of knowledge and understanding of their own policies, falsification of evidence etc).

5.6 Swimming pool assessment and actions

5.7 The site visit

A site visit is essential to understand the layout of the facilities. It is useful to view the nature and location of water-features, and the proximity of pools in a multi-pool setting. The check list (Appendix 1) provides details of what to record during a site visit. Read through this first so that sufficient time can be allocated for the site visit, depending on the number of pools and complexity of the facility, and appropriate personnel are available on site. A schematic of the pool, as fitted, should be provided to show where the water is coming from and where it goes, with details of the treatment and disinfection regime, filters, pumps, dosing equipment, tanks, valves, sample points, routing of the pipes.

Review the pool maintenance log for engineering failures, adverse results and remedial actions, and the water quality records noting failures and actions taken.

Any changes in operating practice, pool usage, problems, and incidents such as faecal accidents must be reviewed.

Where possible, photographs should be taken to illustrate the pool design and features of the water treatment systems – to aid your own and other outbreak control team members' understanding. You might imagine, for example, that all flume slides end with the user being immersed into pool water – however in one recent pool-related outbreak, a site visit identified that the flume slide actually ended in a deceleration platform outside of the pool: users had to step off and out of the flume housing and walk to the nearest pool. You may discover that there are fixed structures like slides within the centre of toddler pools – which could make cleaning-up after faecal incidents problematic, and which might influence your risk assessment.

It may also be important to visit the pool when it is being used – in one recent outbreak, a site visit during a pool lesson for young babies with their parent demonstrated the opportunities for exposure to the pool water and the potential for leakage from swim nappies. You can also directly observe how staff maintain the pool / pool features and deal with incidents.

5.8 Emergency actions following a faecal accident at a pool

Emergency actions include those interventions to reduce the risk to pool customers and inspecting the pool to ensure appropriate actions have been taken. Note that although super-chlorination is of uncertain benefit for many pools, and poses difficulties in application, it has a place in response to contamination in pools with high velocity filters (see 5.2.2 and PWTAG Technical Note Faecal Contamination, www.pwtag.org).

Circumstances and interventions to reduce risk from *Cryptosporidium* in swimming pools

- If people have been infected and the pool water remains suspect, close the pool.
- If the pool is contaminated with faeces, undertake procedure for dealing with a faecal accident
- If filtration is ineffective in removing particulates, ensure coagulation is effective and continuous.
- If filter bed inspection shows evidence of channelling, an uneven bed, cementation, and if backwashing of the filter does not result in fluidisation, close the pool and replace the underdrain/lateral system and filter media.
- If there is evidence of fundamental problems with the pool water circulation or treatment, the pool may need to be closed and the system re-engineered
- Ensure that backwashing is conducted at the end of the day after swimming has stopped.

Cleaning

Where a cluster of cases or an outbreak of *Cryptosporidium* is associated with a swimming pool facility, the investigating officers will need to ensure that measures are taken to prevent infection of other customers. This will involve a thorough review of the policies and procedures relating to cleaning of the facility and equipment used within it. Cleaning guidance is published by PWTAG.

The premise's Normal Operating Procedures (NOPs) will state which cleaning procedures must be undertaken to keep the facility clean and help prevent infections. Those NOPs should state exactly how each task is to be performed. With regards to *Cryptosporidium* the following NOPs must be assessed by the investigating officer for compliance with the PWTAG CoP:

- Dealing with a faecal accident.
- Cleaning of equipment used when dealing with a faecal accident (scoops, vacuums etc.).
- Cleaning of equipment used in the pool, such as inflatables.
- Cleaning of pool fixtures such as flumes and fixed slides.
- Cleaning of the pool, pool covers and pool surround.
- Backwashing procedure.

All routine cleaning should be recorded and the officer should check routine cleaning records as well as any incident record during the investigation. If the investigation identifies any areas of concern with regard to cleaning, the officer must ensure that appropriate remedial action is taken and if necessary the facility closed in the interim.

The investigating officer should also ensure that the cleaning procedure for a contaminated solid surface avoids contaminating the pool water. Any faeces visible on pool surrounds or equipment should be physically removed and disposed of in a toilet.

Cleaning products must be kept out of the pool and transfer channel because of potential problems they may cause in the pool water or treatment. Deposits above the water line can be cleaned off with a chemical-free scouring pad (which should be disposed of as foul waste) using sodium bicarbonate or carbonate solution if necessary, removing waste as far as possible. The surface can then be wiped clean with a chlorine based disinfectant. If solid faeces have become smeared, for example on a slide, the risk of dispersion of oocysts, if present, will be increased if the soiling has not been removed as soon as it occurred. If there is evidence that smearing has led to pool water contamination then the action for a liquid faecal accident should be followed (see below).

Dealing with a faecal accident

The investigating officer must check that the NOP for handling faecal incidents is consistent with the most up to date advice in the PWTAG CoP and Technical Note Faecal Contamination (www.pwtag.org) and is adequate to safely remove contaminated matter from the pool. The officer should also check what actually happens in practice; it should not be assumed that both are the same.

Of particular concern should be the potential for a perceived solid stool to smear against hard surfaces such as slides and increase the potential to release oocysts significantly within the pool area, especially if it is not cleaned as soon as it occurred. If a stool remains intact the officer can be satisfied if the PWTAG procedure for solid stools is followed. Disposal of faecal matter must take place down the nearest toilet. The investigating officer should specifically check that no staff are disposing of it elsewhere such as the poolside transfer channels which are sometimes mistakenly regarded as foul drains. It is important the poolside channels are not contaminated with faeces as the water gets re-circulated into the pool.

It is recommended that the officer ensures that the PWTAG procedure for liquid stools is followed if any uncertainty exists as to whether the stool remained intact.

Swimmers evacuated from a pool in the event of a faecal incident must not be allowed to simply re-enter the pool after the incident or enter any other pool whilst the clean up takes place. Instead, in order to prevent contamination of pools by evacuated swimmers, it must be ensured that they are directed to shower before being allowed entry or re-entry to any pool. When checking the faecal incident procedures, the investigative officer should find out what happens to evacuated swimmers in practice and in particular, during any such incidents that are under investigation.

The equipment used to clean up faecal matter must either be disposed of or disinfected immediately after use.

Proprietary cleaning kits will come with their own instructions and generally be entirely disposable. The officer should check to ensure that all staff have been trained in using these proprietary kits and know where / how to dispose of them.

Equipment that is not disposable such as a faecal scoop must be disinfected after use with a 1% hypochlorite solution.

Other equipment may be used within pools such as inflatables, floats and arm bands. The officer should check that all such equipment is subject to routine cleaning and that the methods for doing so are specified in the NOP. If these are directly contaminated by faeces they should be removed from the water and cleaned without contaminating the pool, if at all possible. In these circumstances, the faecal contamination procedure should take over from routine cleaning procedures.

The pool surface and surround must be cleaned regularly and the officer should check that this is done. The method should be specified in the NOP. The faecal contamination procedure should take precedence if there is faecal contamination.

Routine housekeeping rules will affect cleanliness of the pool surround such as the need to prohibit external footwear. The officer should check that the system for minimising poolside contamination remains intact.

5.9 Action following filtration failure

If there is evidence that filtration is not effective because of inadequate backwashing, indicated by the filter-bed not fluidising, cementation or mudballing of the bed, the presence of visual channels in the filter bed or failure to restore the pressure differentials to the manufactures stated levels for normal operation, the filtration system and filter media should be investigated, adequate backwashing procedures facilitated and possible replacement of the filter media considered.

Without a glass inspection port it may be very difficult to know whether or not the bed is fluidising even though backwash water flow rates are being achieved. Sometimes there are restrictions on the duration of backwashing because of drainage restraints

If filters are not effective in removing particulates, coagulation procedures should be investigated.

Where there is evidence of fundamental problems in the pool water treatment, the system may need to be re-engineered.

5.10 Superchlorination

If the pool water circulation, coagulation and filtration are optimal then six turnovers of the pool water will provide sufficient reduction in oocyst numbers to mitigate the public health risk. The time this takes will depend on the circulation rate of the pool. An alternative approach, advocated in the USA, is superchlorination (CDC Healthy Swimming). Superchlorination is a process where free chlorine is increased to provide a Ct value sufficient to kill *Cryptosporidium*. From bench scale studies under chlorinated recreational water conditions at pH7.5 and pool temperatures the Ct inactivation value (3 log reduction) has been estimated to be 15300 (Shields et al., 2008). This can be achieved by applying 20 mg/l for 765 minutes, or 10 mg/l for 1530 minutes, under supervised conditions at pH 7.5 and >25^{o}C.

In practice, many pools would find maintaining such residuals difficult with standard dosing equipment. Coagulation, filtration and backwashing are certainly also needed. Operators should be confident that the pool plant, including valves etc, will withstand superchlorination. Any UV or ozone plant should be switched off and by-passed during superchlorination. PWTAG Technical Note Superchlorination of Swimming Pool Water is a how-to guide and includes subsequent dechlorination. If there is evidence that treatment is not effective then the pool will need refurbishment to ensure that it is safe to operate.

Difficulties with super-chlorination are that:

- it may generate extra unwelcome by-products of disinfection
- the residuals are difficult to achieve with standard dosing equipment
- is difficult to monitor with standard test kits
- it generates a need to return residual chlorine levels back to normal, either chemically or by water replacement
- effectiveness is difficult to monitor
- Not sorting out the filtration means continuation of the problems.

For low or medium velocity filters, the PWTAG guideline method of dealing with contamination takes no longer in time and provides effective removal as long as circulation, coagulation, filtration and backwashing are effective. However, there is a place for superchlorination, for example where contamination of a pool with high velocity filters has occurred.

5.11 Sampling for *Cryptosporidium*

Cryptosporidium is not a routine test parameter for swimming pools. Sampling for *Cryptosporidium* may be indicated, particularly where filtration is sub-optimal and filter beds are suspected of being contaminated. Depending on the circumstances it may be sufficient to sample the pool water only, or a suite of samples may be required. However, remedial action may be indicated immediately and sampling is less important.

The detection of oocysts in pool water samples only means that the water has been contaminated at some time and that they are present in the portion tested. This could be for a number of reasons:

- Continuing contamination from bathers if the pool is still open.
- Continuing contamination from sewage due to faulty plumbing.
- Failure of the filters to remove contamination (this would be most easily demonstrated in a pool that has been closed to the public).
- Poor circulation resulting in oocysts emerging from some areas of the pool.
- Back-contamination from the filters during backwashing.

The absence of oocysts only means that none could be detected in the sample tested. It does NOT mean that the pool is safe for bathing. A panel of samples (pool water, filter sand, backwash water) provides the most complete information but may not always be necessary or readily obtainable; sampling the pool water will indicate contamination of most concern.

The test is for the detection of the parasite only. It provides no information about the viability or infectivity of the oocysts detected. There are no quantitative standards for the detection of oocysts in swimming pool-related samples and it is not a routine parameter. Human infectivity and dose response studies suggest that single numbers of oocysts ingested may be sufficient to cause disease, so low numbers are unacceptable.

If sampling is considered helpful, it must be done before any intervention at the pool, without compromising remedial actions, and according to current guidance (PWTAG 2017; Anon 2010). The test is available in specialist water testing laboratories. Only those that have UKAS accreditation for water testing for *Cryptosporidium*, use methods based on "The Microbiology of Drinking Water" Part 14 (Anon 2010) and participate in an external quality assurance (EQA) performance monitoring scheme should be used. These can be identified from the UKAS website https://www.ukas.com/search-accredited-organisations/ and entering *Cryptosporidium* in the search tool, then using the filter (top left) and select Organisation Type – Testing Laboratories.

When to sample: sampling for *Cryptosporidium* should be considered if a pool is the suspected cause of an outbreak which is still on-going and if the test results will be considered useful to the formal investigation and provide information for action. However, often the contamination event will have taken place some time ago and in a pool with efficient water treatment the parasite will have been removed. If the pool has been closed, but pool water circulation and filtration maintained, the persistent detection of oocysts in the pool water after several days will provide conclusive evidence of filtration failure.

How to sample for *Cryptosporidium:* this should be undertaken with the full agreement of the incident or outbreak control team and with full consideration of the actions that will be taken in light of the results. Pool water samples need to be high volume *Cryptosporidium* filter samples (Table 6) and more information can be gained by also sampling the pool filter backwash water, filter media and strainer basket contents if possible.

Table 6. Typical sample volumes for *Cryptosporidium* testing (Anon 2010)

Sample type	**Suggested sample sizes**
Backwash waters	1 litre (grab samples)
Swimming pool waters	100 to 1000 litres (filter samples)
Filter sand	500 to 1000 grams (grab samples)

Material retrieved from the strainer basket may also be tested for *Cryptosporidium*.

Routine bacteriological samples should also be taken and analysed by an accredited laboratory. pH, bromine or total and free chlorine and turbidity should also be recorded.

Note that it is not recommended to test the water for *Cryptosporidium* after super-chlorination. Although infectivity will have been reduced, the structure of the parasite will remain intact.

Interpretation of the results will depend on the sample types taken and whether the pool was closed to the public and for how long. Even low numbers of oocysts in pool water are cause for concern. Oocysts in filter sand indicate the pool filters are capturing oocysts, and oocysts in backwashwater indicate captured oocysts are being cleaned off filters. Both indicate the pool had been contaminated at some stage.

5.11.1 Seeking independent advice

During some investigations it may be necessary to seek independent advice, obtain an external overview and perspective about some aspect(s) of the swimming pool under investigation. Areas where advice needs to be sought include:

- General pool design and engineering.
- Filtration and coagulation.
- Disinfection.

- Pool operation and management.
- Outbreak investigation.
- *Cryptosporidium* sampling.
- *Cryptosporidium* typing.
- Posters on pool hygiene.

Help can be sought through the organisations detailed in Appendix 3.

It is important to ensure that the person or company appointed is qualified and experienced to enable them to make such assessment and are deemed to be competent. The assessor should be a member of a recognised professional body within the industry i.e. PWTAG, CIMSPA, and be professionally qualified in microbiology/biology, chemistry or engineering (as appropriate) with a demonstrated track record in swimming pool investigations.

Any independent report commissioned by the outbreak control team should as a minimum consider the following:

- Status of installed plant compared to the schematics if present. Consideration of schematics and the appropriateness of dosing points etc.
- Make up, supply and condition of any cold water feed tanks associated with the pool.
- Positioning of chemical dosing points and their suitability.
- Quantities of chemicals used and in the case of flocculants whether or not the correct dose rate is being achieved.
- Disinfectant operating ranges e.g. Free and combined chlorine, pH
- Bather numbers, opening hours and usage patterns, ages etc. and consideration in relation to the treatment plant.
- Turnover times, filtration velocities, circulation rates and appropriateness of plant design compared with bathing loads and usage patterns.
- Condition of filter bed and, if possible, under-drain system.
- Backwashing procedures including frequencies, time of day undertaken, backwash water flow rate, duration, effectiveness and calculation of volumes of water discharged.
- Water replacement practices.
- Positioning of inlets, outlets and water features, the pool flow characteristics and distribution within the pool. A dye test may be required to confirm the effectiveness of water distribution.
- The potential for dead legs e.g. infrequent usage of features and water treatment thereof of independent circuit.
- Condition of the balance tank if fitted and distribution to and from.
- Pool water records, including on site log and laboratory analyses undertaken.
- Training of staff and its suitability.
- Normal Operating and Emergency Action Plans and their appropriateness including Faecal Action Policy.

- Preventative Planned Maintenance procedures and method statement for pool plant operation and these should be compared with what happens in practice.
- Comments on management systems, reporting procedures, responsible people, call out systems, lifeguarding etc.
- Cleaning procedures and appropriateness thereof.

5.12 Outbreak investigations

The same basic principles should be followed in the epidemiological investigation of cryptosporidiosis as for any other outbreak of communicable disease. The first step is confirmation of the diagnosis and of the existence of an outbreak. There is no standardised 'trigger' value for the number of cases which should arouse suspicion, and prompt further investigation of, the potential association of cryptosporidiosis with a swimming pool.

Further investigation should be undertaken if any of the following occurs:

- Two or more cases of cryptosporidiosis report a history of swimming at a specific swimming pool (or pool complex) within a couple of weeks.
- There is an increase in the proportion of all cryptosporidiosis cases reporting a history of swimming within a defined time period.
- The repeated occurrence of cases linked to a single pool over an extended period may indicate a particular ongoing risk (e.g. contaminated filter) that needs investigation.
- A group of cases are identified who attended the same function e.g. a swimming lesson or swimming pool party.
- There is an increase in the number or proportion of cases occurring among young children.

Most outbreaks are identified and investigated due to reports arising from one (or more) of four information sources:

- Routine surveillance.
- Laboratory reports.
- Calls from health professionals.
- Calls from members of the public.

5.13 Case definition

Case definitions may vary over the course of an investigation as more information becomes available. An initially broad case definition established at the outset in order to carry out case finding may become refined into several separate case definitions to aid clarity. The initial case definition may be developed before the pathogen has been identified. Suggested case definitions in the context of an ongoing cryptosporidiosis outbreak investigation are:

Initial Case Definition: "Persons who attended Premises A from [date X] onwards, or their contacts, who subsequently developed diarrhoea and/or vomiting and/or abdominal cramps".

Confirmed Case: "An individual who attended Premises A on, or after [date X] and who subsequently developed diarrhoea and / or vomiting and/or abdominal cramps within 2 weeks of attendance and for whom laboratory confirmation of *Cryptosporidium* has been obtained".

Confirmed cases may also include secondary cases (see below)

Cryptosporidium may be further refined by species and subtype.

Probable Case: "An individual who attended Premises A on, or after [date X] and had developed diarrhoea, and/or vomiting, and/or abdominal cramps, but for whom a laboratory confirmed diagnosis was not obtained."

Probable cases may also include secondary cases (see below)

Primary Outbreak Case: "An individual who visited Premises A, on or after [date X], and subsequently developed diarrhoea and/or vomiting and/or abdominal cramps within 2 weeks of attendance".

Secondary Outbreak Case: "An individual who developed diarrhoea and/or vomiting and/or abdominal cramps in the 2 weeks after contact with an individual who had attended Premises A on or after [date X]".

Most outbreak investigators describe both "confirmed" and "probable" cases within their case definition.

An individual may be classified 'probable' for more than one reason, for instance:

- An individual reporting a history of symptoms may have recovered before being interviewed by EHOs, and a stool sample may not have been requested or provided.
- Standard laboratory tests used to identify *Cryptosporidium* from stool samples are not 100% sensitive. Occasionally, the test may fail to detect *Cryptosporidium* in a sample especially if the parasite is present in low numbers. Therefore occasionally a negative test result may be obtained for someone who does indeed have *Cryptosporidium* infection.
- Laboratories may have different policies in testing for *Cryptosporidium* which may be important for pools with a wide catchment area (Chalmers et al., 2010).

Note that infection by a different organism or symptoms due to another disease may lead an individual to be wrongly classified as a case of probable cryptosporidiosis.

Consider also including a timeframe within the case definition. However, be mindful not to artificially restrict case ascertainment through confining the search to a very narrow time period – cases may be missed, and potential epidemiological links may be masked. For example, if a point source incident is suspected and a specific date of exposure is stated within the case definition, cases of cryptosporidiosis whose first exposure to the pool water was beyond the stated date may not be included – a possible ongoing source of infection could be missed. A flexible approach is recommended when formulating the case definition to account for the circumstances by which the cases have come to light.

5.13.1 Case finding

Multiple methods are available for case ascertainment; their relative merits will vary depending on the specific circumstances of the investigation.

a) Environmental Health Officers (EHOs) and Health Protection staff

In some regions, **all** cases of cryptosporidiosis notified to Public Health are followed up by EHOs who conduct an interview, in-person or by telephone, with the patient (or parent/guardian). Risk factors are routinely sought, including history of water and food consumption, foreign travel, contact with animals and swimming. This approach is not universal (Chalmers et al., 2002), but is the preferred option as questions need to be asked and responses analysed in a timely manner.

Another method sometimes employed is that cases notified to EHOs/PHE Centres/health protection teams are sent a postal questionnaire for self-completion, with responders' questionnaires being subsequently analysed in a search for common exposures. This strategy may yield lower response rates and introduces delay, so a potential source may not be identified as quickly.

In an outbreak situation, self-completion is replaced by EHO and/or Public Health/health protection administration of the questionnaire. If a potential pool-related exposure is identified, this should be communicated to the EHD in the area where the pool is located.

Since neighbouring EHO and health protection teams may operate very differently, it is worth seeking clarification of exactly what procedures are undertaken. PHE centres/health protection teams need robust systems to detect linked cases which also note venues used by out of area cases.

b) Pool-associated individuals or groups

Private health clubs may be able to provide contact details for each individual who used the facility during the time period of interest. Identification of, and attempts to contact each individual may be a realistic option in these circumstances.

In contrast, investigation of an outbreak associated with a large, multi-pool leisure centre facility whose throughput can be in excess of several thousand persons per week and where records of individuals' attendance are not maintained, will require a different approach. Many pools will however operate a membership system that will record when, where and who uses swimming pools which can be used to identify individuals at risk.

Consider targeting groups who use the pool facilities. This may include:

- persons attending for organised swimming lessons (the leisure centre or class teacher can help with pupil lists, and will be able to tell you if any of the class have been away from lessons).
- children's swimming pool parties. Leisure centres will keep a record of party organisers who may be willing to provide contact details for those who attended the party, or alternatively may be willing to 'ring-around' their party-goers to enquire about symptoms.
- group-hire e.g. local Stroke Association or Aqua-aerobics class or parent-and-baby swimming class. The group organiser will have a list of attendees, and again may be able to either provide direct contact details or be willing to 'ring-around' to enquire about symptoms among members of the group.

c) Neighbouring and other CsCDC and Health Protection teams

Leisure centres and water-parks frequently draw visitors from other towns and local authority areas – particularly if they are new facilities, or run swimming/water-sport classes or children's parties. Notifying fellow public health professionals may lead to the identification of additional cases from neighbouring geographical areas that could otherwise be missed. This could be expanded nationally if holiday facilities are being investigated.

d) NHS 111, NHS Direct Wales, GPs, GP out-of-hours services, Walk-in centres, local hospitals (particularly A&E, paediatricians, microbiologists and infection control teams)

Provision of information to these services heightens awareness of a local investigation and prompts health professionals to consider cryptosporidiosis, and undertake faecal sampling, among patients who present with compatible symptoms. Colleagues are requested to notify such cases by telephone to the health protection team. Appendix 4 contains an example of a letter sent to local GPs, hospitals and out-of-hours services during a pool-related cryptosporidiosis investigation.

e) Self-notification by cases

Cases may contact the leisure centre / pool complex; pool owners; local authority; public health or environmental health to report illness. Good communication between the various organisations (via named individuals if possible) helps co-ordinate efforts and prevents duplication of work.

f) Use of the media for case finding

In some circumstances local media may be used to encourage cases to come forward. It is well known that media reports of a possible link of a given exposure with illness may lead to more accurate recall or increased reporting of that exposure by those with that illness, leading to an observed association that appears stronger than it really is (so-called recall bias). However, this is often inevitable as the pool may be closed because of the outbreak.

5.13.2 Enhanced questionnaires

If an association is suspected from initial trawling questionnaires, detailed case histories should be ascertained for people fulfilling the case definition. A questionnaire, designed for the outbreak, should be used when interviewing cases (or their parents) in order to gain sufficient detail about the specific locations visited and activities undertaken during the pool visit. Usually there are other possible associations including animal contact, day care nursery attendance, drinking water etc. that need to be investigated as well. Issues related to the pool investigation to consider include:

Which pool was used in a multi-pool setting, at what date and time and for what duration?

- What is meant by ‘use’ of pool? – some responders attribute sitting at the pool edge with feet dangling in water as ‘using’ the pool.
- What is the competence of the swimmer? – learners may be at increased risk of swallowing pool water compared to a competition swimmer.
- Whether water features such as slides or fountains were used, how many times, and how were they used e.g. did they stand under the fountain for a long time, or run in-and-out beneath it?
- Which changing rooms / toilets were used?
- Is the case (or parent) aware of any pool closure / faecal accident that occurred during the pool visit?
- What other activities were undertaken at the pool premises? – drank from water fountain, or ate at café?
- What other activities were undertaken outside of the pool premises? – e.g. holiday or farm visit?

Appendix 5 contains an example of an Enhanced Questionnaire for use when investigating possible associations with activities at swimming pools.

5.13.3 Analytical epidemiology

On the basis of descriptive epidemiology, hypotheses on the source of infection and mode of transmission should be generated. Analytical epidemiology is a useful adjunct to outbreak investigation. Studies can be conducted to capture additional information not routinely sought. For example, they can be used to investigate hypothesised associations between specific pool-related features and risk of developing cryptosporidiosis.

For all analytical studies, a protocol should be written. In the context of an outbreak investigation, the two most common types of study undertaken are case-control and cohort. Unless you are very skilled in undertaking analytical studies, you would be strongly advised to consult with a Regional Epidemiologist on the appropriate study design, methods and analysis for your circumstances.

Cohort studies are feasible only for well defined populations (where a complete list exists, for example where cases occur among a school class) of sufficient size.

Case control studies are useful when the population at risk is not well defined, such as when cases of cryptosporidiosis are occurring among apparently unconnected members of the public. They can be conducted on a smaller number of cases than cohort studies.

5.13.4 Media interest

Co-operation between the Communication Teams of all the Public bodies involved is essential in order to present consistent messages to the media and public. Provision of clear, regular press releases from a single and consistent Outbreak Control Team Spokesperson to local and regional/national media can be of benefit during investigations, performing several functions:

- Raising awareness among members of the public, prompting self-referral to health services or public health.
- Raising awareness among health professionals, prompting consideration of cryptosporidiosis among the differential diagnosis.

Use of Local Authority and Public Health Wales or Public Health England websites to provide updates on the investigation process and pool closure/opening information to the public has proven beneficial in past outbreak investigations. It also has the benefit of minimising the number of enquiries from the public/partners to environmental health / public health professionals who will be busy trying to conduct the outbreak investigation.

5.14 Public Health Messages and Actions: a targeted and timely approach

Public health messages relating to the risks and preventive measures for cryptosporidiosis and swimming pool use can be conveyed to the community by adopting a number of different approaches. Utilising information from previous outbreak investigations and national surveillance, informed decisions can be made on when messages should be conveyed, what messages should be given and whether messages should be conveyed to all or targeted to those at greater risk. Seasonal messages may be appropriate, ahead of peak use periods and the “outbreak season”.

Using the check list (Appendix 1) to inspect local pools seasonally or in response to an outbreak is warranted. Use face-to-face meetings with pool managers and operators to encourage best practice.

5.14.1 The basis for managing public health messages

The following evidence relating to cryptosporidiosis forms the basis for managing public health messages (Nichols et al., 2006):

1. Swimming pools within the UK contribute to an increase in cryptosporidiosis within local communities especially during late summer/autumn.
2. There is a strong suggestion of a link between infections in returning tourists and subsequent swimming pool outbreaks in the UK.
3. There is an increase in cryptosporidiosis following Easter and August bank holidays.
4. Cryptosporidiosis is more commonly associated with children under 5, is more commonly reported in boys than girls and for adults illness is more commonly reported in females of child bearing age.

Further, there is a marked increase in the use of pools by school children, families and summer camps in the school summer holidays.

Table 7. The key public health messages that should be conveyed to the public under all circumstances

Message	Why
• Do not use a swimming pool if you have diarrhoea and/or vomiting • Do not use a swimming pool for 48 hours after your symptoms have stopped. • If your GP has diagnosed you with cryptosporidiosis you must not go swimming until 14 days (2 weeks) after your symptoms have stopped.	You will spread your infection to your family and friends who accompany you to the pool and to other pool users. Even when you feel better you are still infectious and able to pass the illness to others through the water and in the changing rooms.
• Always wash your hands with warm water and liquid soap and dry them properly, especially after using the toilet, helping others to do so, changing nappies and before eating or preparing food. • Always shower thoroughly before you swim	This is the most effective way of protecting yourself against infection and if you are ill, reducing the chances that you will spread the illness to others. Even though you may not have symptoms you may still carry the “bug”, showering helps make sure that “bugs” don’t get into the water.

5.14.2 Reactive Public Health Messages

Reactive messages relate to circumstances such as responding to general public enquiries and interviewing confirmed or suspected sporadic or outbreak cases. Relevant infection control advice will be dependent on individual circumstances but can include:

- Washing hands after using the toilet or helping others to do so, changing nappies, contact with animals or their excreta, and before preparing or eating food.
- Using separate hand and bath towels for each member of the household.
- Using separate toilet facilities.
- Refraining from using swimming pools even where they routinely attend lessons/classes or have party invitations.
- If a case's occupation might increase the risk of spreading Cryptosporidium, the case should inform their employer. This includes working at a leisure centre or swimming pool, as any duties that might involve pool use, such as lifeguard duties or swimming instruction, will need to be suspended until 14 days after symptoms cease.

Cases and enquirers should also be routinely offered advice notes on cryptosporidiosis (Appendix 6).

Key messages to bathers on prevention of swimming pool contamination

- Shower, with soap, before using the swimming pool. Nude showering is preferable.
- Make sure there is no faecal matter adhering to the skin – clean hands and clean bottoms please!
- Always washing hands after changing nappies or using the toilet.
- Take children to the toilet before swimming and offer frequent toilet breaks
- Children who are not potty or toilet trained must wear waterproof double wrap swim nappies when using the swimming pool. They should never swim in the nude or wearing ordinary nappies.
- Please use the nappy changing facilities provided. Nappies must never be changed in the swimming pool areas.
- Do not swallow the swimming pool water.
- People with diarrhoea must not swim.
- People who have had diarrhoea must not swim for 48 hours after symptoms have ceased.
- People who have had a cryptosporidiosis diagnosis must not swim for 2 weeks after the symptoms have ceased.

5.14.3 Proactive public health messages

Proactive messages focus on targeting specific pool users, pool managers and staff in the absence of a current incident or outbreak. Collaboration with pool managers and staff is crucial, and may require additional effort on the part of

EHOs as levels of awareness of cryptosporidiosis amongst pool staff can be limited. EHOs may wish to consider:

- Organising a presentation to leisure pool staff for the effective management of *Cryptosporidium* in swimming pools.
- Displaying posters in reception reminding swimmers of the exclusion period[6].
- Display of notices in changing rooms reminding customers to shower before using the pool[7].
- Training reception staff to remind swimmers, and especially the parents of infants and toddlers, about the "no swim rule" if they have suffered from diarrhoea or vomiting within the exclusion period.
- Providing simple flyers at reception for swimmers to take away.
- Encouraging pool staff to convey key public health messages as a matter of routine to individuals, clubs and organisations seeking to book the pool at the time of booking (e.g. school/private swimming lessons, canoeing, life saving, children's parties etc). This could involve information being provided on booking forms and through leaflets. Suitable leaflets are available from the ISRM.
- Highlighting that, in the case of lessons, public health messages can be further reinforced by the Instructor to the user, parent, teacher or person responsible particularly where a swimmer has been absent with illness or appears unwell.
- Alternative format leaflets (e.g. large print, audio media) or supplementary verbal reinforcement may be appropriate for some disabled pool-users. Those with severe learning difficulties may require extra verbal or written reinforcement particularly in relation to faecal contamination.
- Conveying public health messages to user groups which do not routinely book in advance such as mother and toddler groups and aqua aerobic groups may be managed by providing new users with information and then relying on the vigilance of group instructors.
- Encouraging pool managers to ban those users who are found to continually and deliberately defecate in the pool.

Procedures on how to behave when going swimming should be included in the National Curriculum for children in Physical Education at key stages 1 and 2 (Years 1/2/3) Unit 7: Swimming activities and water safety (1) Beginners.

5.14.4 Seasonal public health messages

As with any public health message timeliness can be critical to raising awareness. In the case of cryptosporidiosis, swimming pool cases are known to be associated with the second peak of the year in late summer/early autumn. A survey of swimming pool in summer and autumn 2017 found that most detections were in August when pools were busiest (Chalmers et al., in preparation). This time period

[6] For example, those supplied by the ISRM and PWTAG

[7] For example, those supplied by the ISRM

also incorporates the school holidays and increased pool usage by individuals and summer camps some of which are run by leisure centres. A range of additional promotional activities can be considered at the start of and during school holidays:

- Displaying posters at the reception desk or in the changing rooms.
- Organising poster events or competitions.
- Providing information to parents booking their children on summer camps and when returning from holiday abroad. The reinforcement of this by leisure staff.
- Conveying information through pool facility or council websites.
- EHOs may consider organising cryptosporidiosis awareness training for leisure staff in July.

EHOs may also consider raising awareness within summer camps known to operate in their area by sending a letter and information on cryptosporidiosis and staff responsibilities.

6 Maintenance of the Guidance

- The maintenance and annual review of this Guidance is the responsibility of the Head of the Cryptosporidium Reference Unit.

- The definitive current version of the Guidance can be accessed at www.publichealthwales.org/cryptopoolguidance/

- Any comments on the Guidance should be sent to Swansea.crypto@wales.nhs.uk

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7 Appendices

The following Appendices are available as separate documents, downloadable from www.publichealthwales.org/cryptopoolguidance/

Appendix 1. *Cryptosporidium* risk assessment checklist.

WITHDRAWN Appendix 2. Sampling swimming pools for *Cryptosporidium.*

Appendix 3. Sources of independent advice regarding swimming pools.

Appendix 4. Example of letter to GPs/Hospital Trusts/NHS Direct.

Appendix 5. Example enhanced questionnaire for the investigation of cases linked to a swimming pool.

Appendix 6. Example cryptosporidiosis advice notes.