Recommendations for reducing Cryptosporidium infection risk at swimming pools

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EH₂O Recreational Water Virtual Conference
January 18 – 19, 2017
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?
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

DuPont et al., 1995; Hlavsa et al. 2015; Hunter and Nichols, 2002; Okhuysen et al., 1999; Shields et al. 2008; Yoder and Beach, 2010
What do we know about Cryptosporidium?

Number of outbreaks associated with recreational water, by year - United States, 1978 - 2012
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 x 10^-4 | 3.9 x 10^-3 | <4.5 x 10^-3^a | 2.5 x 10^-2 | 6.1 x 10^-2 | 1.2 x 10^-1 |
| Adults                          | 2.5 x 10^-4 | 6.8 x 10^-3 | <2.3 x 10^-3^a | 2.2 x 10^-2 | 6.5 x 10^-2 | 1.1 x 10^-1 |
| Children                        | 3.5 x 10^-4 | 5.4 x 10^-3 | 5.2 x 10^-4    | 2.9 x 10^-2 | 6.1 x 10^-2 | 1.3 x 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
Methods for reducing Cryptosporidium infection risk
How can we reduce Cryptosporidium infection risk at swimming pools?

- Treated water venues are ideal for Cryptosporidium outbreaks:
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- Use alternative disinfectants
- Stop introduction of oocysts
- Use more effective filtration techniques
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* $C_t = 15,300$: 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:

*Environmental Science & Technology*

*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†

†Waterborne Disease Prevention Branch, Division of Foodborne, Waterborne, and Environmental Diseases, Centers for Disease Control and Prevention, Atlanta, Georgia 30333, United States
Use alternative disinfectants

Inactivation of *Cryptosporidium* in chlorinated pool water

<table>
<thead>
<tr>
<th></th>
<th>No cyanuric acid</th>
<th>8 ppm cyanuric acid</th>
<th>50 ppm cyanuric acid</th>
<th>100 ppm cyanuric acid (MAHC limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine (ppm)</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>pH</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>77</td>
<td>77</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>Time (h)</td>
<td>8</td>
<td>14</td>
<td>62 (2.5 days)</td>
<td>72 (3 days)</td>
</tr>
<tr>
<td>Log reduction</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Murphy et al. 2015
Use alternative disinfectants

2016 CDC fecal incident response guidelines

<table>
<thead>
<tr>
<th></th>
<th>No cyanuric acid</th>
<th>1 - 15 ppm cyanuric acid</th>
<th>15 + ppm cyanuric acid: drain pool to ≤15 ppm CYA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine (ppm)</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>pH</td>
<td>≤7.5</td>
<td>≤7.5</td>
<td>≤7.5</td>
</tr>
<tr>
<td>Temperature (°F)</td>
<td>≥77</td>
<td>≥77</td>
<td>≥77</td>
</tr>
<tr>
<td>Time (h)</td>
<td>12.75</td>
<td>28</td>
<td>28</td>
</tr>
</tbody>
</table>
Use alternative disinfectants

Approved alternative disinfectants to chlorine in MAHC

<table>
<thead>
<tr>
<th></th>
<th>Pro</th>
<th>Con</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine</td>
<td>Leaves a residual</td>
<td>No published Ct values for Cryptosporidium inactivation</td>
</tr>
<tr>
<td>UV light</td>
<td>Inactivates Cryptosporidium quickly</td>
<td>No residual</td>
</tr>
<tr>
<td>Ozone</td>
<td>Inactivates Cryptosporidium quickly</td>
<td>No residual</td>
</tr>
<tr>
<td>Copper/silver ions</td>
<td>Leaves a residual</td>
<td>No published Ct values for Cryptosporidium inactivation</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td>Inactivates Cryptosporidium quickly</td>
<td>Only for water quality remediation when swimmers are absent</td>
</tr>
</tbody>
</table>
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
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
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

Amburgey, 2011; Amburgey et al., 2012; Lu and Amburgey, 2016; Amburgey (unpublished)
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; Amburgey et al., 2012; Lu and Amburgey, 2016
What are the most feasible methods for Environmental Health Specialists to reduce *Cryptosporidium* infection risk?
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


