Cryptosporidium - what pool operators need to know?

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Cryptosporidium
This note provides swimming pool operators with necessary information about Cryptosporidium (the microorganism), cryptosporidiosis (the disease it causes) and measures for their control.

What is Cryptosporidium?
Cryptosporidium is a protozoan parasite that multiplies in the gut of humans and other animals. The life cycle stage that is shed in faeces is called an oocyst. People become infected when they swallow oocysts; one single oocyst is enough to make someone ill with cryptosporidiosis.

What is cryptosporidiosis?
Cryptosporidiosis is the illness caused by infection with Cryptosporidium. Anyone can get cryptosporidiosis, but it is especially common in young children. The main symptoms are watery diarrhoea, abdominal pain, nausea and/or vomiting and low-grade fever.

People might swallow oocysts when they have close contact with an infected person or animal and their faeces, or through eating contaminated food, or swallowing contaminated water. Most people become ill 5 to 7 days after ingesting oocysts.

Symptoms usually last up to 2 weeks, but sometimes longer – and may come and go before full recovery. Some people with very weakened immune systems have serious, possibly life-threatening illness.

How cryptosporidiosis is spread

When people or animals have cryptosporidiosis, they shed large numbers of oocysts in their faeces (a million per gram). People may continue to shed oocysts for two weeks after they get better.

Figure 1. Cryptosporidium on the move

How much Cryptosporidium in a contaminated pool?
If someone with cryptosporidiosis infection passes diarrhoea in a swimming pool, this is the maths:

- 1 million oocysts per ml of diarrhoea x 150ml diarrhoea = 150 million oocysts entering the pool
- in a typical 25x12m pool (450m3) that would be an average concentration of 333 oocysts per litre

- it has been estimated that children aged 6-18 years consume 37ml of pool water in a training session, so would swallow 12 oocysts
- 12 oocysts is more than enough to make someone ill.

Chlorine-resistant Cryptosporidium
Cryptosporidium presents difficulties because, unlike most other microorganisms, it is resistant to chlorine disinfection at the levels normally used to treat swimming pool water.

Table 1. Time needed to kill 99.9% (3log reduction) of some microorganisms in swimming pool water

Chlorine survival* 1mg/L, pH7.5, 25°C	
Escherichia coli	< 1 min
Giardia (another protozoan)	45min
Cryptosporidium	10.6 days

Source: www.cdc.gov

Oocysts will therefore survive in swimming pool water and present an infection risk unless removed by filtration.

Removal of Cryptosporidium
Good filtration – low or medium-rate and with coagulation – is the key to removing oocysts. But not all oocysts will be removed in a single pass of pool water through the filters, however good the pool's water circulation, so a number of passes are necessary and the pool will have to be closed if infestation is suspected so that the water can be circulated through the filters sufficiently to remove the contamination. Secondary disinfection (UV or ozone) also helps, and super-chlorination can also be considered.
There is much more detail on all this in three PWTAG technical notes (www.pwtag.org.uk):

- Faecal contamination
- Blood or vomit in the pool
- Super-chlorination of swimming pool water

Outbreaks of cryptosporidiosis
An outbreak is when more people get cryptosporidiosis than is usually expected. Cryptosporidium is the most common cause of outbreaks of diarrhoea linked to swimming pools. Cryptosporidiosis outbreaks can happen in other settings, such as open farms where people have contact with animals, or nurseries where children are in close contact with each other, or in communities where drinking water has become contaminated. But swimming pools are the most common setting for outbreaks of cryptosporidiosis.

Table 2. Non-foodborne outbreaks of Cryptosporidium reported in England and Wales: 2017

Agent	Total Affected	Laboratory Confirmed	Hospitalised	Deaths	Setting	Food description
Cryptosporidium parvum IIaA17G1R1	9	8	1	0	Open/petting farm	No food identified
Cryptosporidium spp.	5	5	0	0	Open/petting farm	No food identified
Cryptosporidium spp.	4	4	0	0	Open/petting farm	No food identified
Cryptosporidium parvum	11	11	0	0	Open/petting farm	No food identified
Cryptosporidium spp.	3	3	0	0	Open/petting farm	No food identified
Cryptosporidium parvum IIaA17G1R1	4	4	0	0	Open/petting farm	No food identified
Cryptosporidium spp.	5	5	1	0	Open/petting farm	No food identified
Cryptosporidium spp.	3	3	1	0	Swimming pool	No food identified
Cryptosporidium spp.	6	2	1	0	Swimming pool	No food identified
Cryptosporidium hominis IbA12G3	5	3	0	0	Swimming pool	No food identified

Table 3: Regional distribution[2] of laboratory reports of Cryptosporidium in England and Wales: 2017

Country	Region	Number of laboratory reports	Per 100,000 population
England	East Midlands	378	7.9
England	East of England	539	8.7
England	London	250	2.8
England	North East	275	10.4
England	North West	554	7.6
England	South East	582	6.4
England	South West	590	10.6
England	Yorkshire and The Humber	450	8.3
England	West Midlands	414	7.1
Wales	Wales	260	8.3

Source tables 2 and 3: https://www.gov.uk/government/publications/cryptosporidium-national-laboratory-data/cryptosporidium-data-2008-to-2017

Preventing cryptosporidiosis

Make sure your pool tells users not to use the pool when they have diarrhoea, or for 48 hours after symptoms stop. If they have had cryptosporidiosis, they must extend that to a fortnight after symptoms stop. If an outbreak of cryptosporidiosis has been identified, it may be that some regular bathers will have had diarrhoea, but not had

the illness diagnosed. They too should be excluded from using the pool for a fortnight after symptoms have stopped.
There are other, important, routine safeguards (featured in PWTAG's poster, on this website):

- encourage parents to take children to the loo before swimming and to offer them frequent toilet breaks
- make sure handwashing and nappy disposal facilities are adequate.
- make sure proper swim nappies are used by babies and toddlers.
- implement a PWTAG-compliant and clear policy for recognising, reporting and dealing with faecal accidents (see PWTAG's Technical Note Faecal contamination).

Despite these measures, bathers in the vicinity of faecal contamination by someone infected with Cryptosporidium will be at risk if they swallow pool water. Risks to public health can be minimised by ensuring swimming pool construction, engineering, management, procedures and pool water circulation, treatment and disinfection are optimal and in accordance with current guidelines detailed in PWTAG's book Swimming Pool Water and Technical Notes (www.pwtag.org.uk).

Mains water contamination
Occasionally water companies are affected by adverse circumstances resulting in an increased risk that Cryptosporidium oocysts get into the water supply.
Water companies may then advise domestic customers to boil water for drinking and food preparation. Generally, in a well-designed and operated swimming pool – following PWTAG guidelines on turnover, filtration, and disinfection etc. – the risk to public health should be low and no special action will be required.

In these circumstances, pool operators should also receive advice from the multi-agency incident team, issued via the water company to its business customers. It is particularly important for pools, which don't routinely operate to PWTAG standards to follow this advice.

Faecal contamination – See TN2 – PWTAG website
If a pool is contaminated with faeces, the pool operator must decide quickly on an appropriate course of action in order to prevent any possible illness in users. This is particularly important with diarrhoea, which may contain the chlorine-resistant organism Cryptosporidium ('Crypto') so it is crucial to be prepared. It is also important to do everything possible to prevent such contamination in the first place – see the Prevention section of this Technical note.

Preparation
Operators need to be aware of the potential health risks and have the necessary procedures, equipment and chemicals in place and accessible at all times. All pools should have a written procedure, as part of their emergency action plan, stating what action to take in the event of a faecal incident. Staff must be trained in these procedures, and the training recorded. There should also be a schematic drawing of the installed water treatment, which is vital for the informed operation of the pool and in the investigation of problems including outbreaks of infectious disease.

Operators should follow the PWTAG Code of Practice (on www. pwtag.org.uk).

Dealing with a faecal incident
If faecal contamination has only been reported, and there is some doubt about the accuracy of the report, its presence should be confirmed by pool staff. If it cannot be confirmed, pool operators must assess the risk and may decide that the risk of harmful contamination is low and allow bathing to continue. This assumes that pH and disinfection are within normal limits. Pools should maintain a faecal accident log.

All faeces contain potentially harmful microorganisms. The actual risk to pool users depends on whether the faeces are solid or runny.

Solid faeces
Solid faeces are relatively easy to deal with. It is unlikely that the perpetrator is suffering from an acute gastrointestinal illness. And the microorganisms in it are relatively contained.
1 The stools should immediately be removed from the pool using a scoop or fine mesh net and flushed down the toilet (not put in any pool drains).
2 There must be certainty that all the faeces have been captured and disposed of. If not, and there is possible widespread distribution of the faeces in the pool, then the pool should be closed and the advice below for runny faeces considered.
3 All equipment that has been used in this process should be disinfected using a 1% solution of hypochlorite.
4 If the pool is operating properly with appropriate disinfectant residuals and pH values, no further action is necessary.
5 Depending on the extent of the contamination, how public it has been, and how quickly it can be dealt with, operators should consider clearing the pool of bathers for, say, 30 minutes while steps 1-4 are negotiated. This is certainly necessary if the faeces have broken up. Bathing should not resume until all the faeces have been removed.

Runny faeces
If the stool is watery, runny or soft (something like diarrhoea), the risk of infection is greater: the perpetrator is more likely to be carrying enteric pathogens, and if so, they are likely to be spread through the pool water. It will certainly be impossible to remove the faecal material as it is with solid stool.

The infectious causes of diarrhoea include viruses, bacteria and protozoa. (Other causes include alcohol, emotion, diet and medicine side effects.) Most bacteria and viruses that cause diarrhoea – E coli, Shigella, norovirus, for example – are killed within minutes in a satisfactorily disinfected pool water. But if the diarrhoea contains oocysts of the chlorine-resistant protozoa Cryptosporidium, normal levels of chlorine will not be effective. Crypto is a significant cause of relatively serious gastroenteritis, particularly in pools. Young children are both the likeliest sources of the infection, and those worst affected (along with the immunocompromised).

Investigations of outbreaks linked to pools frequently reveal inadequate design and management issues, which would have made the pool vulnerable to an outbreak following contamination with diarrhoea.

In most cases of diarrhoea in a swimming pool, the operator will not know if Crypto is involved, so the safest option is to assume that it is and immediately close the pool. There are in principle three procedures that will in time remove Crypto – coagulation/ filtration, UV and super-chlorination. The procedures to be followed primarily depend on the efficiency of the pool's filtration. These procedures are endorsed by Public Health England and the national Cryptosporidium Reference Unit which is part of Public Health Wales.

Pools with medium-rate filtration (up to 25 metres per hour)
This should include most public pools. Here the main emphasis is on filtration, which if effective should remove some 99% of the Cryptosporidium oocysts in each pass of pool water through the filter. Coagulation is critical in this: it should be continuous, and the residence time (that between the injection of coagulant and treated water reaching the filter) must be long enough for flocculation to happen – at least 10 seconds at a flow velocity no more than 1.5m/ sec. Secondary disinfection (UV or ozone) and super-chlorination are also relevant – see below.

How long it takes for all the pool water to pass through the filter will depend on two factors. First is the pool hydraulics – crucially, how well mixed the pool water is. Dead spots will delay the passage of all the pool water through the filters. The second factor is the turnover period – the length of time it takes for a volume of water equivalent to the pool water volume to go from pool to plant room and round to the pool again. It might take as long as 24 hours for all the pool water to pass through the filters – based on the 3 to 4-hour turnover period common to many pools.

This, then, is the procedure:

1. Close the pool – and any other pools whose water treatment is linked to the fouled pool. If people transfer to another pool, perhaps from a teaching pool to a main or leisure pool, they should shower first using soap and water.
2. Hold the disinfectant residual at the top of its set range for the particular pool (e.g. 2.0mg/l free chlorine if the range is 1.0 to 2.0mg/l) and the pH value at the bottom of its range (e.g. pH 7.2-7.4). This will maintain the normal level of microbiological protection.
3. Ensure that the coagulant dose is correct – for continually dosed PAC, 0.1ml/m3 of the total flow rate.
4. Filter for six turnover cycles (which may mean closing the pool for a day). This assumes good hydraulics and well-maintained filters with a bed depth of 800mm and 16/30 sand. This applies also to pools with secondary disinfection.
5. Monitor disinfection residuals throughout this period
6. Vacuum and sweep the pool. Cleaning equipment, including automatic cleaners, should be disinfected after use. This will at least move faecal contamination off surfaces and into the main pool water circulation, for eventual removal.
7. Make sure the pool treatment plant is operating as it should (filters, circulation, disinfection)
8. After six turnovers, backwash the filters.
9. Allow the filter media to settle by running water to drain for a few minutes before reconnecting the filter to the pool.

10. Circulate the water for 8 hours. This will remove any remaining oocyst contamination of the pool and allow the filters to ripen. It is optional, depending on the pool operator's confidence in backwashing procedures.
11. Check disinfection levels and pH. If they are satisfactory re-open the pool.
12. Any moveable floors and booms should be moved around from time to time during the whole process.

Pools with high-rate filtration (over 25 and up to 50 metres per hour)
High-rate filters do not filter Cryptosporidium oocysts, or anything else, as well as medium-rate filters. But because many pools have them, it is important to know how to deal with faecal contamination.

The main emphasis is on super-chlorination (see also below and the PWTAG technical note on super-chlorination). High-rate filters without coagulation remove as little as 10% of Cryptosporidium oocysts in each pass. Even with coagulation, and perhaps 50% removal, it could take two days to be safe.
The procedures below also apply to tier filters.

1. Close the pool – and any other pools whose water treatment is linked to the fouled pool. If people transfer to another pool, they should shower first using soap and water.
2. If coagulation is not the norm, a supply of polyelectrolyte coagulant should be available so it can be hand-dosed in these circumstances, following manufacturers' instructions.
3. Super-chlorinate to 20mg/l adjusting the pH to 7.2-7.4 and leave for 13 hours (or 50mg/l for 5 hours). Procedures and supplies must be in place for this (see PWTAG Technical note on super-chlorination).
4. Vacuum and sweep the pool.
5. Make sure the pool treatment plant is operating as it should.
6. Backwash the filters.
7. Allow the filter media to settle by running to drain for a few minutes (rinse cycle) before reconnecting the filter to the pool.
8. Reduce the free chlorine residual to normal by dilution with fresh water or using an approved chemical. This may mean using the chemical gradually; procedures and supplies must be in place for this. See the Technical note on super-chlorination for details.
9. When the disinfectant residual and pH are at normal levels for the pool, re-open.
10. Super-chlorination should remove any current contamination but will not guarantee future water quality, so it is important to review procedures for the control and removal of contamination by Crypto.

Pools with no filtration (fill and empty pools)
Here there is the possibility of emptying the pool altogether. This might apply to a paddling or plunge pool, for example. For any pool, if operators are confident that they can safely empty the pool, this is the procedure that should be followed.

1. Close the pool – and any other pools whose water treatment is linked to the fouled pool.
2. Super-chlorinate the pool to 20mg/l for 13 hours or 50mg/l for 5 hours.

3. Vacuum and sweep the pool.
4. Drain, rinse and refill.
5. Re-treat and when disinfectant residual and pH are at normal levels for the pool, reopen the pool.

Pre-coat filters (including regenerative media filters)
Pools with these filters can be dealt with like those with medium-rate sand filters – but with the media discarded after the six turnovers. If, however, there is any doubt about the operation of the filters (see Technical note 25) then super-chlorination (see below) may be a better option. It is important that operators use only the grade of filter medium recommended by the manufacturer.

Water features
If a pool is closed for six turnovers after faecal contamination, the circulation should include any water features, which should be kept running. The same applies if super-chlorination (see below) is employed.

Secondary disinfection
Secondary disinfection using UV is strongly recommended by PWTAG – partly to counter the threat from Cryptosporidium and partly for its other water quality benefits, including allowing pools to operate with lower disinfectant residuals. UV plus good coagulation and filtration provides a multi-barrier defence against Cryptosporidium.
All pools should do a risk assessment to determine whether secondary disinfection is required. The risk assessment should consider the hydraulic and filter characteristics of the pool, as well as the risk from routine unseen contamination. It is particularly recommended for hydrotherapy pools and pools used by young children. Their users are likely to be more vulnerable to – and to be carriers of – Cryptosporidium.

Where used, UV should be applied to the full flow and be capable of a 3log (99.9%) reduction in viable Cryptosporidium oocysts. UV installations should be medium pressure, 60mJ/cm2 and monitored to ensure an effective dose rate.
PWTAG's book, Swimming Pool Water, has more details about UV (and ozone) use.

Super-chlorination
The US Centre's for Disease Control (CDC) recommends high chlorine concentrations alone (e.g. 20mg/l for 13 hours) to inactivate Cryptosporidium if any swimming pool is contaminated.
In practice, many pools would find achieving and maintaining such residuals difficult with standard dosing equipment. Then there is the possibility of generating unwelcome disinfection by-products as a result. And finally, there is the challenge of reducing residual levels afterwards – either chemically or by water replacement. The effectiveness of this approach is difficult to monitor and is no quicker than the coagulation and filtration method above. Coagulation, filtration and backwashing are certainly also needed. And any UV (or ozone) plant should be switched off and by-passed during super-chlorination.
Operators may wish to consider super chlorination, either on its own or alongside PWTAG's filtration method – belt and braces. Operators should be confident that the pool plant, including valves etc, will withstand super-chlorination.
There is a PWTAG Technical note with details of super-chlorination and dechlorination.

Prevention
Because pool operators are unlikely to know what the cause is of any contamination with diarrhoea, and because it can get into a pool unnoticed, the best defence against infections including Cryptosporidium is good Hygiene (refer to PWTAG - Swimming Pool Water Book, chapter 3), Hydraulics (chapter 6) and Filtration (chapter 7). Secondary disinfection with UV is a good second line of defence. Investigations of Crypto outbreaks linked to pools frequently reveal inadequate design, operation and management issues which would have made the pool vulnerable to an outbreak following contamination with diarrhoea. Attention to these issues is vital.

Prevention can be summarised.

- Control entry using notices at reception saying that people with diarrhoea must not swim – then, or for 48 hours afterwards.
- Those who have been diagnosed with cryptosporidiosis must not swim for 14 days after diarrhoea has stopped, as infective Cryptosporidium oocysts can still be released in that period. If an outbreak of cryptosporidiosis has been identified, it may be that some regular bathers will have had diarrhoea, but not had the illness diagnosed. They too should be excluded from the pool for a fortnight after symptoms have stopped.
- Encourage bathers to wash and shower before swimming. Someone who has recovered from cryptosporidiosis could still have oocysts around their anus. Pre-swim showering is good for water and air quality in any case, as it minimises combined chlorines.
- Encourage bathers to use the toilets before they swim and to wash their hands afterwards. Children should be offered frequent toilet breaks.
- Young children should ideally have their own pools. There should be good baby changing facilities, and babies should wear special swimming nappies (but not swim if they have diarrhoea). There should be provision for safe disposal of soiled nappies.
- Continuous low-level dosing of a coagulant is recommended for all pools to improve the filtration efficiency and increase the removal of any contaminants from the pool. This procedure significantly reduces the risk associated with any unseen faecal release.
- Backwashing protocol is critical; when neglected, for example, it can be a factor in outbreaks of cryptosporidiosis. Backwashing must not take place when the pool is being used and should be done at the end of bathing for the day, normally in the evening. This is because after backwashing and rinsing it can take several hours for the filter to fully ripen – a process whereby the media settles back down and re-compacts to provide an efficient filtration system. Repeated backwashing throughout the day when the pool is in use is therefore wrong.
- Backwashing of medium-rate filters should be done at least once a week or more frequently as the filter pressure differential dictates and according to the manufacturer’s literature for the filters installed.

Avoid high-rate filters if possible. If they are in place, they may need to be backwashed more often than once a week (as the pressure difference dictates) but

this should never be more than once a day, and only when bathing has finished for the day.

- Ensure there is an effective disinfectant residual, and an appropriate pH, at all times.
- The pool hydraulics should ensure appropriate turnover periods and good mixing of water in the pool; short circuits and dead legs should be avoided.

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