Source, Fate, and Transport of Cryptosporidium in the Red River Watershed

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Content

- Background
- *Cryptosporidium* adsorption onto natural soil
- *Cryptosporidium* transport under rainfall and snowmelt conditions
- *Cryptosporidium* transport under storm events
Background – *General*

- A waterborne protozoan
- Cryptosporidiosis
  - An infectious diarrheal disease in humans and agricultural animals
  - Life-threatening for immuno-compromised individuals
Background – Epidemiology

Outbreaks

44 (1988)

45 (2007)

12 (2006)

225 (2000)

56 (2006)

700 (2000)

370,000 (1993)

20 (1996)

123 (2006)

77 (1995)

8000 (2007)
Background - characteristics

• **Shape and Size**
  – Spherical shaped biological colloid
  – Diameter in the range of 4-6 μm

• **Charge**
  – Neutral to negative charge (-30 mV)

• **Density**
  – Heavier than water - 1.025-1.070 g/cm³

• **Transport**
  – Preferential flow of water
  – Straining, physiochemical filtration and adsorption
Background - *species*

- **C. hominis**
  - Humans
- **C. parvum**
  - Humans, cattle and ruminants
- **C. andersoni**
  - Cattle
- **C. bovis**
  - Cattle and deer
- **C. suis**
  - Pig
Background - *routes*

- Manure application
- Transportation routes
  - Overland flow
  - Infiltration = Percolation + Interflow
Cryptosporidium adsorption onto natural soil
Methodology - soil sampling

- Two different locations in North Dakota
- Air-dried, crushed, and passed through a 2-mm sieve
- No background Cryptosporidium in soil

Embden, North Dakota
- Loam soil - 52% sand, 36% silt, & 12% clay

Fairmount, North Dakota
- Clayey soil - 95% clay
Results - *manure*

- **Without manure**
  - Rocky sand - 61.7%
  - Loam soil - 96.8%
  - Clayey soil - 97.9%

- **With manure**
  - Rocky sand – 91.3-93.0%
Key findings

1. Oocysts adsorb on soil
2. High adsorption to loam and clay
3. Manure
   - Manure can increase adsorption of oocysts to the soil, which can prevent oocysts from contaminating the groundwater
Cryptosporidium transport under rainfall and snowmelt conditions
Precipitation contributes to *Cryptosporidium* transport by a number of pathways, including infiltration, overland flow, and sub-surface drainage. The objective of this study was to investigate the effect of simulated rainfall and snowmelt conditions on *Cryptosporidium parvum* transport.
Transport experiment

- Soil box with a surface area of 172 cm$^2$.
- Chloride tracer or *C. parvum* was applied to the surface of a saturated soil box.
- A rainfall intensity of 2.5 cm/h for 1 h duration was simulated using a syringe pump. This was selected to represent 1 year rainfall event for Fargo, North Dakota, USA.
- To simulate snowmelt, the saturated soil box was kept at -20°C for 24 h, after which 200 g/ of ice (~116 ml of water, 150 to 200 minute melting time) was applied.
Flow conditions

Simulated rainfall

Simulated snowmelt
Flow regimes

- Subsurface drain
- Subsurface outlet
- Surface runoff
- Infiltration
Data show that a simulated 1 year rainfall event and snowmelt event (200 g of ice) were insufficient to completely remove *C. parvum* from the drainage and the surface runoff.

The numbers of *C. parvum* in the effluent varied from 50% to 90% of the influent (snowmelt, subsurface drain and surface runoff).
Cryptosporidium transport during storm events
Background – *The Red River*

- **The Red River of the North watershed**
  - 40,000 mi²
  - Northeast corner of South Dakota and major parts of North Dakota and Minnesota
- **At Fargo the river**
  - Drains an area of 6800 mi²
  - Is the major source of drinking water for North Dakota’s biggest city, Fargo
Background – Fargo

• Flood stage is above 18 ft
  – 2009 - 40.9 ft
  – 2010 - 36.9 ft
  – Heavy precipitation following a rapid thaw

• During flood events
  – *Cryptosporidium* can migrate faster and further
  – Keeping track of pathogens under storm events can help in understanding epidemiological existence of waterborne illnesses.
  – 2001 flood in Midwest – Increased gastrointestinal symptoms (Wade et al. 2004)
Sampling

- Sample Collections
  - 30 samples (10-15 L) during crests of 2009/2010

Sampling locations

<table>
<thead>
<tr>
<th>Sampling locations</th>
<th>Assigned letters</th>
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</thead>
<tbody>
<tr>
<td>Red at Wall St. Avenue Bridge Crossing</td>
<td>A</td>
</tr>
<tr>
<td>Rush at County Road 11 crossing</td>
<td>B</td>
</tr>
<tr>
<td>Maple at County Road 11 crossing</td>
<td>C</td>
</tr>
<tr>
<td>Sheyenne Diversion at 52nd Ave, West Fargo</td>
<td>D</td>
</tr>
<tr>
<td>Overflow flow at Oakport Township, Clay County, Minnesota</td>
<td>E</td>
</tr>
<tr>
<td>Wild Rice at I-29 crossing</td>
<td>F</td>
</tr>
<tr>
<td>Buffalo River</td>
<td>G</td>
</tr>
</tbody>
</table>

Graph showing daily gage heights with marked dates:
- 4/2, 4/3
- 4/19, 4/21
- 4/5, 4/6, 4/7

Dates and gage heights correspond to the sampling locations.
Key findings

1. Positive samples
   - 2009 - 69%
   - 2010 - 88%

2. Cryptosporidium andersoni
   - 2009 - 78%

3. Major source of contamination during the flooding event
   - Cattle

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2010</th>
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<tbody>
<tr>
<td>Positive samples (PS)/Total samples</td>
<td>9/13</td>
<td>15/17</td>
</tr>
<tr>
<td>C. andersoni/PS</td>
<td>7/9</td>
<td>3/15</td>
</tr>
<tr>
<td>C. suis/PS</td>
<td>1/9</td>
<td>0/15</td>
</tr>
<tr>
<td>Deer mouse geneotype III/PS</td>
<td>1/9</td>
<td>0/15</td>
</tr>
<tr>
<td>W12 genotype/PS</td>
<td>0/9</td>
<td>1/15</td>
</tr>
<tr>
<td>Novel genotype/PS</td>
<td>0/9</td>
<td>1/15</td>
</tr>
<tr>
<td>Not characterized/PS</td>
<td>0/9</td>
<td>10/15</td>
</tr>
</tbody>
</table>
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Questions?

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