

THE REMOVAL OF CRYPTOSPORIDIUM OOCYSTS IN THE TREATMENT OF SWIMMING POOL WATERS

By

Brian Croll BSc, PhD, FCIWEM

SUMMARY

Conclusions derived from work into drinking water treatment

1. Direct filtration of drinking waters at filtration rates similar to those used in pool filtration (14 to 40 m/h) can give 3 to 4 log removal of *Cryptosporidium* oocysts. This level of performance is critically dependent on optimal coagulation and flocculation of the water and may involve a coagulant, a coagulant aid and a filtration aid.
2. When coagulation and filtration are sub-optimal oocyst removal drops to 1.5 log.
3. Without coagulant, drinking water treatment at 5 to 10 m/h gave less than 1 log (90%) removal and long term turbidity removal was about 50%.
4. Coagulation and flocculation conditions are more critical than downflow rate but there is some deterioration of performance at higher downflow rates.
5. Up to 50% of 2 to 5 μm particles passing the filter during the whole filter run pass during the "filter ripening" period. This can be reduced by about 30% by using slow start-up of the filter but wasting or recycling the water is much more effective. Poor filter backwashing increases particle break-through.
6. Stopping a filter part way through a run and re-starting without backwash gives a peak of 2 to 5 μm particles similar to that on initial start-up after backwashing. Backwashing before re-start reduces the peak.
7. Rapid changes in flow rate can give a peak of 2 to 5 μm particles similar to that on initial start-up after backwashing. Slow start and slow stop of filters taken out for backwashing will minimise this effect on the other filters in a bank.
8. A new adsorbent material has been developed which is claimed to adsorb oocysts and kill the sporozoites. It can be easily and cheaply incorporated into filters.
9. Ozone can give 2 to 3 log inactivation at drinking water disinfection doses. At pool water treatment doses inactivation is likely to be about 1 log, although it could be higher due to the higher water temperature.

- 10 Medium pressure UV irradiation can give better than 3.5 log inactivation at normal disinfection doses.

IMPLICATIONS FOR POOL WATER TREATMENT

1. A coagulant should always be used prior to filtration. The coagulation and filtration conditions should be optimised as far as is practical.
2. If possible the water produced during the "filter ripening" period after backwash should be wasted or recycled as backwash water. Recycling the whole flow for a period should be helpful.
3. Slow start-up of the flow to a filter will reduce the "filter ripening" period quality deterioration.
4. In order to avoid unnecessary "filter ripening" periods filter runs should be as long as possible consistent with no turbidity breakthrough.
5. Filter backwash should be checked to ensure that the filter underdrains and media are in good order and that the filter is fully cleaned.
6. Deeper filter beds will improve performance.
7. Filters should be backwashed before returning to service if stopped part way through a filter run.
8. Where more than one filter is used, the quality deterioration produced by rapid changes in flow rate when one is taken out for backwashing should be minimised. Slow start-up and slow stopping of the filters reduces the effect.
9. Ozone treatment should be retained with as high a dose and as long a contact time as possible.
10. The installation of medium pressure UV disinfection at normal disinfection doses can give better than 3.5 log oocyst inactivation and should be easily installed.
11. A newly developed adsorbent offers high log inactivation of oocysts and is claimed to be relatively cheap and easily installed in filters. These claims require confirmation.

THE REMOVAL OF CRYPTOSPORIDIUM OOCYSTS IN THE TREATMENT OF SWIMMING POOL WATERS

By

Brian Croll BSc, PhD, FCIWEM

In addition to the literature survey and report produced by The University of Wales, Swansea, a search of the American Waterworks Association Research Foundation current project descriptions has been made, this was not available to Swansea. Dr Tom Hall of WRc (performed the UKWIR oocyst removal in drinking water work), Prof Hugh Smith (PHLS Glasgow) and Dr John Watkins (performing Cryptosporidium surveys for DWI) have been contacted to see if they are aware of any other new developments.

1. FILTRATION

1.1 Swimming Pool Filtration

Only one reference was found to experiments specifically designed to investigate the removal of oocysts in swimming pool filters. This was done in connection with the outbreak in Doncaster in 1980 at PHLS, Northern General Hospital, Sheffield (1). Oocysts were seeded onto a laboratory pilot filter, in distilled water, without a coagulant. Under these conditions very poor oocyst removal would have been expected but none of the 10^6 oocysts applied to the top of the filter were found in the filtrate.

There is a mistake in the paper in that the downflow rate of the filter is quoted as 15 m/h whereas calculations from the pilot filter diameter and flow rate give a downflow of 15 cm/h. The author has been contacted and says that the pilot filter flow rate is wrong and the downflow rate was 15m/h. From the drinking water work, 15 cm/h downflow would be consistent with the results obtained in this paper and this work is at odds with all the drinking water results.

1.2 Drinking Water Filtration

1.2.1 Normal Drinking Water Filtration Rates (5 to 10 m/h downflow rate)

In the absence of coagulant, oocyst removal is poor, being less than 1 log (90%) (2). The removal of turbidity has been found to correlate reasonably well with oocyst removal in most cases. The results of long term monitoring of roughing filters prior to slow sand filters at Thames Water shows an average of 50% turbidity removal as shown in table 1 (Thames Water Annual Reports).

Table 1. Slow Sand Roughing Filter performance at Thames Water

STAGE	E COLI No/100ml	TURBIDITY NTU
RIVER	100 - 25,000	2 - 50
RESERVOIR	0 - 1000	1 - 10
PRIMARY	0 - 1000	0.5 - 5
SLOW SAND	0 - 100	0.1 - 0.5
CHLORINATED	0	0.2

When a coagulant is added before a settlement or flotation stage prior to the filter or directly before the filter, oocyst removal rises to 2 to 3 log (3) . There is one claim that flotation is better than settlement and that 4 log can be reached (4). The correct coagulant and coagulation and flocculation conditions are critical to the achievement of good performance and when non optimal conditions are used removal can drop to 1 to 2 log (5). The filter depth and downflow rate are less critical to good performance than coagulation and flocculation conditions, although there is some deterioration with higher flow rates.

The filter “ripening” period is very important in oocyst removal and up to 50% of the 2 to 5 µm particles passing through the filter during a filter run can pass during this period. Slow filter start can reduce this effect by up to 30% (6) but the only way to eliminate it is to waste or recycle the water produced during the ripening period.

Restarting a filter which was stopped part way through a filter run gives a peak of 2 to 5 µm particles similar to initial start-up after backwashing. Backwashing before bringing back into service can greatly reduce the peak.

Rapid changes in flow rate, such as happens when one filter is taken out of service for backwashing while the works output remains unchanged, can also give peaks of 2 to 5 µm particles. These can approach the size of the peak on initial start-up after backwashing but are generally smaller. Slow start and slow stop of the filters minimises this effect.

Poor backwashing of filters leads to larger start-up peaks of particles.

1.2.2 Rapid Filtration (>10 m/h downflow rate)

There has been a trend to higher filtration rates in drinking water treatment in order to save on capital costs. Simply increasing the flow rates of existing filters has limited application as the consequent reduction in filter run times is limited by operational needs at a waterworks. Filter runs of less than 24h between backwashing are inconvenient and detrimental to works output. This approach has been mainly investigated in the USA, where raw waters are generally of lower turbidity than in Europe.

High rate filters are now being designed with coarse media (1 to 3 mm diam) to reduce the build-up of headloss and greater bed depths (up to 3m) to achieve the required quality (7). Such filters can give excellent performance for direct filtration after coagulation and flocculation, provided that the raw water turbidity is relatively low (<20 FTU).

As with filters operated at normal drinking water filtration rates, the achievement of good performance is more dependent on the correct coagulation and flocculation conditions than on filtration rate.

A summary of high rate direct filtration results is given in Table 2.

Table 2. High Rate Direct Filtration of *Cryptosporidium* Oocysts.

Filtration Rate m/h	Media depth mm	Media Size (Mean) mm	Log Removal	Reference
14	Anthracite 610 Sand 510		1.31 to 3.78 mean 2.97	8
11.7			2.57 to 2.92 mean 2.79	8
39	Anthracite 2290	1.5	3.94	9
39	Anthracite 1524 Sand 762	2.0 1.0	4.08	9
12.2	Anthracite 457 Sand 220 Garnet 147	1.0 to 1.1 0.45 to 0.55 0.18 to 0.22	2.7 to 3.1 (1.5 with sub-optimal coag)	5

It will be seen that good oocyst removal (3 to 4 log) can be obtained at high filtration rates as used for pool water filtration but that this is dependent on optimal coagulation. In most cases a coagulant and coagulant aid were dosed followed by a small dose of a polyelectrolyte filtration aid.

1.3 New Adsorbent Filtration

Very recently (10) scientists at the Australian National University, Canberra have developed an adsorbent which is claimed to adsorb oocysts so strongly that the

cysts collapse, killing the sporozoites inside. Pending a Patent application no further details on the adsorbent nor the details of the experimental work have been released. It is also claimed that it would be simple and cheap to produce a swimming pool filter using the material.

2. DISINFECTION

In disinfection studies the method by which the viability of the oocysts is measured is critical to the conclusions and has led to great variability on the published results. The methods normally used in the UK are based on dye staining and excystation, these give an estimated kill of at least one order less than the mouse infectivity method normally used in the USA and Canada. Assays using human cell cultures are now being developed and these give results very similar to the mouse infectivity assays. Thus it is generally accepted by microbiologists that the mouse infectivity results are more reliable than dye staining and excystation.

2.1 Ozone

Ozone applied at drinking water disinfection doses (0.3 mg/l after 10 to 20 min contact) gives 2 to 3 log kill of oocysts as estimated by mouse infectivity (11). At swimming pool doses (0.4 mg/l after 2 min contact) it is likely that the kill would be about 1 log but the higher water temperature may give better results.

2.2 Ultra Violet Irradiation

Medium pressure UV lamps, which emit a relatively broad band radiation around the 254 nm germicidal frequency, have been shown by mouse infectivity assay, to give oocyst inactivation of at least 3.5 log at normal water disinfection doses (20 mW.sec/cm²) (12).

The efficacy of low pressure lamps is less certain and some workers have obtained similar results to medium frequency lamps whilst others have recorded >4 log kill as measured by mouse infectivity only with high UV doses of 4000 to 8000 mW.sec/cm² (13).

2.3 Novel Irradiation Methods

Both pulsed UV irradiation and pulsed white light are claimed to give similar results to medium pressure UV.

2.4 Combined Disinfection Methods

Combinations of disinfectants such as ozone and chlorine, chlorine dioxide and chlorine and chlorine plus monochloramine have been claimed to act synergistically. However results have been erratic between different workers and at present it would be inadvisable to rely on the effect.

3. CONCLUSIONS

Derived from work into drinking water treatment

- 3.1 Direct filtration of drinking waters at filtration rates similar to those used in pool filtration (14 to 40 m/h) can give 3 to 4 log removal of *Cryptosporidium* oocysts. This level of performance is critically dependent on optimal coagulation and flocculation of the water and may involve a coagulant, a coagulant aid and a filtration aid.
- 3.2 When coagulation and filtration are sub-optimal oocyst removal drops to 1.5 log.
- 3.3 Without coagulant, drinking water treatment at 5 to 10 m/h gave less than 1 log (90%) removal and long term turbidity removal was about 50%.
- 3.4 Coagulation and flocculation conditions are more critical than downflow rate but there is some deterioration of performance at higher downflow rates.
- 3.5 Up to 50% of 2 to 5 μm particles passing the filter during the whole filter run pass during the "filter ripening" period. This can be reduced by about 30% by using slow start-up of the filter but wasting or recycling the water is much more effective. Poor filter backwashing increases particle break-through.
- 3.6 Stopping a filter part way through a run and re-starting without backwash gives a peak of 2 to 5 μm particles similar to that on initial start-up after backwashing. Backwashing before re-start reduces the peak.
- 3.7 Rapid changes in flow rate can give a peak of 2 to 5 μm particles similar to that on initial start-up after backwashing. Slow start and slow stop of filters taken out for backwashing will minimise this effect on the other filters in a bank.
- 3.8 A new adsorbent material has been developed which is claimed to adsorb oocysts and kill the sporozoites. It can be easily and cheaply incorporated into filters.
- 3.9 Ozone can give 2 to 3 log inactivation at drinking water disinfection doses. At pool water treatment doses inactivation is likely to be about 1 log, although it could be higher due to the higher water temperature.
- 3.10 Medium pressure UV irradiation can give better than 3.5 log inactivation at normal disinfection doses.

4. IMPLICATIONS FOR POOL WATER TREATMENT

- 4.1 A coagulant should always be used prior to filtration. The coagulation and filtration conditions should be optimised as far as is practical.
- 4.2 If possible the water produced during the "filter ripening" period after backwash should be wasted or recycled as backwash water. Recycling the whole flow for a period should be helpful.
- 4.3 Slow start-up of the flow to a filter will reduce the "filter ripening" period quality deterioration.
- 4.4 In order to avoid unnecessary "filter ripening" periods filter runs should be as long as possible consistent with no turbidity breakthrough.
- 4.5 Filter backwash should be checked to ensure that the filter underdrains and media are in good order and that the filter is fully cleaned.
- 4.6 Deeper filter beds will improve performance.
- 4.7 Filters should be backwashed before returning to service if stopped part way through a filter run.
- 4.8 Where more than one filter is used, the quality deterioration produced by rapid changes in flow rate when one is taken out for backwashing should be minimised. Slow start-up and slow stopping of the filters reduces the effect.
- 4.9 Ozone treatment should be retained with as high a dose and as long a contact time as possible.
- 4.10 The installation of medium pressure UV disinfection at normal disinfection doses can give better than 3.5 log oocyst inactivation and should be easily installed.
- 4.11 A newly developed adsorbent offers high log inactivation of oocysts and is claimed to be relatively cheap and easily installed in filters. These claims require confirmation.

REFERENCES

1. Chapman P A and Rush B A "Efficiency of sand filtration for removing cryptosporidium oocysts from water" J Med Microbiol 1990 32 pp 243 to 245.
2. Rachwal et al "Comparisons between slow sand and high rate biofiltration" Graham N and Collins R (eds). *Advances in Slow Sand and Alternative Biofiltration.*, John Wiley and Sons, Chichester, England. 1996 pp 3 to 10.
3. Croll B and Hall T "Control of Cryptosporidium during Drinking Water Treatment - Technological Options" Technical papers from the CIWEM Symposium

"Cryptosporidium in Water - The Challenge to Policy Makers and Water Managers" Glasgow, Scotland, 1997 pp 43 to 57.

4. Edzwald J K and Kelley M B "Control of Cryptosporidium: from Reservoirs to Clarifiers to Filters" *Wat Sci Tech* 1998 37 (2) pp 1 to 8.
5. Ongerth J E and Pectorano J P "Removing Cryptosporidium using multimedia filters" *J Am Wat Wks Assn* 1995 (Dec) pp 83 to 89.
6. Colton J F Hillis P and Fitzpatrick C S B "Filter Backwash and Start-Up Strategies for Enhanced Particulate Removal" *Wat Res* 1996 30 (10) pp2502 to 2507.
7. Clark S C, Lawler D F and Cushing R S "Contact Filtration: Particle Size and Ripening" *J Am Wat Wks Assn Res and Tech* 1992 (Dec) pp 61 to 71.
8. Neiminski E C and Ongerth J E "Removing Giardia and Cryptosporidium by Conventional Treatment and Direct Filtration" *J Am Wat Wks Assn* 1995 (Sept) pp 96 to 106.
9. Swaim P D et al "High Rate Direct Filtration for *Giardia* and *Cryptosporidium* Removal" 1996 Proc AWWA Ann Conf Toronto Canada.
10. *New Scientist* 29th July 2000 p10.
11. Gyurek L L et al, "Disinfection of *Cryptosporidium parvum* using single and sequential of ozone and chlorine species" Proceedings of the AWWA Water Quality Technology Conference, Boston MA USA November 1996
12. Bolton et al "Inactivation of *Cryptosporidium parvum* by Medium-Pressure Ultraviolet Light in Finished Drinking Water" Proceedings of the 1998 American Waterworks Association Conference, Dallas, Texas USA June 1998.
13. Clancy J L , Marshall M M and Dyksen J E " Inactivation of *Cryptosporidium parvum* oocysts in water using advanced ultraviolet irradiation" in Fricker C R, Clancy J L and Rochelle P., Eds , AWWA Denver CO USA 1997, pp 219 to 228.