Recommendations for reducing *Cryptosporidium* infection risk at swimming pools

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Objectives

- Understand why there is risk of *Cryptosporidium* infection at swimming pools
- Explore methods for reducing *Cryptosporidium* infection risk at swimming pools
- Discuss the most feasible methods for Environmental Health Specialists to reduce *Cryptosporidium* infection risk at swimming pools

Why is there risk of *Cryptosporidium* infection at swimming pools?

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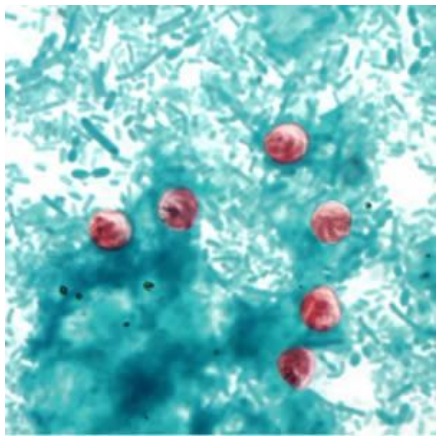
What do we know about *Cryptosporidium*?

- Cryptosporidiosis
  - Vomiting, diarrhea, nausea, death
  - Immunocompromised
    - 20% of U.S. population
    - Including children
- *Cryptosporidium* caused 50% of treated recreational water-associated outbreaks between 2011-2012
- Treated recreational water venues are ideal for *Cryptosporidium* outbreaks:
  - Oocysts highly resistant to chlorine (inactivation: 20 ppm for 12.75 hr)
  - Swimming ="community bathing"
  - Bathers can excrete 10^9 oocysts/fecal release
  - *Cryptosporidium* has low infectious dose
  - Oocyst release up to 50 days post-diarrhea cessation
  - Swimmers perceive pool water is sterile
  - Swimming pool water is recirculated



Cryptosporidium oocysts (CDC, 2013)

DuPont et al., 1995; Hlavsa et al. 2015; Hunter and Nichols, 2002; Okhuysen et al., 1999; Shields et al. 2008; Yoder and Beach, 2010

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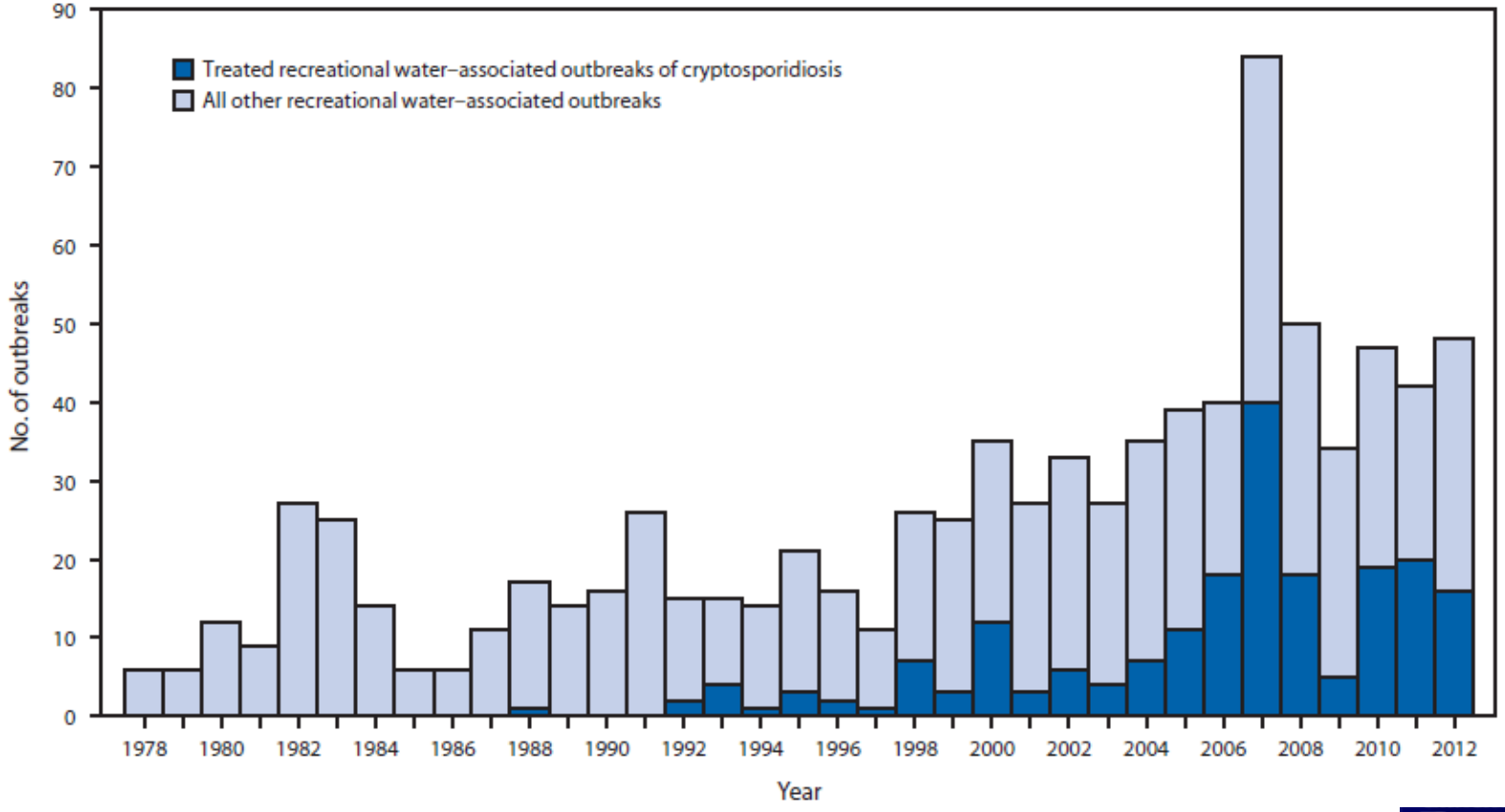
What do we know about *Cryptosporidium*?

Number of outbreaks associated with recreational water, by year - United States, 1978 - 2012



Hlavsa et al. 2015

What do we know about *Cryptosporidium*?

Per-swim and Annual Risk of *Cryptosporidium* Infection from Swimming in Treated Recreational Water

Table 3
Average, standard deviation, and 95th/99th percentile per-swim and annual *Cryptosporidium* infection risks from swimming in treated recreational water among sub-populations.

	Infection Risk Per-swim Event			Annual Infection Risk		
	Mean	SD	95th Percentile	Mean	SD	95th Percentile
All swimmers	2.6×10^{-4}	3.9×10^{-3}	$<4.5 \times 10^{-3}$ [a]	2.5×10^{-2}	6.1×10^{-2}	1.2×10^{-1}
Adults	2.5×10^{-4}	6.8×10^{-3}	$<2.3 \times 10^{-3}$ [a]	2.2×10^{-2}	6.6×10^{-2}	1.1×10^{-1}
Children	3.5×10^{-4}	5.4×10^{-3}	5.2×10^{-4}	2.9×10^{-2}	6.1×10^{-2}	1.3×10^{-1}

[a] 99th percentile risk value.

- Risk of *Cryptosporidium* infection in one year of swimming pool visits:
  - 29 infections per 1,000 child swimmers (≤18)
  - 22 infections per 1,000 adult swimmers

Suppes et al. 2016

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Methods for reducing *Cryptosporidium* infection risk

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How can we reduce *Cryptosporidium* infection risk at swimming pools?

- Treated water venues are ideal for *Cryptosporidium* outbreaks:

Oocysts highly resistant to chlorine (inactivation: 20 ppm for 12.75 hr)	→ Use alternative disinfectants
Swimming ="community bathing" Bathers can excrete 10^9 oocysts/fecal release *Cryptosporidium* has low infectious dose Oocyst release up to 50 days post-diarrhea cessation Swimmers perceive pool water is sterile	→ Stop introduction of oocysts
Swimming pool water is recirculated	→ Use more effective filtration techniques

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Use alternative disinfectants

- Current free chlorine levels recommended in the Model Aquatic Health Code (MAHC) will not inactivate *Cryptosporidium* in a timeframe that reduces swimmer risk
  - *Cryptosporidium* Ct = 15,300: It would take 10 days to achieve a 3 log reduction in oocysts at 1 ppm chlorine
- Higher levels of chlorine will inactivate *Cryptosporidium* faster
  - Hyperchlorination is recommended following a fecal incident to inactivate *Cryptosporidium*

Use alternative disinfectants

- Problems with using hyperchlorination as a method to inactivate *Cryptosporidium*:
  - Must use *a lot* of chlorine
    - Expensive
      - Chlorine product
      - Closure time (CDC guidelines: 20 ppm chlorine for 12.75 h)
  - Must maintain 20 ppm the entire 12.75 h
    - Employee overtime
    - Test kit capability and reliability
    - Operator error
  - Must know if and when fecal incident occurred
  - Hyperchlorination does not work well in pools with high cyanuric acid concentrations

Use alternative disinfectants

- Hyperchlorination and cyanuric acid:

Article

pubs.acs.org/est

Effect of Cyanuric Acid on the Inactivation of *Cryptosporidium parvum* under Hyperchlorination Conditions

Jennifer L. Murphy,*[,†] Michael J. Arrowood,[†] Xin Lu,[†] Michele C. Hlavsa,[†] Michael J. Beach,[†] and Vincent R. Hill[†]

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Use alternative disinfectants

Inactivation of *Cryptosporidium* in chlorinated pool water

	No cyanuric acid	8 ppm cyanuric acid	50 ppm cyanuric acid	100 ppm cyanuric acid (MAHC limit)
Chlorine (ppm)	20	20	20	20
pH	7.5	7.5	7.5	7.5
Temperature (°F)	77	77	77	77
Time (h)	**8**	**14**	**62 (2.5 days)**	**72 (3 days)**
Log reduction	3	3	1	0.8

Murphy et al. 2015

Use alternative disinfectants

2016 CDC fecal incident response guidelines

	No cyanuric acid	1 - 15 ppm cyanuric acid	15 + ppm cyanuric acid: **drain pool to ≤15 ppm CYA**
Chlorine (ppm)	20	20	20
pH	≤7.5	≤7.5	≤7.5
Temperature (°F)	≥77	≥77	≥77
Time (h)	12.75	28	28

CDC, 2016

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Use alternative disinfectants

Approved alternative disinfectants to chlorine in MAHC

	Pro	**Con**
Bromine	Leaves a residual	No published *Ct* values for *Cryptosporidium* inactivation
UV light	Inactivates *Cryptosporidium* quickly	No residual
Ozone	Inactivates *Cryptosporidium* quickly	No residual
Copper/silver ions	Leaves a residual	No published *Ct* values for *Cryptosporidium* inactivation
Chlorine dioxide	Inactivates *Cryptosporidium* quickly Leaves a residual	Only for water quality remediation when swimmers are absent

CDC MAHC 2nd edition 2016; Murphy et al. 2014

Stop introduction of oocysts

- Is *stopping* introduction possible? Probably not, but we can *reduce* contamination by controlling sources
  - Some controls are better than others
    - Environmental Health Hierarchy of Controls:
      - Elimination
      - Substitution
      - Administrative
      - Engineering
      - Personal Protective Equipment

Stop introduction of oocysts

- Swimming ="community bathing"
  - Separate children and adults
  - Expose the truth about swim diapers
- Bathers can excrete 10^9 oocysts/fecal release
  - Do not allow ill swimmers into the pool
  - Make better swim diapers
  - Improve fecal incident observation and reporting by swimmers, parents of swimmers and pool staff
  - Enforce bathroom breaks
- *Cryptosporidium* has low infectious dose
  - Educate swimmers on the importance of avoiding pool water ingestion
    - Do parents allow kids to drink bathtub water?
- Oocyst release up to 50 days post-diarrhea cessation
  - Do not allow previously-ill swimmers into the pool
  - Enforce pre-swim showering
- Swimmers perceive pool water is sterile
  - Educate swimmers on pool water hazards
  - Educate swimmers on test kit use

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Stop introduction of oocysts

- Elimination
- Substitution
- Administrative
- Engineering
- Personal Protective Equipment

- Elimination controls
  - Do not allow ill swimmers into the pool
  - Do not allow previously-ill swimmers into the pool
    - Signage – do not swim if you have diarrhea
    - Group education on recreational water illness – swim teams, water aerobics, swim classes
    - Waivers – open swim, fitness facility users, swim classes, swim teams, water aerobics

Stop introduction of oocysts

- Administrative controls
  - Expose the truth about swim diapers
    - Signage – swim diapers are the same as a bathing suit
    - Group education on recreational water illness – swim teams, water aerobics, swim classes
  - Educate swimmers on the importance of avoiding pool water ingestion
  - Educate swimmers on pool water hazards
    - Group education on recreational water illness – swim teams, water aerobics, swim classes
  - Educate swimmers on test kit use
    - Group education on recreational water illness – swim teams, water aerobics, swim classes
    - Require pool facilities to provide test strips and make water chemistry standards available to swimmers
  - Improve fecal incident observation and reporting by swimmers, parents of swimmers and pool staff
    - Group education on recreational water illness – swim teams, water aerobics, swim classes
    - Train lifeguards on indicators of diarrheal release
      - Indicators should be researched
  - Enforce bathroom breaks
    - Swim teams, open swim – everyone out of the pool every 30 min
  - Enforce pre-swim showering
    - Hire staff to check if swimmers entering pool area have wet hair or clothing

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Stop introduction of oocysts

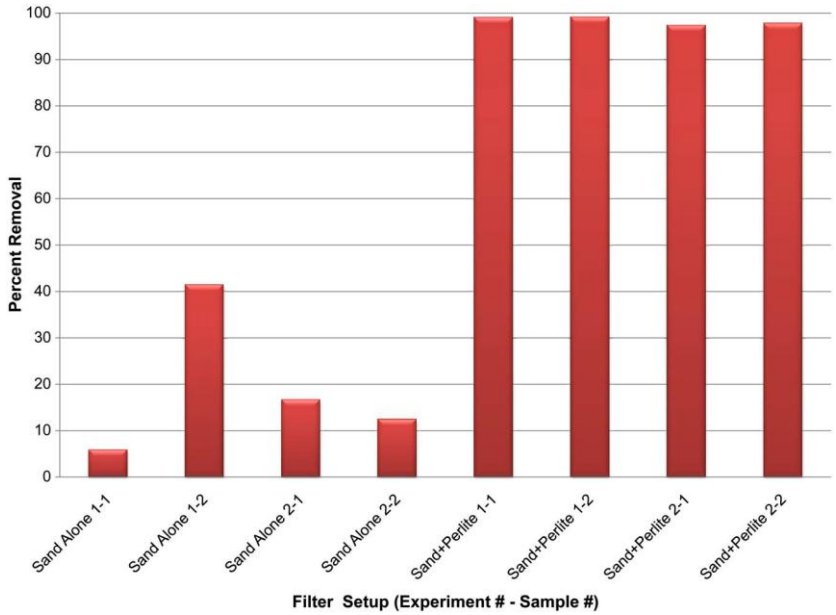
- Engineering/PPE controls
  - Separate children and adults
    - Build separate pools for adults and children
      - Perhaps easier to control *Cryptosporidium*
        - Child pool, routine treatment to remove *Cryptosporidium* from pool water
  - Make better swim diapers
    - Current swim diapers release 50 – 97% of *Cryptosporidium* oocysts into pool water within 5 min of swimming after diarrhea

Amburgey, Anderson and Brian, 2011

Use more effective filtration techniques

- Swimming pool water is recirculated
  - Use secondary disinfection (UV or ozone)
  - Maximize efficiency of the pool filter
    - Sand
      - Polyaluminum chloride coagulants at appropriate flow rates with deep sand
      - Add thin layer of precoat media

Percent particle removal for different sand filtration scenarios



Amburgey 2011

Amburgery, 2011; Amburgey et al., 2012; Lu and Amburgey, 2016; Amburgey (unpublished)

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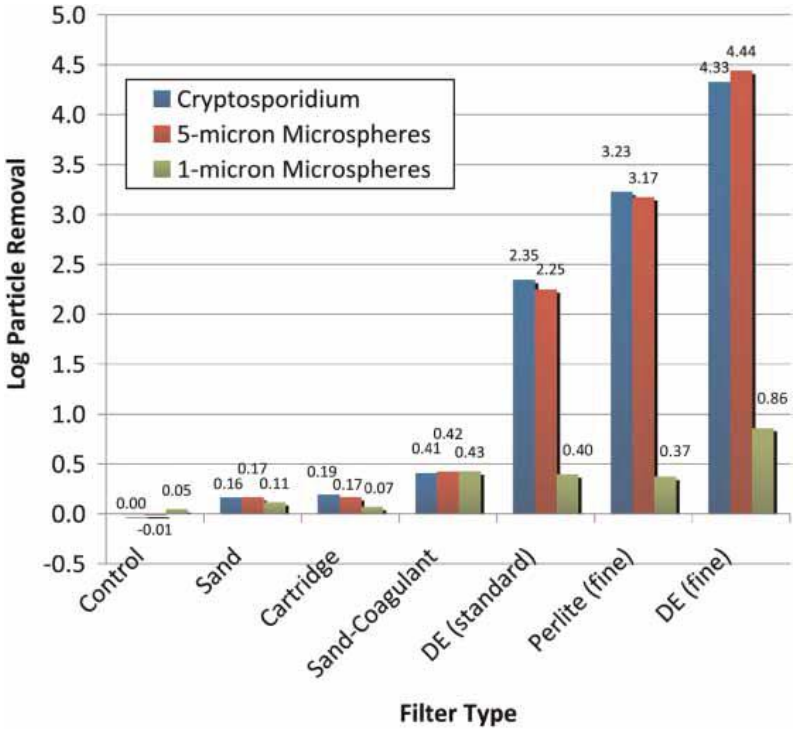
Use more effective filtration techniques

- Swimming pool water is recirculated
  - Use secondary disinfection (UV or ozone)
  - Maximize efficiency of the pool filter
    - Sand
      - Polyaluminum chloride coagulants at appropriate flow rates with deep sand
      - Add thin layer of precoat media
    - Precoat media
      - Perlite media
      - Diatomaceous Earth

Log particle removal for different filtration scenarios



Amburgey et al., 2012

Amburgery, 2011; Amburgey et al., 2012; Lu and Amburgey, 2016

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What are the most feasible methods for Environmental Health Specialists to reduce *Cryptosporidium* infection risk?

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What are the most feasible methods for reducing *Cryptosporidium* infection risk?

- A combination of controls must be used to reduce risk of *Cryptosporidium* infection:
  - Group education on recreational water illness
    - Environmental Health Specialists
      - Provide education materials (fact sheets, videos, handouts) to aquatic venues that host groups of swimmers, and encourage or require organized trainings
      - Provide trainings to groups of swimmers

What are the most feasible methods for reducing *Cryptosporidium* infection risk?

- Waivers as a form of education
  - Environmental Health Specialists
    - Provide waiver examples to aquatic facility staff
      - By swimming in this pool, you agree not to:
        - Swim until two weeks after diarrhea has stopped
        - Intentionally swallow pool water
        - Allow children with diarrhea to swim in bathing suits or swim diapers since neither control diarrheal releases
        - Intentionally pee or poop in the pool water
        - Splash other swimmers in the face (associated with pool water ingestion)
        - Enter the pool without showering for at least 60 sec. (recommended minimum pre-swim shower length)
        - Fail to report a diarrheal release into pool water

Keuten et al. 2014; Suppes et al. 2014

What are the most feasible methods for reducing *Cryptosporidium* infection risk?

- Environmental Health Specialists can also:
  - Require pool facilities provide swimmers with test strips and handouts or signage on pool water quality standards
  - Suggest implementation of mandatory breaks for open swim or swim teams every 30 min. to high-use facilities
  - Explain the purpose and importance of the new CDC Fecal Incident Response Guidelines to pool operators
    - Make sure operators understand how to respond appropriately to a diarrheal release
  - Require pool facilities install secondary disinfection
  - Suggest operators with sand filters routinely apply a coagulant
    - Operators should follow manufacturers instructions when dosing pool water with a coagulant
  - Adopt parts of the Model Aquatic Health Code when updated with recommendations for improving filtration and disinfection techniques to remove *Cryptosporidium* from pool water

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