# Research Update: Enhancing Filtration to Maximize Cryptosporidium Removal

*James Amburgey, Ph.D.*

Dr. James Amburgey is an Assistant Professor in the Department of Civil and Environmental Engineering at the University of North Carolina at Charlotte where he teaches courses like Water Treatment Engineering and Environmental Chemistry. Dr. Amburgey earned his Bachelor of Science degree in Civil Engineering at the University of North Carolina at Charlotte. He holds Master of Science and Doctor of Philosophy degrees from Georgia Tech in Atlanta, GA, and he completed two years of Post-doctoral research at the Centers for Disease Control and Prevention (CDC) as an APHL Emerging Infectious Diseases Research Fellow. Dr. Amburgey was named as one of the Aquatics International Power 25 in 2008, 2010, and 2011 in recognition of the contribution of his research to the aquatics industry. He is the chairman of the Model Aquatic Health Code's Technical Committee on Filtration and Recirculation Systems. His research has been published in numerous scholarly journals such as Water Research, ASCE Journal of Environmental Engineering, Journal American Water Works Association, and AQUA: Journal of Water Supply: Research and Technology, Applied and Environmental Microbiology, and Journal of Microbial Methods. He has invented and applied for patents on new water treatment technologies and operates his own company, Water Treatment Research, Inc., in his spare time.

**Abstract**

Our understanding of swimming pool water filtration has made significant advances in recent years primarily because of the investments made into research. This presentation will summarize some of the ways that filtration systems in swimming pools can be modified to increase Cryptosporidium removal. It will highlight the both the changes that did and did not work effectively and briefly discuss the theory behind them as well as potential future trends.

# Research Update: Enhancing Filtration to Maximize *Cryptosporidium* Removal

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- **All of you for attending this presentation!**

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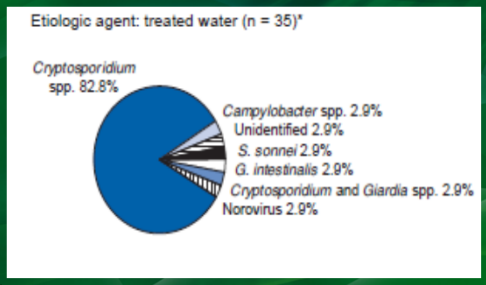
## *Cryptosporidium* is the Single Largest Threat to U.S. Swimmers




- U.S. Recreational water outbreaks 2005-2006
- MMWR: Surveillance Summaries 57 (No. SS-9): 1-38.

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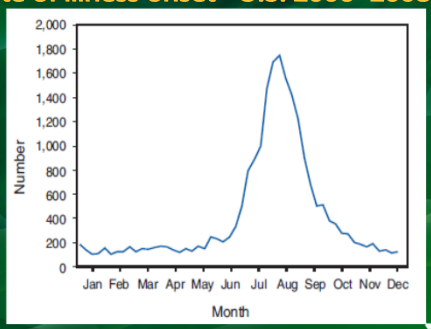
## Number of cryptosporidiosis case reports, by date of illness onset –U.S. 2006–2008




Source: (Yoder et al., 2010)

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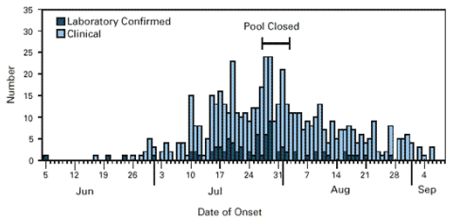
## *Crypto Outbreaks Can Last for MONTHS!*

**FIGURE 1. Number of laboratory-confirmed* and clinical† cryptosporidiosis cases, by date of onset — Delaware County, Ohio, June–September 2000**




* Diarrhea, vomiting, or abdominal cramps and a stool specimen that tested positive for *Cryptosporidium*.
† Diarrhea (three loose stools during a 24-hour period) for at least 1 day.

- MMWR *Weekly* May 25, 2001 / 50(20);406-410

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## How do filters work?

- Common filter media (sand) is usually 0.5 mm in diameter, which has a pore size (flow path) of approx. 0.05 mm or 50 µm
- Most pathogens are smaller than about 5 µm
- Similar to a 5 ft tall person swimming through an 50 ft diameter tunnel system
- A *Cryptosporidium* oocyst might randomly collide with the wall and could stick to it, but otherwise passes through the filter and back into the pool

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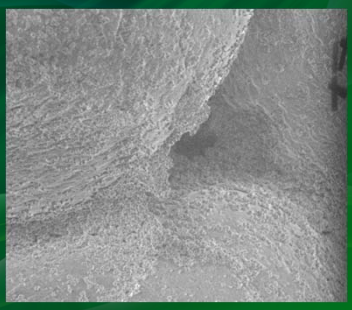
## Image from Inside of a Sand Filter

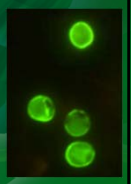
- SEM of sand grains
- 5-10 micron silicate particles
- 1 mm sand grains
- At 46 cm into bed after 3 hrs



*Graphic: Courtesy of Water Quality & Treatment 4th ed.*

## Non-Infectious *Crypto* Surrogate?

- Same size, shape, & density as *Crypto*
- Consistent (non-biological)
- Safe (non-infectious)
- Cheaper than *Crypto* and easy to get
- More stable, last longer
- Useful for performance evaluations
- Can be used full-scale with swimmers
- **Accurate? Removed similar to Crypto?**



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## Disinfection Options

- UV
- Ozone
- Chlorine Dioxide

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## Filtration Options

- Granular media filters (e.g., sand)
- Precoat filters (e.g., DE and perlite)
- Cartridge filters
- Membrane filters (e.g., MF, UF)

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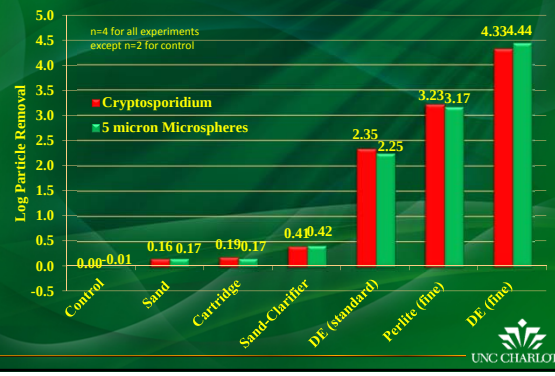
## Summary: *Crypto* & Microspheres

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## Filtration Options

- Granular media filters (e.g., sand)
  - Sand alone is not effective
  - Sand + Coagulant (e.g., Polyaluminum chloride)
  - Sand + Perlite (e.g., SwimBrite, Celaperl)
  - Sand + DE (e.g., Celatom)
  - Charged zeolites (e.g., Zeobrite Xtreme)
  - Fine ceramic media (e.g., Macrolite M1 Ultra)
- Precoat filters (e.g., DE and perlite)
- ~~Cartridge filters~~
- ~~Membrane filters (e.g., MF, UF)~~ $$$

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## Combined DE/Sand Filter

- Amount: 0.5 lbs/ft$^2$
- Depth: 6-8 mm (1/4" +)
- Filter loading rate: up to 20 gpm/ft$^2$

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## Spa-Scale Filter System

- Properly sized
- Better control
- Excellent monitoring

## Spa-scale Filter Performance

| Filter Type: | Mean % Removal Day 1 | Mean Log Removal Day 1 | Mean % Removal Day 3 | Mean Log Removal Day 3 |
|---|---|---|---|---|
| Sand Filter | 22 % | 0.11 | 23.4 % | 0.12 |
| Coagulant/Sand | 99.95 % | 3.29 | 99.92 % | 3.12 |
| DE/Sand | 99.98 % | 3.66 | 99.97 % | 3.62 |
| Perlite/Sand | 99.7 % | 2.63 | 99.7 % | 2.65 |
| Zeolite | 21.6 % | 0.11 | 31.5 % | 0.16 |

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## Filtration Options

- Granular media filters (e.g., sand)
  - ~~Sand alone is not effective~~
  - Sand + Coagulant
  - Sand + Perlite
  - Sand + DE
  - Fine ceramic media (e.g., Macrolite M1 Ultra)
  - Charged zeolites (e.g., Zeobrite Xtreme)
- Precoat filters (e.g., DE and perlite)
- ~~Cartridge filters~~
- ~~Membrane filters (e.g., MF, UF)~~ $$$

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## Filter Design & Operation

**Percent Microsphere Removal in 10L Batch Lab-scale Filtration Experiments after dosing 2 mg/L of cationic polymer**

| Filtration Rate ($gpm/ft^2$) | % Removal (12" Sand) | % Removal (24" Sand) |
|---|---|---|
| 15 | 90.0 | 99.0 |
| 10 | 95.0 | 99.7 |
| 7 | 97.0 | 99.8 |

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## Percent Microsphere Removal in Spa-scale Filtration Experiments with no coagulant (Control Experiments)

| Filtration Rate ($gpm/ft^2$) | % Removal (300 mm Sand) | % Removal (600 mm Sand) |
|---|---|---|
| 15 | 32.9 | -- |
| 10 | -- | 24.5 |

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## Percent Microsphere Removal in Spa-scale Filtration Experiments with Aluminum Sulfate at 0.1 mg/L as Al

| Filtration Rate (gpm/ft²) | % Removal (12" Sand) | % Removal (24" Sand) |
|---|---|---|
| 15 | 31.0 | -- |
| 10 | -- | 33.0 |

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## Percent Microsphere Removal in Spa-scale Filtration Experiments with Aluminum Sulfate at 0.1 mg/L as Al

| Time (hours) | % Removal (12" Sand) | % Removal (24" Sand) |
|---|---|---|
| 0 | -- | 33.0 |
| 24 | -- | 94.8 |
| 48 | -- | 89.8 |
| 72 | -- | 75.1 |

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## Percent Microsphere Removal in Spa-scale Filtration Experiments with Polyaluminum Chloride at 0.1 mg/L as Al

| Filtration Rate (gpm/ft²) | % Removal (300 mm Sand) | % Removal (600 mm Sand) |
|---|---|---|
| 15 | 56.0 | 99.2 |
| 10 | 92.0 | 99.7 |

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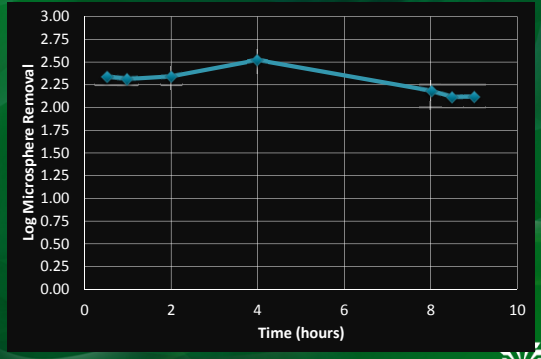
## Log Removal vs. Time (Swim Spa)




*37 m/h, 300 mm of sand, dosing 3.12 mg/L of cationic polymer UNC CHARLOTTE

## Streaming Current vs. Time (Swim Spa)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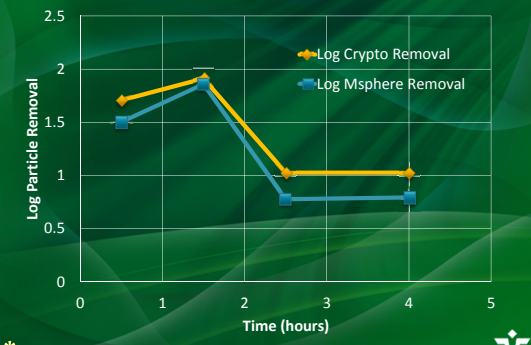
## Log Removal vs. Time (Full-Scale)




*37 m/h, 300 mm of sand, after slug dosing 3.12 mg/L of cationic polymer UNC CHARLOTTE

## Streaming Current Monitor and Controller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## Cationic Polymer Titration


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## Cost of Filtration Options

- Granular media filters (e.g., sand)
  - ~~Sand alone is not effective~~
  - Sand + Coagulant = Cost of pump + coagulant
  - Sand + Perlite = Cost of perlite
  - Sand + DE = Cost of DE
  - Charged zeolite = Cost of media and replacement
  - Ceramic media = Cost of media and replacement
- Precoat filters (e.g., DE and perlite)
  - Cost of media (and maybe new filters/installation)
- ~~Cartridge filters~~
- ~~Membrane filters (e.g., MF, UF)~~ $$$

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## Filtration Recommendations (for the future)

- Deeper sand beds (>24")
- Lower filtration rates (<10 gpm/ft$^2$)
- Coagulant feed systems (Continuous feed)
  - Cationic Polymers ("clarifier" products)
  - PolyAluminum Chloride
- Hybrid systems
  - Perlite/Sand
- Emerging Filter Media ???
  - Fine ceramic media (e.g., Macrolite M1 Ultra)
  - Charged zeolites (e.g., Zeobrite Xtreme)

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## Backwashing Recommendations

- Higher backwash flow rates (>20 gpm/ft$^2$)
- Air scour for enhanced cleaning of media
- Viewing windows to observe backwash

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## Conclusions (1 of 2)

- Polyaluminum chloride and cationic polymers can enhance the removal of *Cryptosporidium*-sized particles via swimming pool sand filters.
- Continuous coagulant feed is recommended.
- Filter depth and filtration rate have significant influences on filter performance with each coagulant.
- Either underdosing or overdosing coagulants in pools can be problematic… SCMs are used extensively in drinking water treatment practice for this purpose.

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## Conclusions (2 of 2)

- A Hybrid (sand + precoat media) filter can enhance the removal of *Cryptosporidium*
- "Bumping" precoat filters can decrease *Cryptosporidium* removal, but the removals can still be much higher than sand alone
- New medias for "sand" filters are being investigated and show some promise
- The CDC's MAHC will be a good resource on filtration information once completed (i.e., in the Annex).

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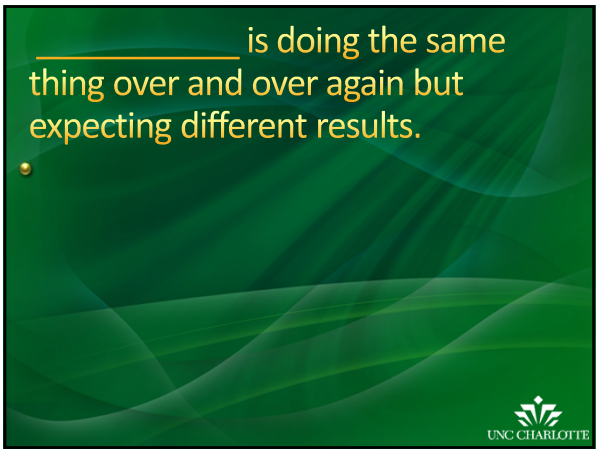
## FACTS: Sand Filters & Coagulants

- **FACT: Swimming pool sand filters without coagulants are relatively ineffective at removing pathogens and particles smaller than 5-microns.**
- **FACT: *Crypto* removal is typically only about 25% per turnover for sand filters without coagulants.**
- **FACT: Removing 25% of 100 million *Crypto* will only leave 75 million *Crypto* in the pool.**
- **FACT: The USEPA will not allow drinking water treatment plants to operate sand filters without a coagulant.**
- **FACT: After 12 years of research on removal of *Crypto* with filters, I would emphatically recommend that sand filters NOT be used for public swimming pools without additional enhancement.**

## Future Steps…

- We already have more than enough research completed to know that sand filters alone are not effective for pathogen removal.
- We need more research to tell us how to best use coagulants (or other filtration measures) in full-scale pools around the country.


_____ is doing the same thing over and over again but expecting different results.
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