Role of filtration in managing risk from *Cryptosporidium* in commercial swimming pools

Martin Wood and Lester Simmonds
(and others)

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What we do

Supporting best practice

✓ optimising pool filtration and disinfection

✓ improving efficiency of chemical, water, energy use

✓ improving customer experience (water clarity, pool air quality).

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Role of filtration in managing the risk from *Cryptosporidium* in commercial swimming pools – a review

Martin Wood, Lester Simmonds, Jitka MacAdam, Francis Hassard, Peter Jarvis and Rachel M. Chalmers

ABSTRACT

Most commercial swimming pools use pressurised filters, typically containing sand media, to remove suspended solids as part of the water treatment process designed to keep water attractive, clean and safe. The accidental release of faecal material by bathers presents a poorly quantified risk to the safety of swimmers using the pool. The water treatment process usually includes a combination of maintaining a residual concentration of an appropriate biocide in the pool together with filtration to physically remove particles, including microbial pathogens, from the water. However, there is uncertainty about the effectiveness of treatment processes in removing all pathogens, and there has been growing concern about the number of reported outbreaks of the gastrointestinal disease cryptosporidiosis, caused by the chlorine-resistant protozoan parasite *Cryptosporidium*. A number of interacting issues influence the effectiveness of filtration for the removal of *Cryptosporidium* oocysts from swimming pools. This review explains the mechanisms by which filters remove particles of different sizes (including oocyst-sized particles, typically 4–6 μm), factors that affect the efficiency of particle removal (such as filtration velocity), current recommended management practices, and identifies further work to support the development of a risk-based management approach for the management of waterborne disease outbreaks from swimming pools.

Key words | *Cryptosporidium* oocysts, filtration, particle counting, swimming pools, turbidity

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Crypto - a major risk to pool users

Cryptosporidium oocysts

Released in runny faeces

Microscopic (4-6 micron)

Resistant to chlorine

Easily swallowed

Removed from pool water by filtration

BUT…

Filters need to be working at their best

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Faecal contamination

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

- **Subject**: Faecal Contamination
- **Date**: February 2014; supplemented July 2016

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').

Pools with medium-rate filtration - emphasis is on filtration

- ✓ Close the pool
- ✓ Optimise disinfectant residual
- ✓ Ensure correct coagulant dosing
- ✓ Filter for 6 turnover cycles
- ✓ Backwash filters
- ✓ Rinse filters
- ✓ Circulate water for 8 hours (optional)

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Crypto - the microbial challenges

Could be ~10 billion oocysts in a single accidental faecal release (AFR).

Equivalent to ~20 per mL if mixed in a 450 m^3 pool

A child drinks on average 37 mL during 45 minute swim - possibly containing 740 oocysts

Just 1 oocyst can cause infection

So aim to remove at least 99.9% during clean-up

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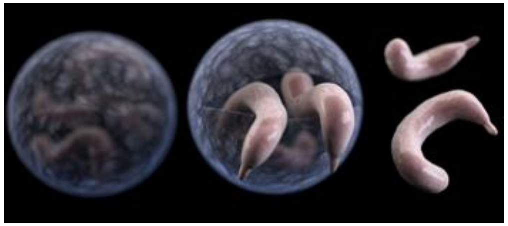

Crypto - the technical challenges

Oocysts are resistant to chlorine levels normally used for pool water disinfection taking 10 days for 99.9% removal.

Most pools rely on filtration to remove oocysts from pool water

BUT…

How do sand filters remove such small particles?
How effective are the filters?

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Pools with medium-rate filtration - emphasis on filtration

..if effective should remove some 99% of the Cryptosporidium oocysts in each pass of pool water through the filter.

Filter for six turnover cycles…This assumes good hydraulics and well maintained filters with a bed depth of 800mm and 16/30 sand.

How do you know if this is the case for your pool?

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Crypto Fact 1. Size Matters

Sand grains

size of particles
size of spaces between particles

Crypto oocysts

big enough for entrapment?
big enough for sedimentation?
big enough for impaction?
small enough for diffusion?

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How do sand filters remove small things?

Sand filters can act as a strainer for big things

For 16/30 sand that's anything bigger than 100 micron (µm)

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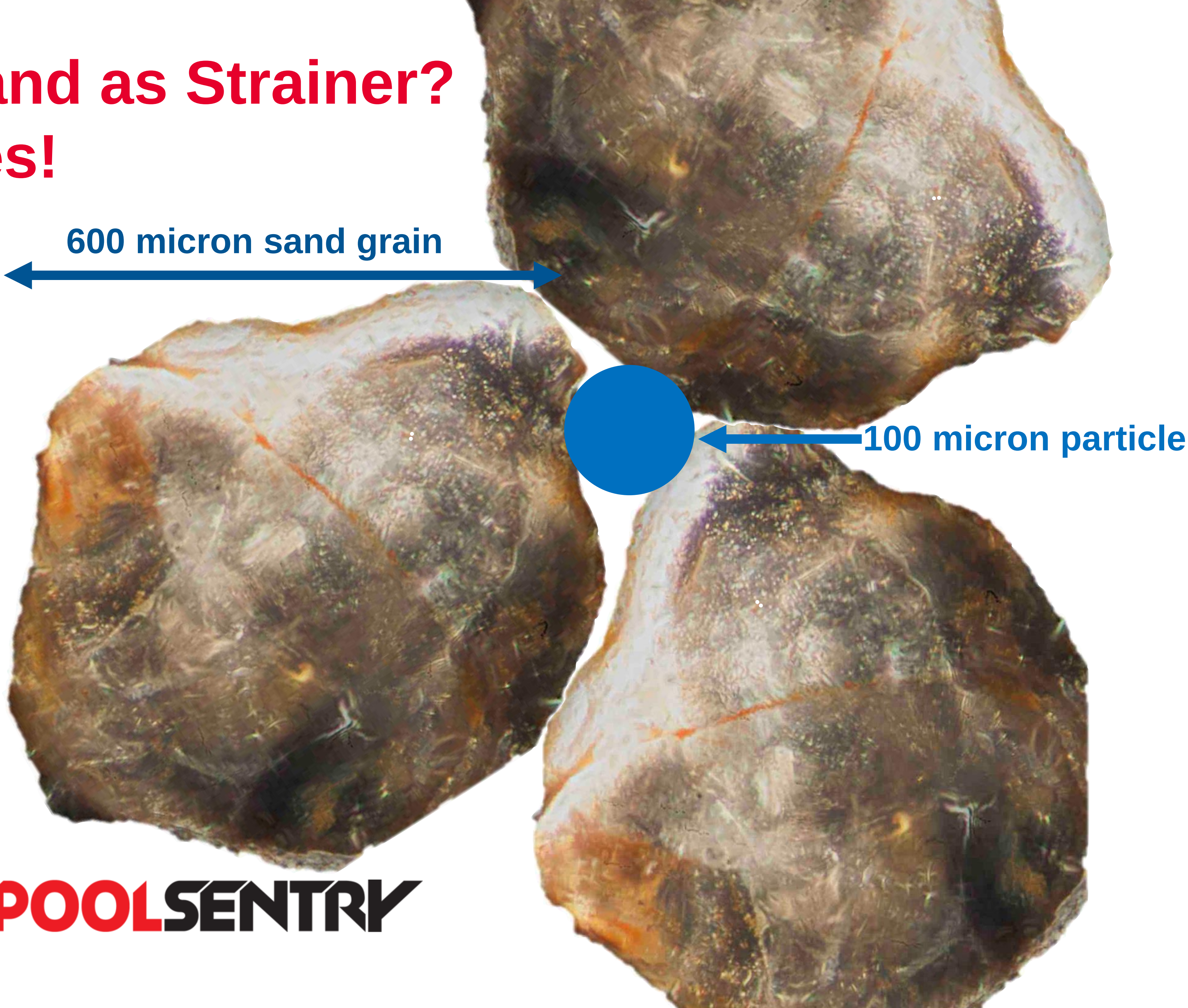
Sand as Strainer? Yes!



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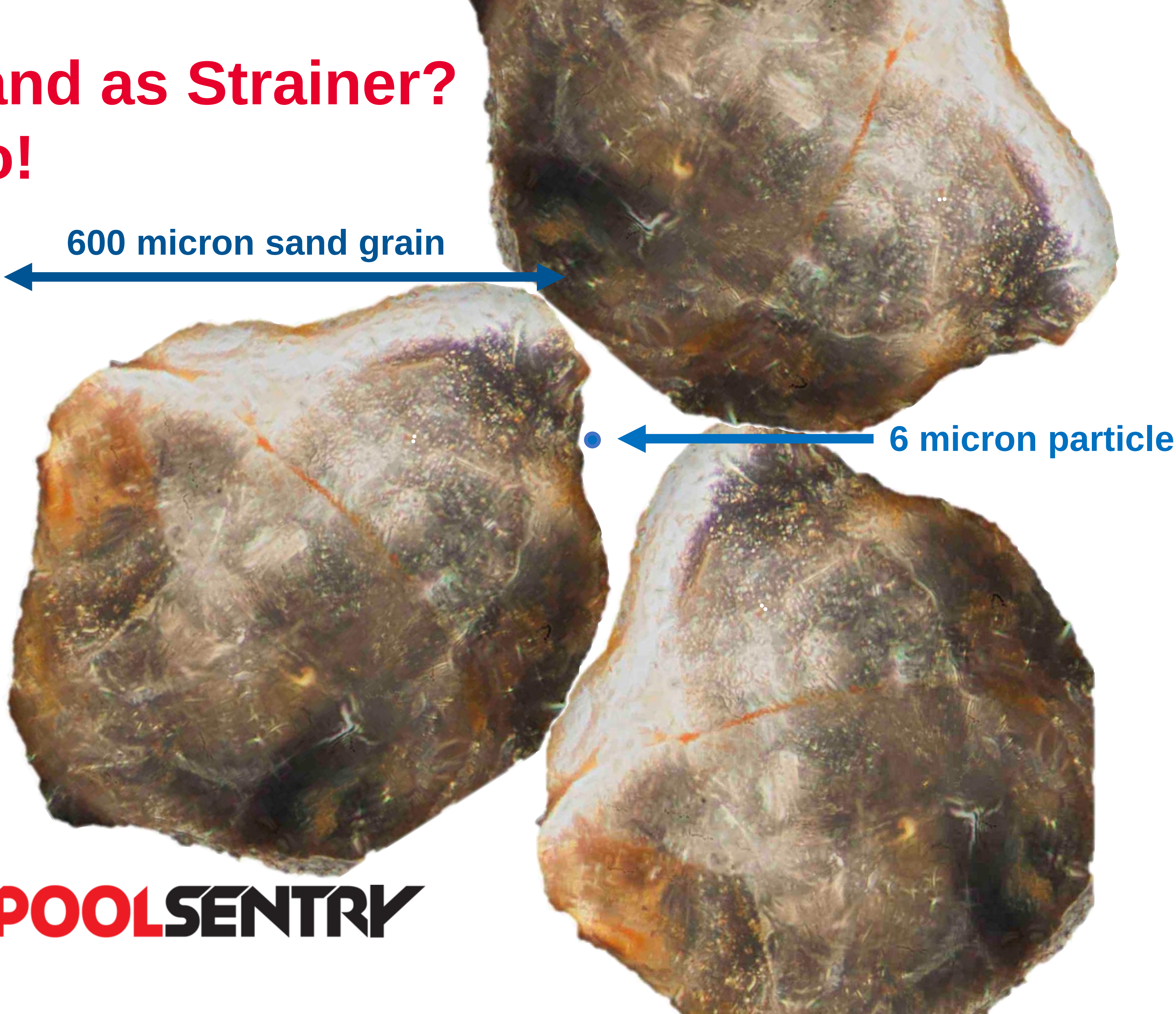
Sand as Strainer? No!



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Let’s zoom in

10 micron

Very small particles will attach to surfaces

But only if they get extremely close

So short-range forces come into play

How is this going to happen?

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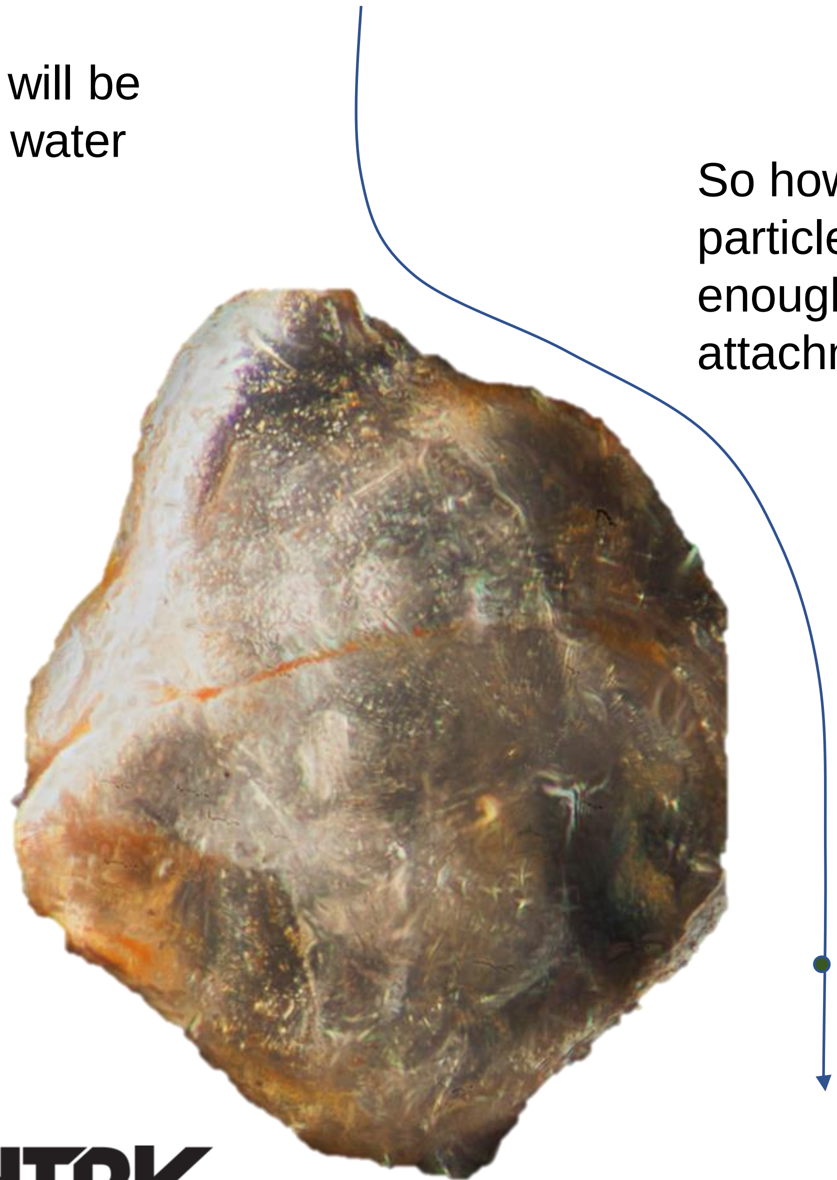
Suspended particles will be carried wherever the water flows



So how will suspended particles ever get close enough to a sand grain for attachment to occur?

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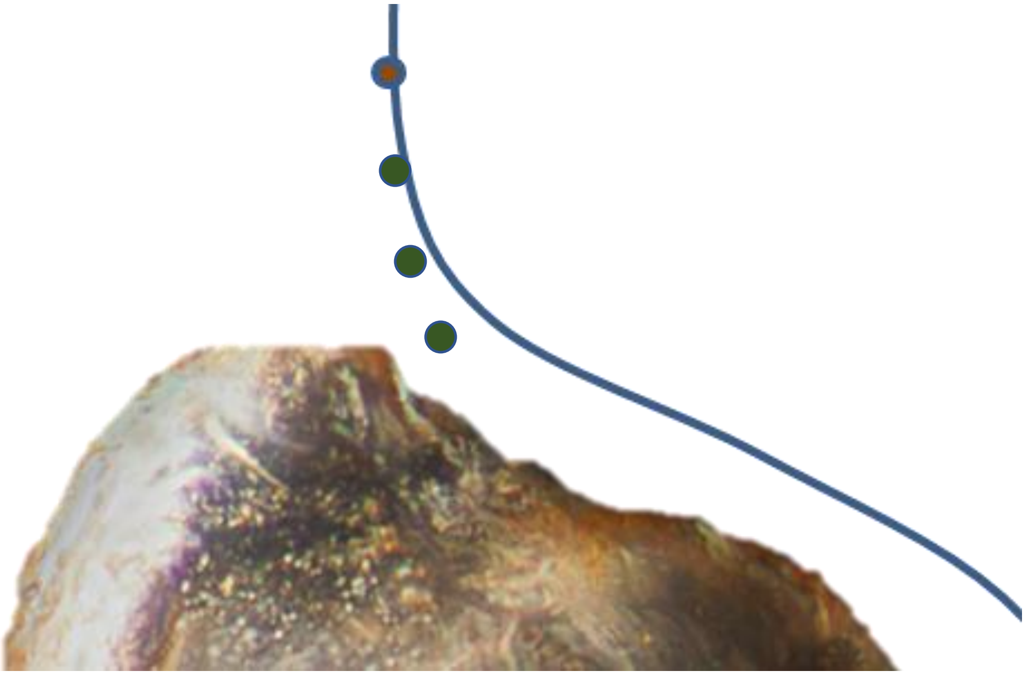
Sedimentation

Particles pulled downwards by gravity
Larger particles have faster settling velocities
so more effective sedimentation



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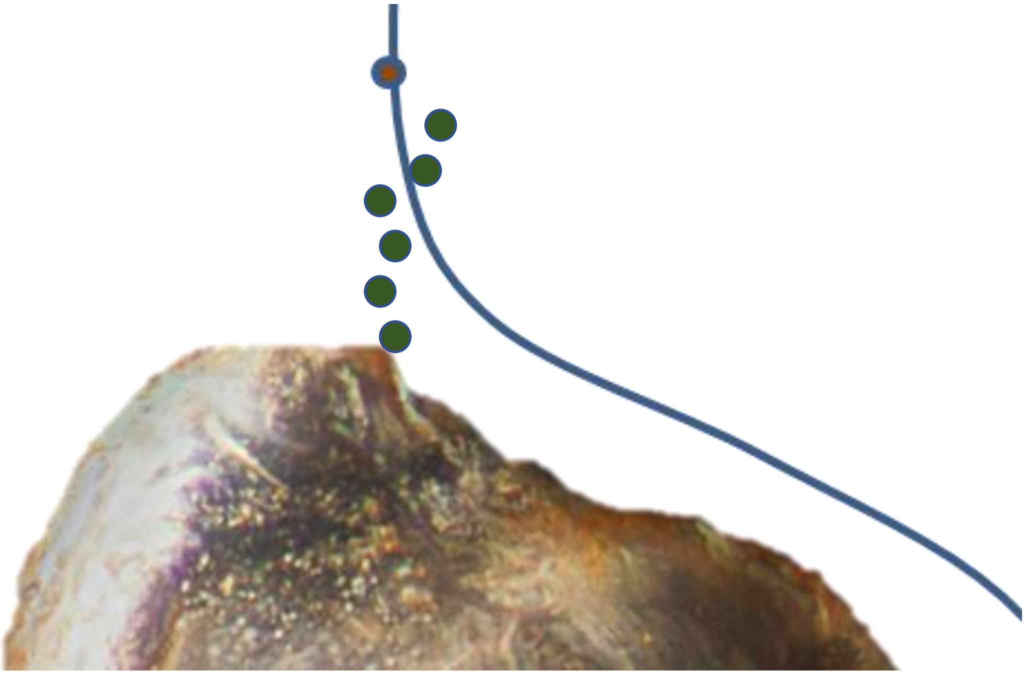
Diffusion

Small particles have random motion within the flowing water
Smaller particles have most random movement as most easily ‘knocked off course’



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What are the chances of meeting?

Crypto oocysts

big enough for entrapment?	**No**
big enough for sedimentation?	**No**
big enough for impaction?	**No**
small enough for diffusion?	**No**

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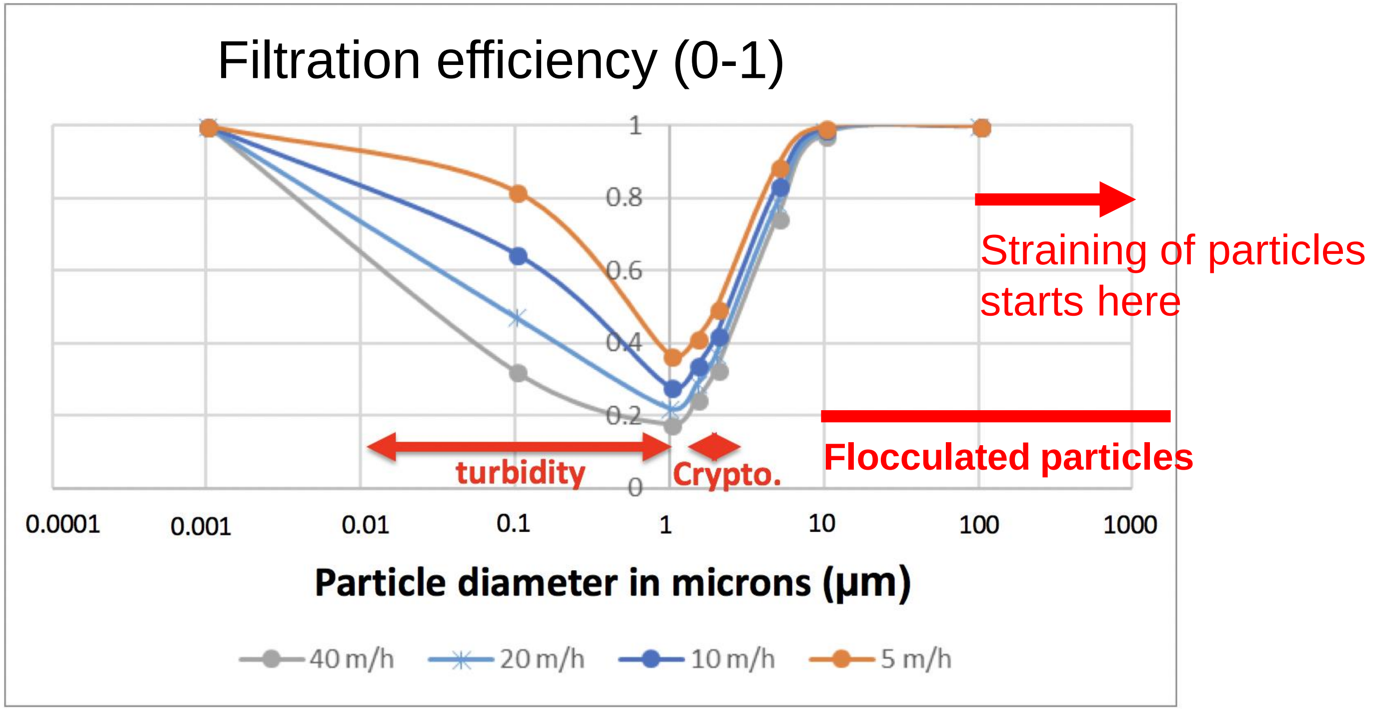
The Challenge of Removing the Crypto-sized Particles using Sand Filters (theory)



Crypto-size particles (4-6 µm) most difficult to remove

Flocculated particles (>10 µm) much easier to remove

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Crypto Fact 2. Surface Matters

Plenty of opportunity for oocysts and sand grains to meet:

1 m^3 of 0.6 mm sand has surface area of 6252 m^2
~size of a football pitch!

Particles will encounter ~4000 sand grains
as they pass through 800mm deep sand bed.

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Crypto Fact 2. Surface Matters

But there's a problem…

They repulse each other because…

…they both have negative charges at the surface

So we need to neutralise the charge

Or we need some kind of go-between.

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Crypto Fact 2. Surface Matters

Despite the initial repulsion… oocysts and sand grains do get together

biomolecules on the oocyst surface?

Chemicals can assist (coagulants and filter aids)

- ✓ aluminium oxides/hydroxides
- ✓ cationic polymers e.g. polyDADMAC

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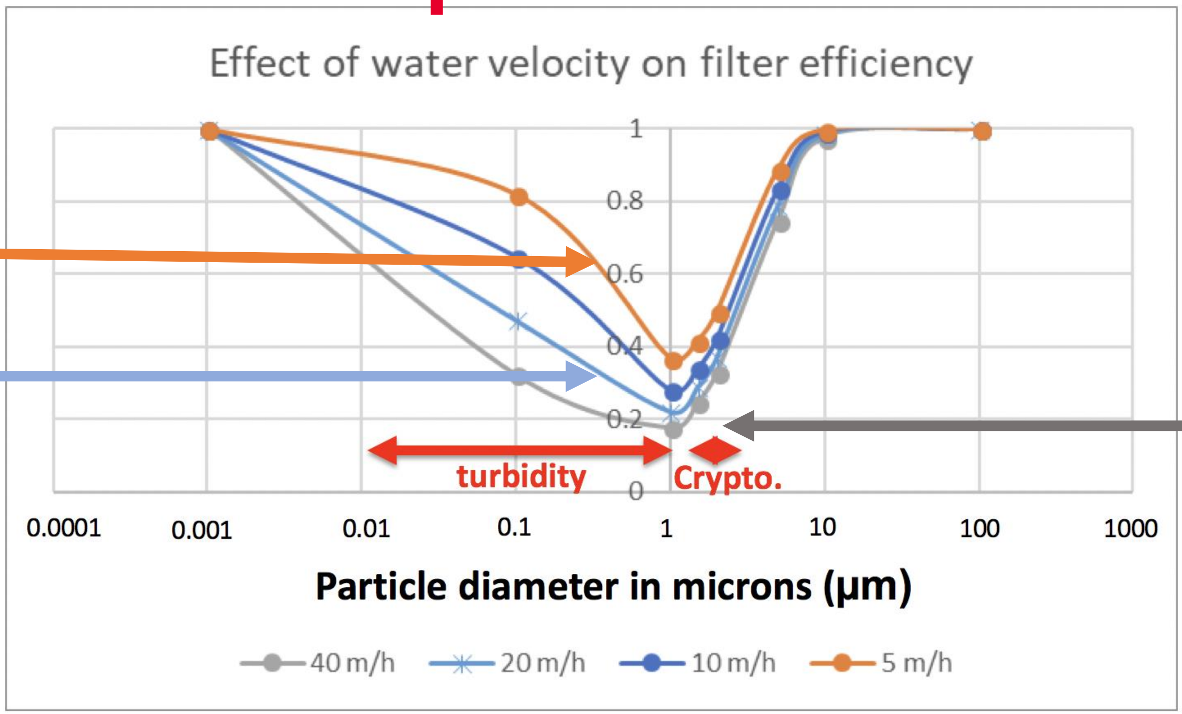
Crypto Fact 3. Speed Matters



Filter efficiency is reduced as circulation rate is increased

Slower filtration is better than faster filtration!

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Crypto removal in practice
- what do we know?

Drinking water industry (full-scale plants)

Slow sand filtration

+

Coagulation/flocculation

+

Sedimentation

Can result in 1.5 - 3 $\log_{10}$ removal of oocysts

(97 - 99.9% removal of oocysts)

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Crypto removal in Pool Industry - what do we know?

We know very little!

<u>Microsphere studies</u>

Brian Croll 2007 - Swansea test rig

James Amburgey 2016 - US test rig

<u>Particle counting</u>

Stauder & Rödelsperger 2011 - German outdoor pool

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Crypto removal - what do we know?

Microsphere studies

Brian Croll et al 2007 - Swansea test rig

Sand filter 25 m/h
0.05 mg/L Al
1-7 micron polystyrene microspheres
<50% removal with no coagulant

>90% removal with PAC.

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Crypto removal - what do we know?

Microsphere studies

James Amburgey 2016 - US test rig

Sand filter 37m/h
1-7 micron polystyrene microspheres

no coagulant 20-63% removal
polyDADMAC >90% removal
PAC 35-70% removal (90% at 30 m/h).

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Crypto removal - what do we know?

Particle counting

Stauder & Rödelsperger 2011 - German outdoor pool

Dual media (sand/anthracite) filter 35m/h
0.05 mg/L Al
~12,000 bathers per day

~99% removal 1-10 micron particles

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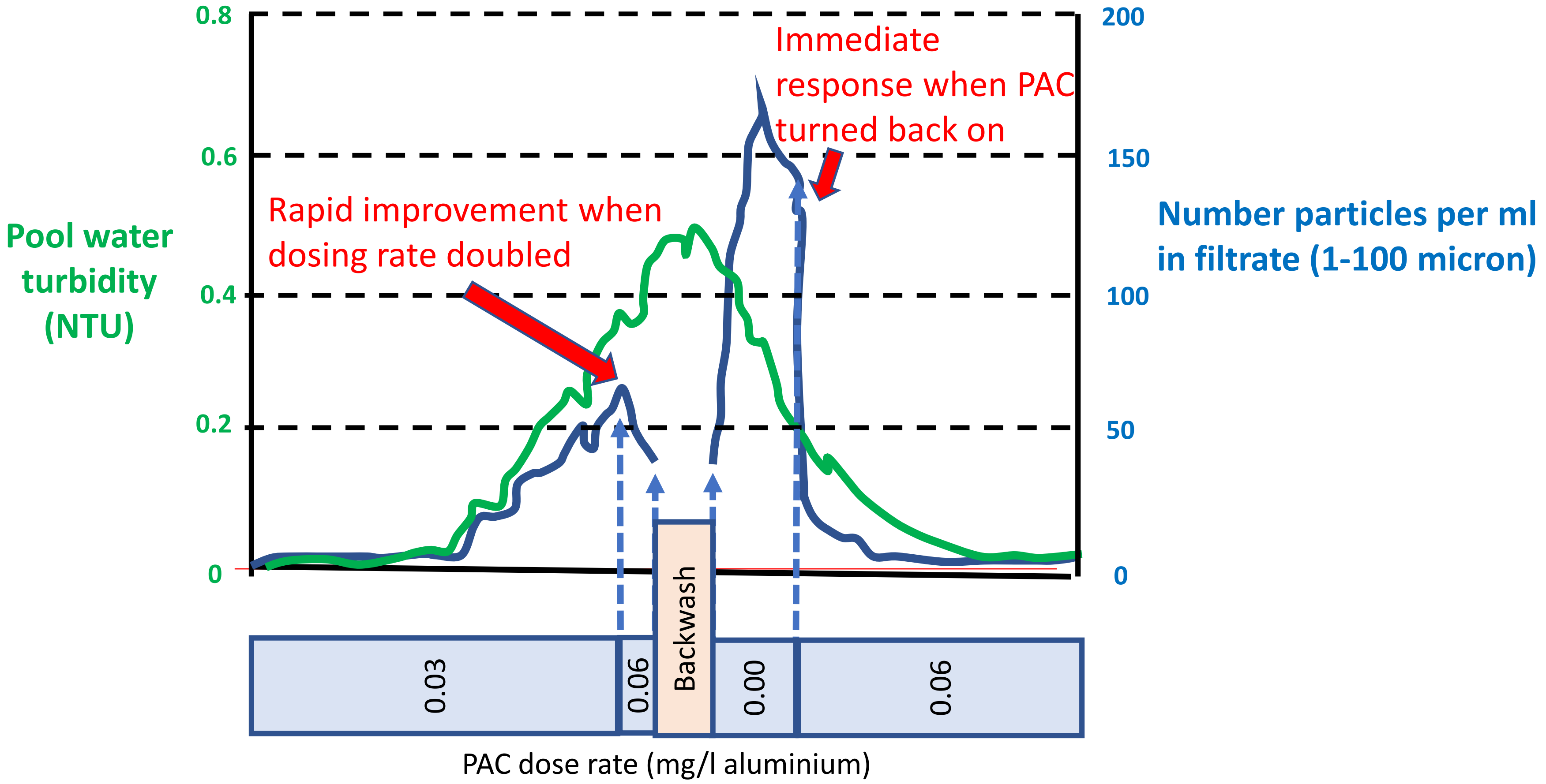
Coagulation - what do we know?

Impact of PAC dosing rate on particle content of filtrate over 24 h



Stauder & Rödelsperger (2011)

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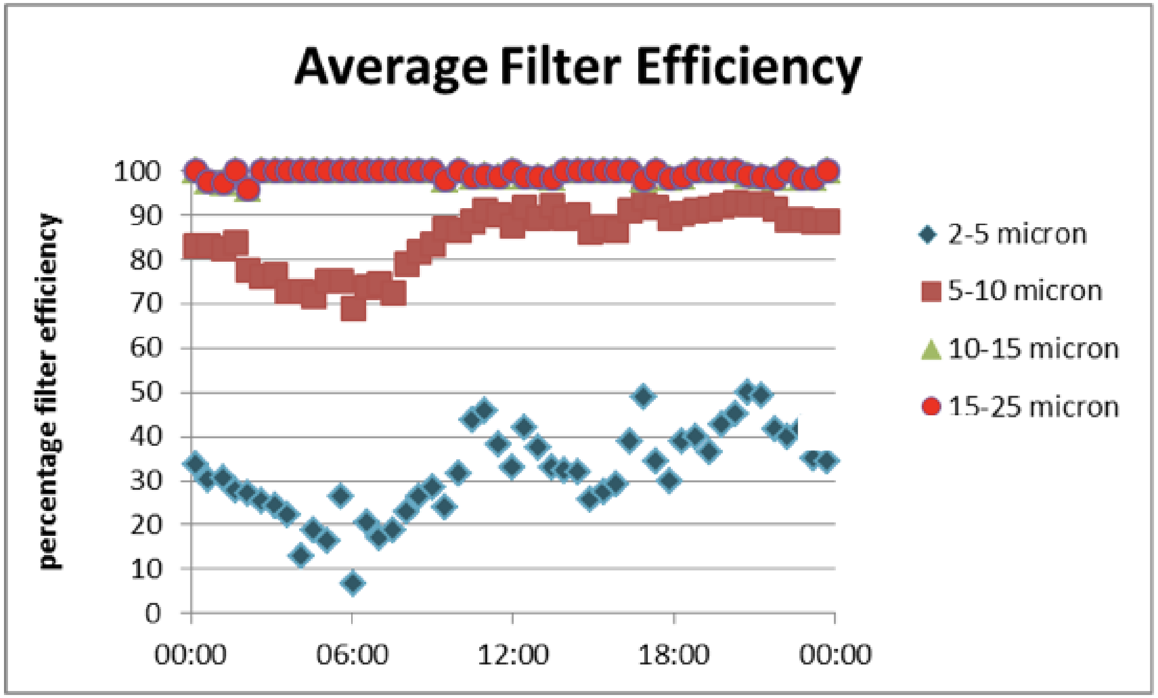
Removal efficiencies in a real filter

Example of an operational filter based on particle counts at the filter inlet and outlet over 24 h



During daytime

~40% of 2-5 micron size particles removed.

~100% of >10 micron size particles removed.

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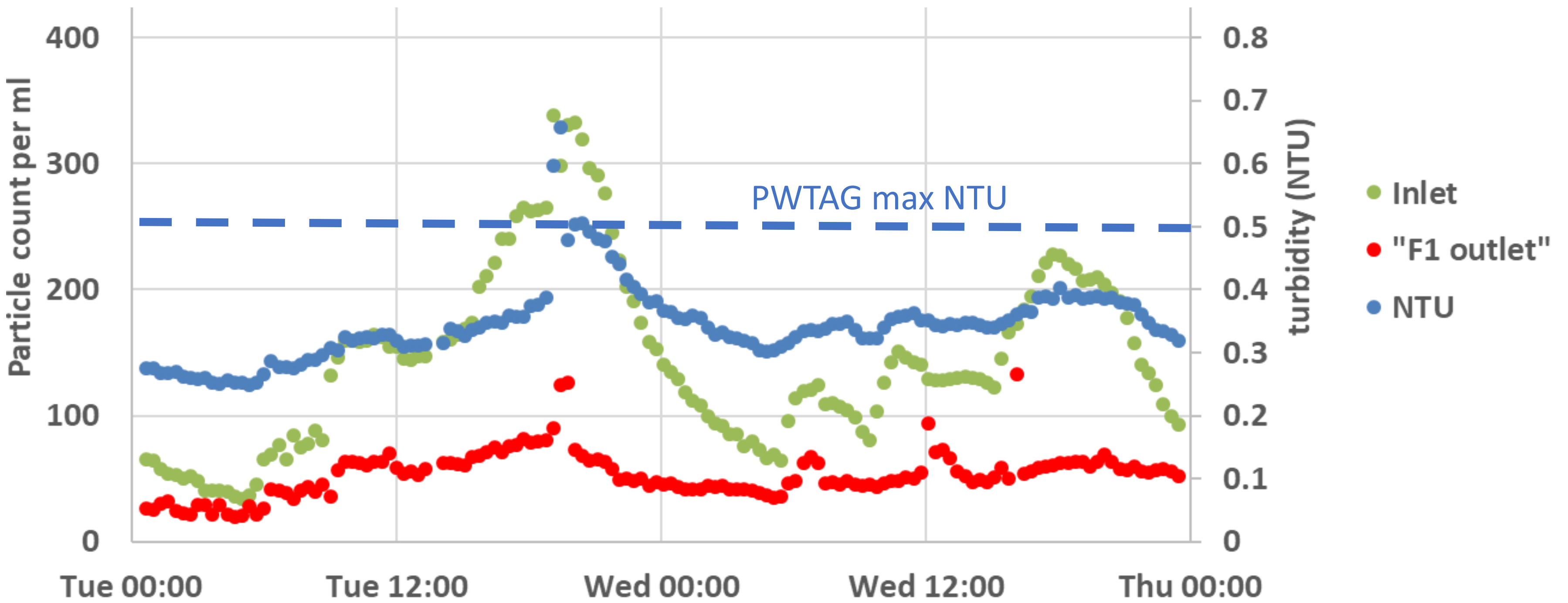
Water being clear doesn't mean filters are ok

Turbidity <0.5 NTU but poor filtration of 2-5 micron size particles



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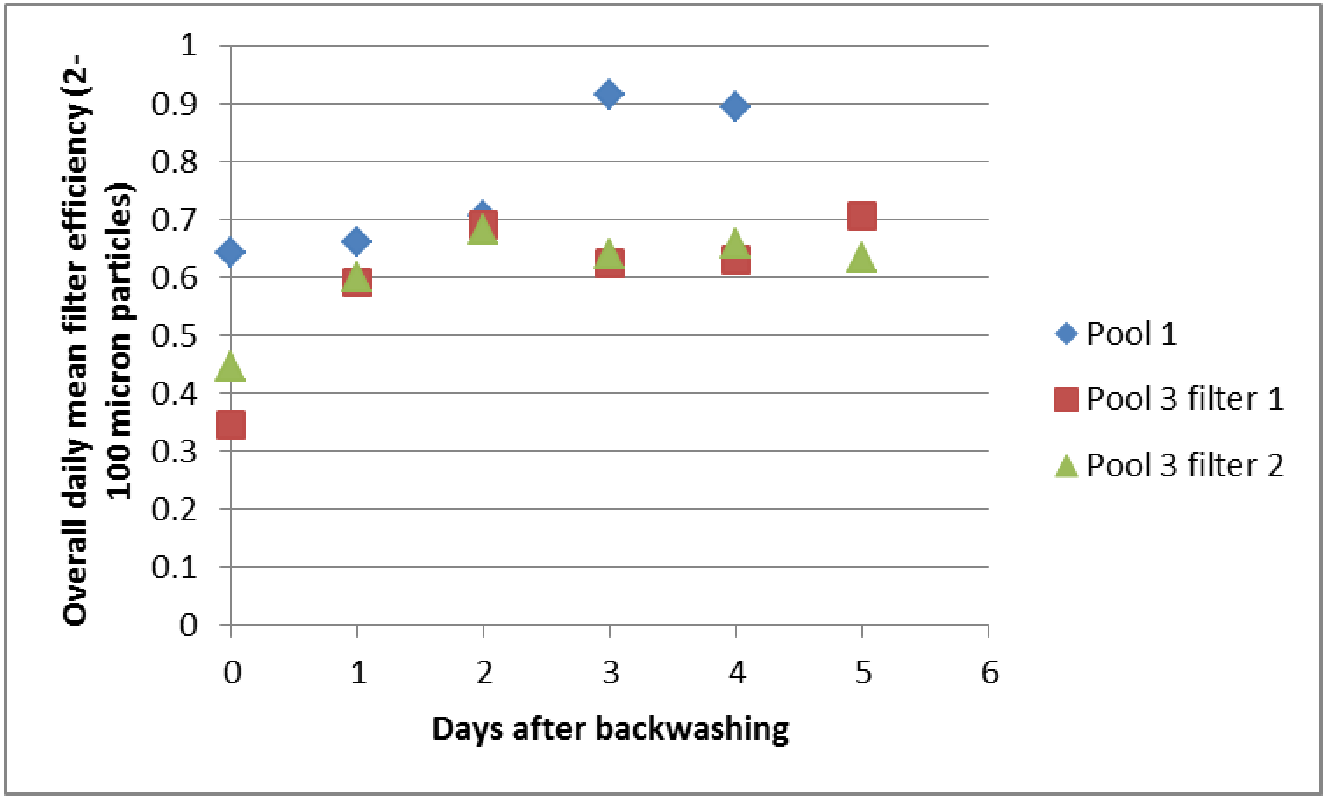
Filter performance following backwashing



Filtration is worst immediately after backwashing
Can take 3 days to recover as filter ripens.

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What happens in one turnover?

You have a busy pool that contains 450 m^3 water with a circulation rate of 150 m^3 /h and there's a Crypto poop incident at 12 pm…

Q. How much of the water that's in the pool at 12 pm will have passed through the filter by 3 pm?

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What happens in one turnover?

You have a busy pool that contains 450 m^3 water with a circulation rate of 150 m^3 /h and there's a Crypto poop incident at 12 pm…

A. 63% of the water that's in the pool at 12 pm will have passed through the filter by 3 pm…
which means 37% still in the pool and not filtered!

Why 6 turnovers?

After 6 turnovers 99.7% of water will have been filtered

0.3% remains untreated.

If 100% oocyst removal in plant room (filters, UV)

99.7% of the oocysts will have been removed

0.3% of the oocysts remain in the pool.

This is the best we can achieve!

…for a well-mixed pool

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What if - 6 turnovers and real filters?

If filters only 50% effective at removing particles…

…10% of oocysts remain in pool after 6 turnovers.

So if a child drinks 37 mL during 45 minute swim…

…this could still contain 74 oocysts

Significant risk of infection!

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Crypto removal - things to consider

Design/operation

- ✓ media
- ✓ flow rate
- ✓ coagulation/flocculation
- ✓ backwashing

Monitoring

- ✓ visual inspection
- ✓ turbidity, particle counting

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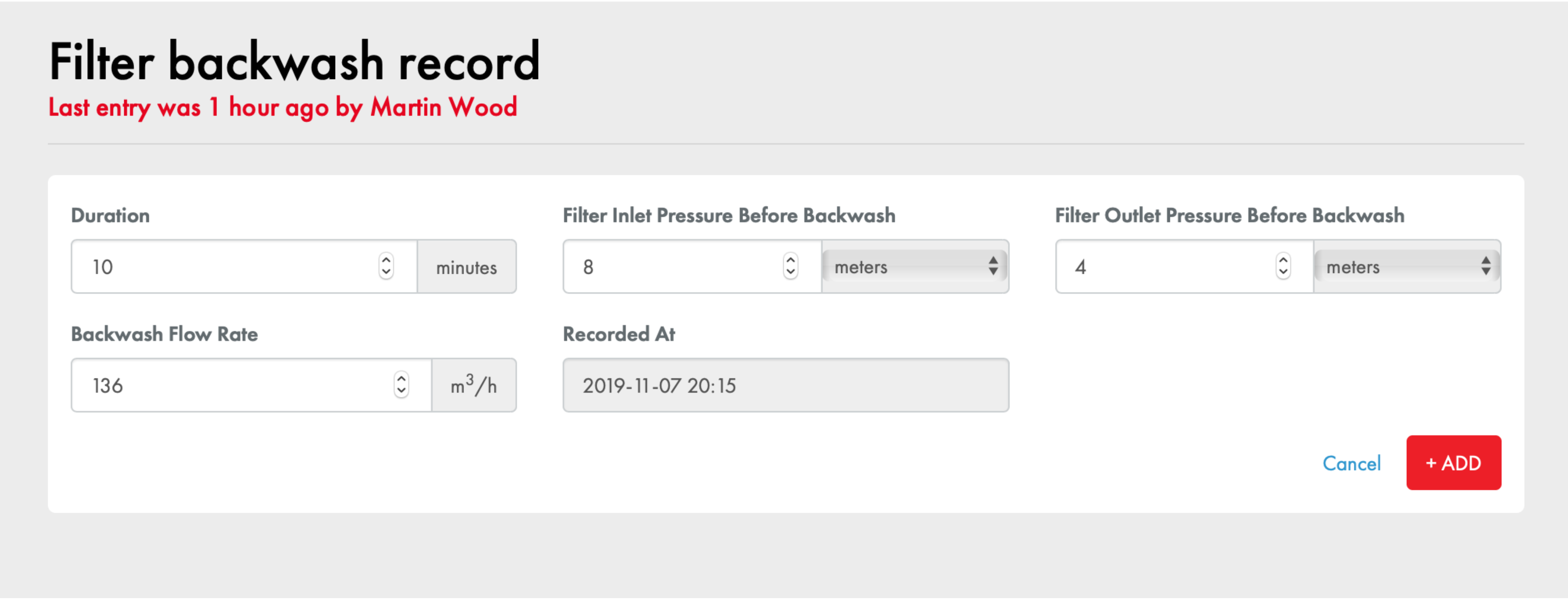
The more data the better - use our Web App



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Thank you!

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