Watershed Monitoring to Prevent Transmission of Waterborne Disease

Kristen Jellison, Ph.D.
Department of Civil and Environmental Engineering
Lehigh University, Bethlehem, PA USA

National Primary Drinking Water Regulations

Contaminant	MCL or TT (mg/L)	Potential health effects from long-term exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal (mg/L)
Turbidity	TT	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration	Soil runoff	n/a
Uranium				
Vinyl chloride				
Viruses (enteric)				
Xylenes (total)				

LEGEND
D Disinfectant
DBP Disinfection By

National Secondary Drinking Water Regulation

National Secondary Drinking Water Regulations are non-enforceable guidelines regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, some states may choose to adopt them as enforceable standards.

Contaminant	Secondary Maximum Contaminant Level
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

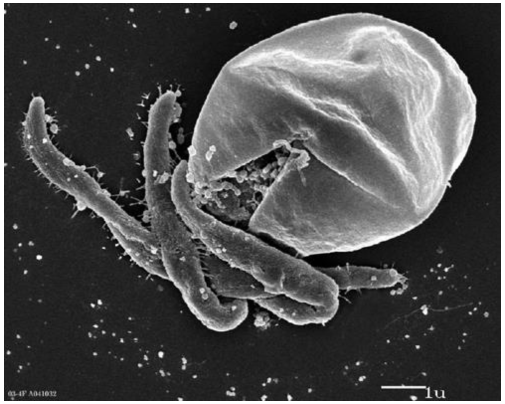
For More Information

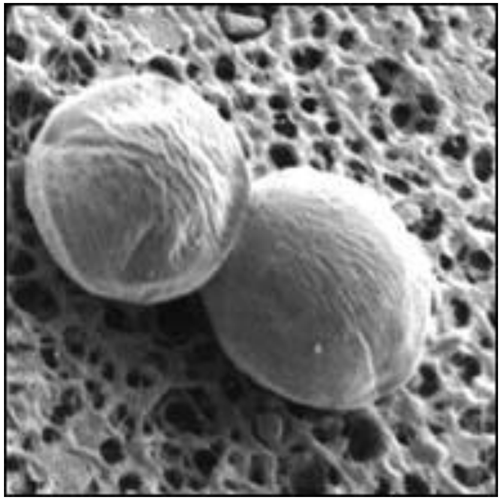
EPA's Safe Drinking Water Web site:
http://www.epa.gov/safewater/

EPA's Safe Drinking Water Hotline:
(800) 426-4791

To order additional posters or other ground water and drinking water publications, please contact the National Service Center for Environmental Publications at:
(800) 490-9198, or
email: nscep@bps-lmit.com

Cryptosporidium spp.





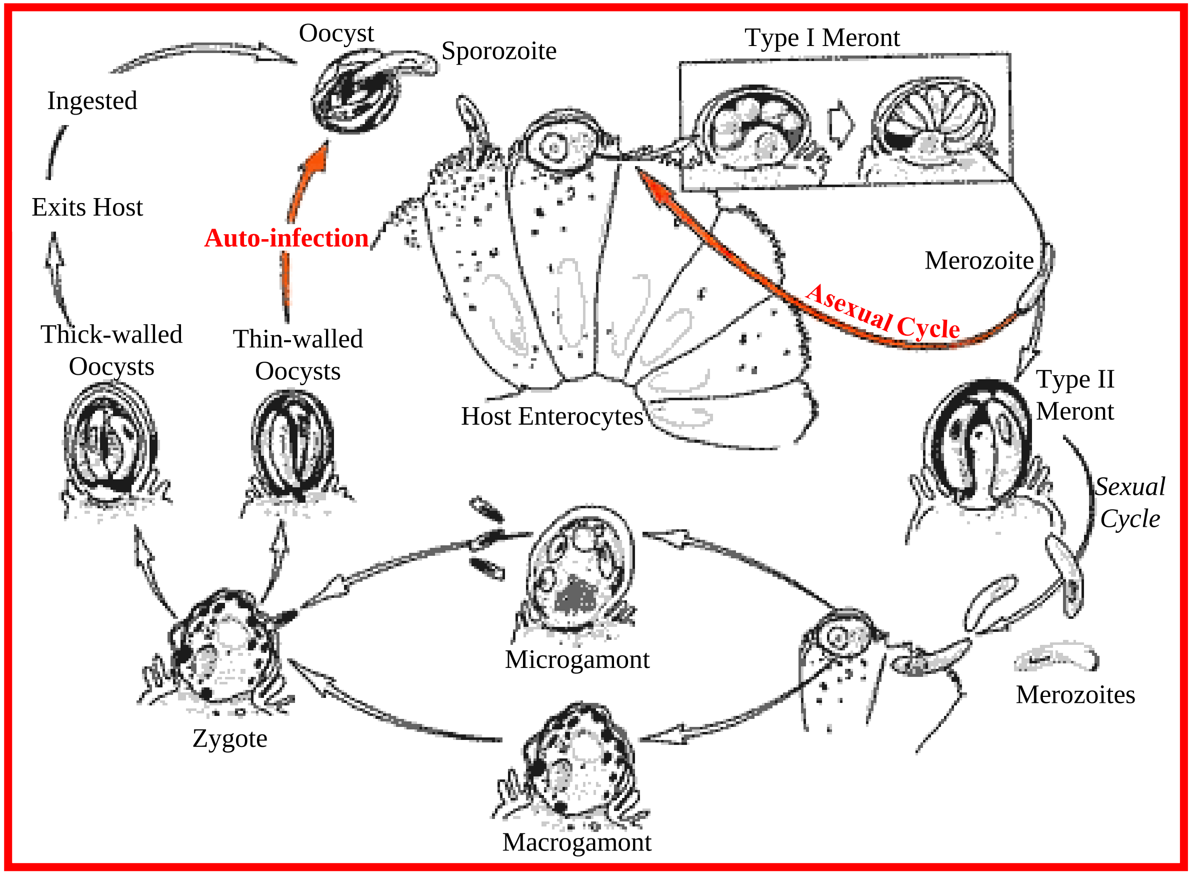
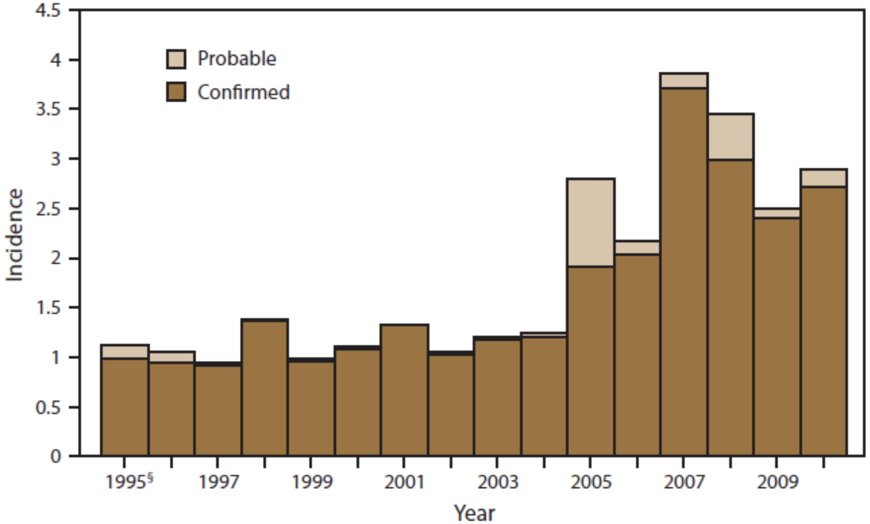


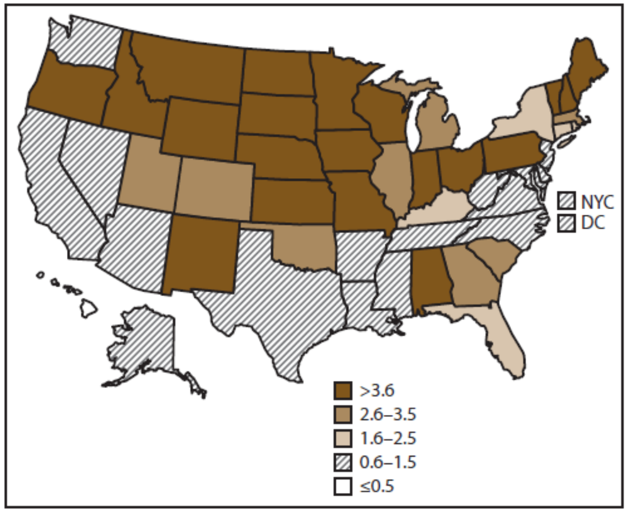
Image Credits: http://www.hominis.mic.vcu.edu/Cparvum_sporozoites.html; http://www.esemag.com/archive/0199/crypto.htm; Current & Blagburn, 1990

National Notifiable Diseases Surveillance System, United States

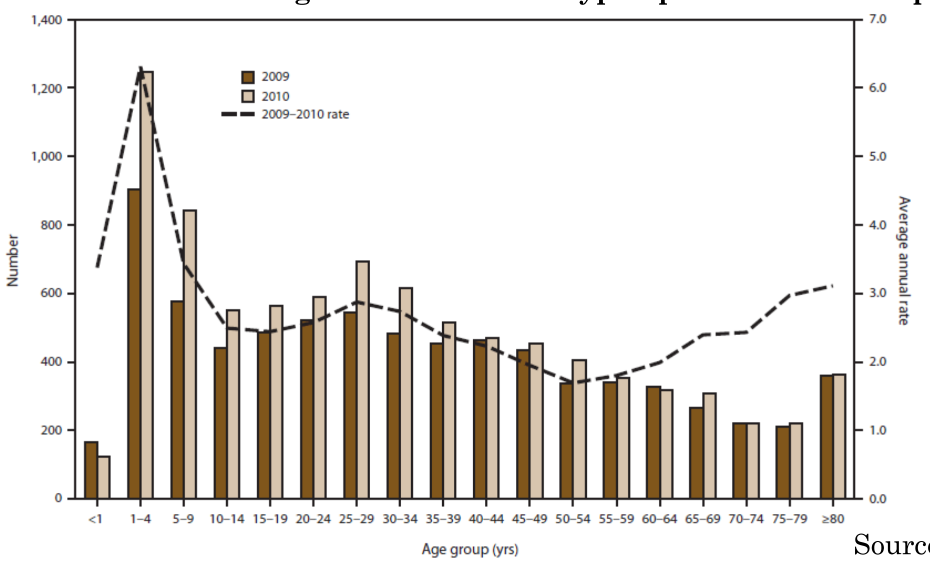
Incidence (per 100,000 population) of cryptosporidiosis



Incidence (per 100,000 population) of cryptosporidiosis, 2010

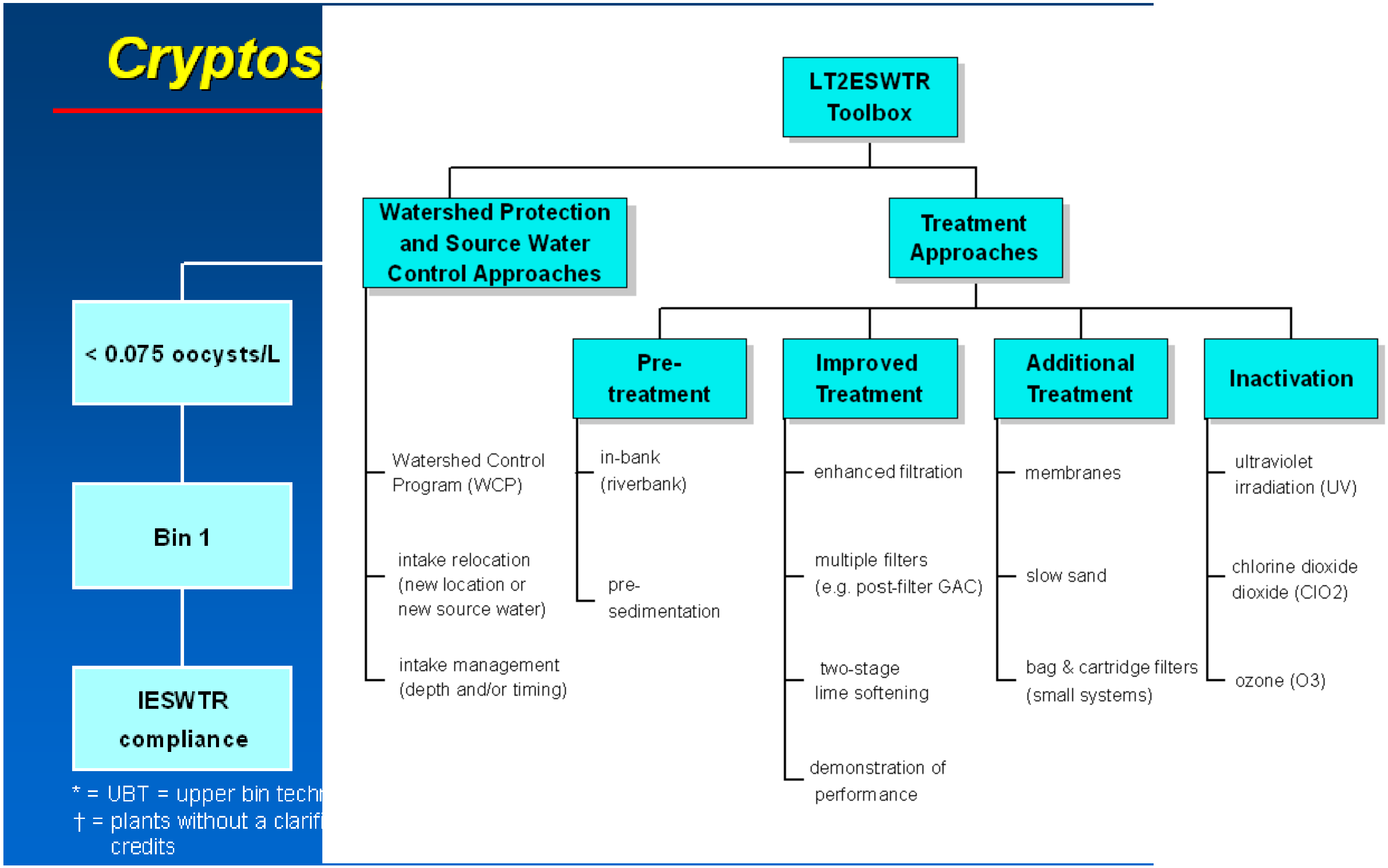


Number and average annual rate of cryptosporidiosis case reports, 2009–2010



Source: http://www.cdc.gov/mmwr/preview/mmwrhtml/ss6105a1.htm

U.S. Environmental Protection Agency LT2ESWTR



Source: http://www.eetinc.com/awwarf/

U.S. EPA Method 1623.1

<u>Limitations</u>

- 10 L sample
- "Snapshot" in time
- Variable recoveries
  - Seeded tap water: 23.5-71.2%
  - Raw source water: 9.5-54.5%

  (McCuin & Clancy 2003)
- Expensive

1. Filtration

↓

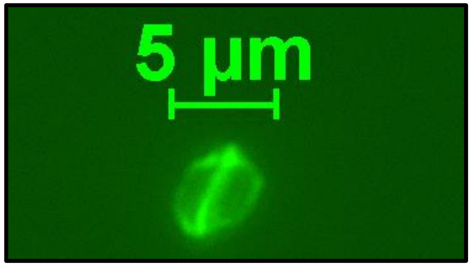
2. Elution

↓

3. Immunomagnetic Separation (IMS)

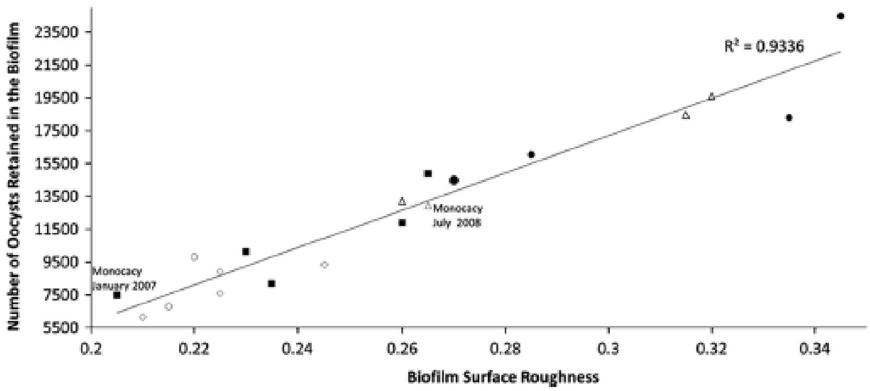
↓

4. Immunofluorescent Assay (IFA)



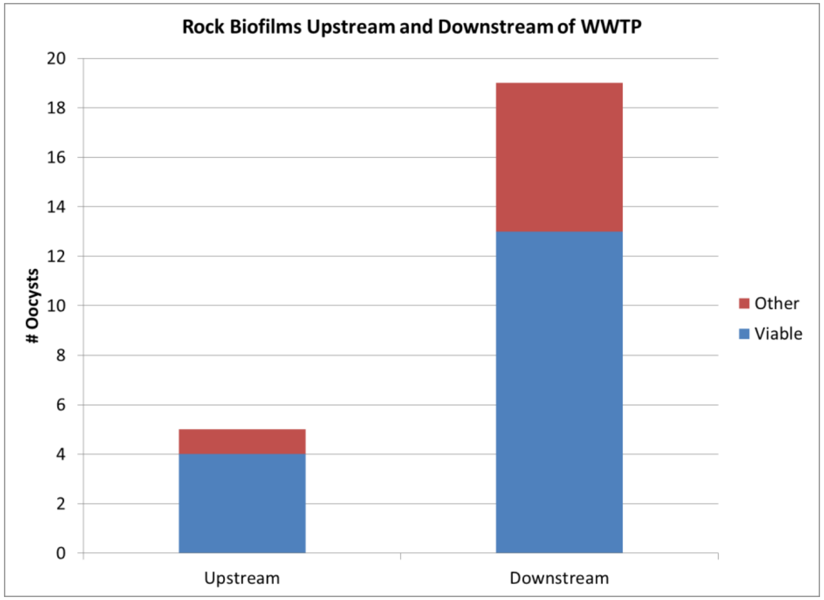
Biofilms

- *C. parvum* attaches to (and persists in) biofilms (Helmi et al. 2008; Howe et al. 2002; Rogers & Keevil 1995; Searcy et al. 2006; Wolyniak-DiCesare et al. 2012; Wolyniak et al. 2009; Wolyniak et al. 2010)
- Some fraction of oocysts remain attached even after oocysts are removed from feed (Wolyniak et al. 2009; Wolyniak et al. 2010)
- Retention of attached oocysts correlates strongly with biofilm roughness (Wolyniak-DiCesare et al. 2012)



Biofilms

- Biofilms sampled from benthic rocks collected upstream and downstream of a WWTP



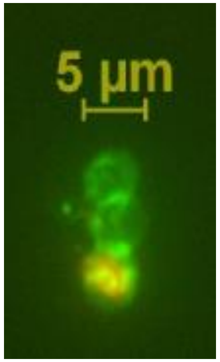
Rocks Scraped (6 up/6 down)

↓

IMS

↓

IFA/FISH

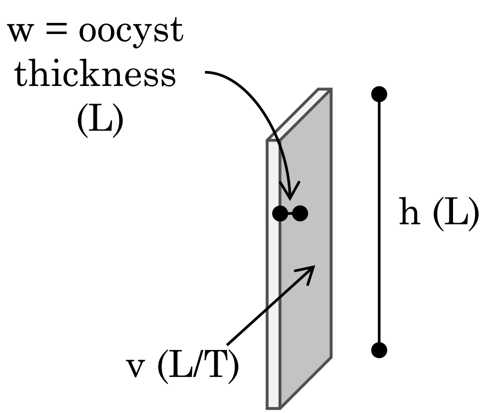


<u>Viable</u> = viable *C. parvum* or *C. hominis*

<u>Other</u> = nonviable *C. parvum* or *C. hominis* OR viable/nonviable other *Cryptosporidium* species

Biofilm Sampler

- Monitor stream quality over time
- Inexpensive
- Quantitative data is attainable given stream velocity (and attachment efficiency, K_A)



t = duration of time deployed

n = number of slide surfaces

$$\text{Oocyst concentration} = \sum_{i=1}^{n} \frac{\#\ oocysts\ counted \cdot K_A}{v \cdot h \cdot w \cdot t}$$

Sampling Results 2013-2014

WTP (July 2013-August 2014)

Slides
$\bar{x}$=14.7 d
s.d. 2.9 d
range: 10-24 d
n=28

Slides → Scraped → IMS → FISH/IFA ⇢

36% positive (10/28)
0-8 oocysts
None viable

Filters
$\bar{x}$=85.1 L
s.d. 30.3 L
range: 21-142 L
n=28

Filters → Eluted → IMS → FISH/IFA ⇢

32% positive (9/28)
0-3 oocysts
None viable

Stream (October 2013-August 2014)

Slides
$\bar{x}$=15.1 d
s.d. 3.4 d
range: 10-24 d
n=19

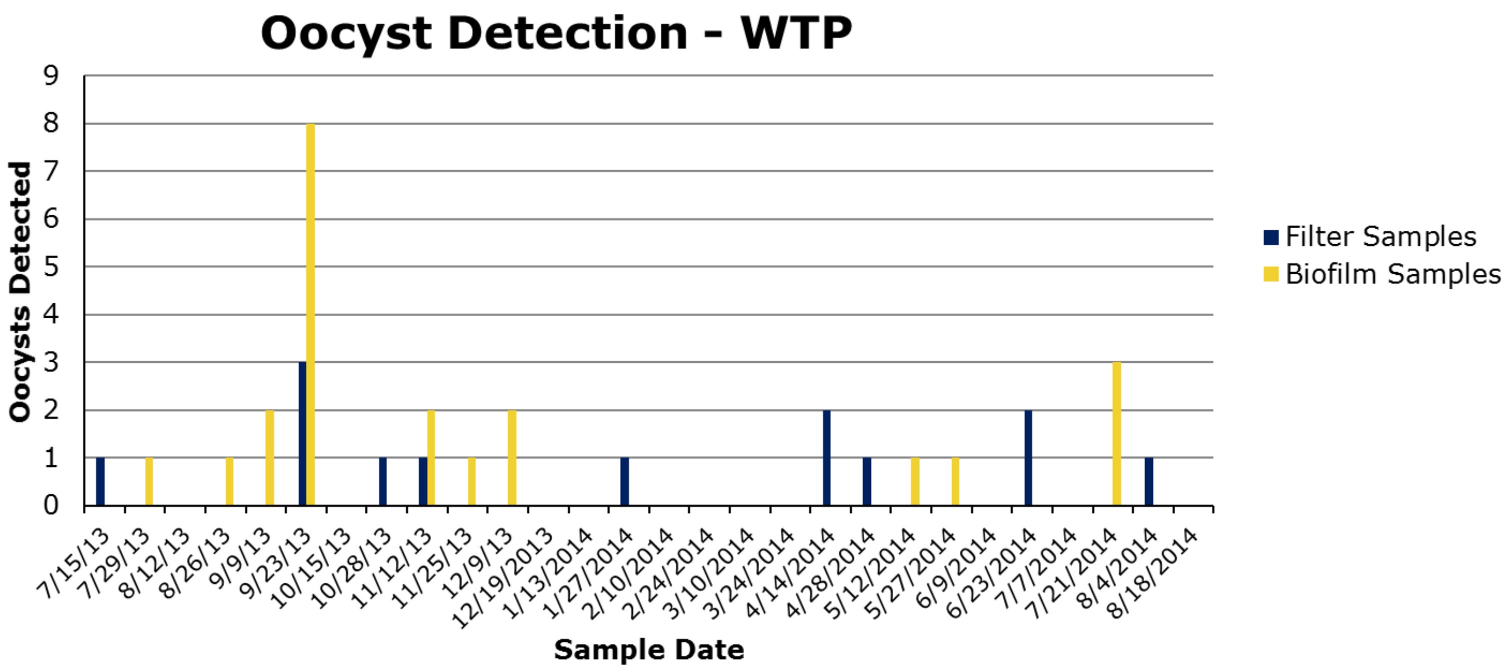
Slides → Scraped → IMS → FISH/IFA ⇢

53% positive (10/19)
0-3 oocysts
None viable

Filters
$\bar{x}$=75.4 L
s.d. 32.0 L
range: 22-133 L
n=22

Filters → Eluted → IMS → FISH/IFA ⇢

45% positive (10/22)
0-4 oocysts
None viable


Oocyst Detection - WTP
Oocysts Detected
Sample Date
Filter Samples
Biofilm Samples
7/15/13
7/29/13
8/12/13
8/26/13
9/9/13
9/23/13
10/15/13
10/28/13
11/12/13
11/25/13
12/9/13
12/19/2013
1/13/2014
1/27/2014
2/10/2014
2/24/2014
3/10/2014
3/24/2014
4/14/2014
4/28/2014
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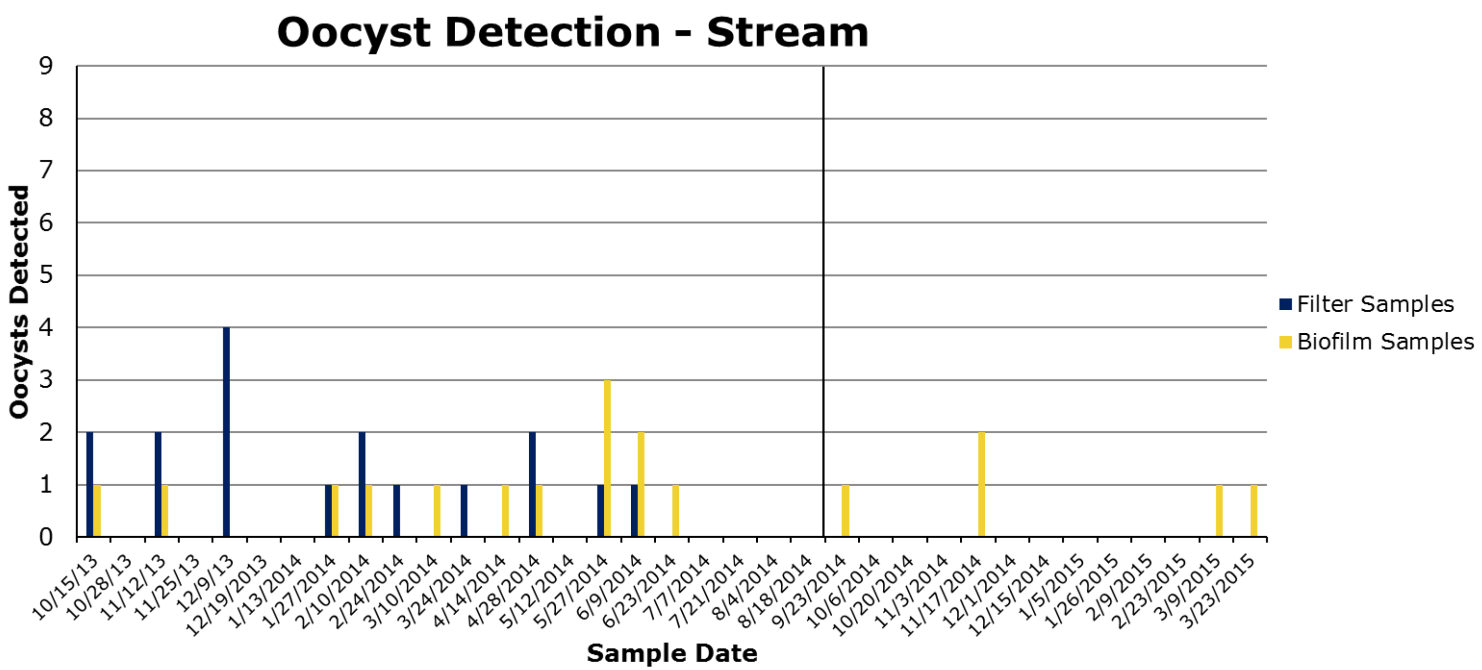
7/21/2014
8/4/2014
8/18/2014


Oocyst Detection - Stream
Oocysts Detected
Sample Date
Filter Samples
Biofilm Samples
10/15/13
10/28/13
11/12/13
11/25/13
12/9/13
12/19/2013
1/13/2014
1/27/2014
2/10/2014
2/24/2014
3/10/2014
3/24/2014
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11/3/2014
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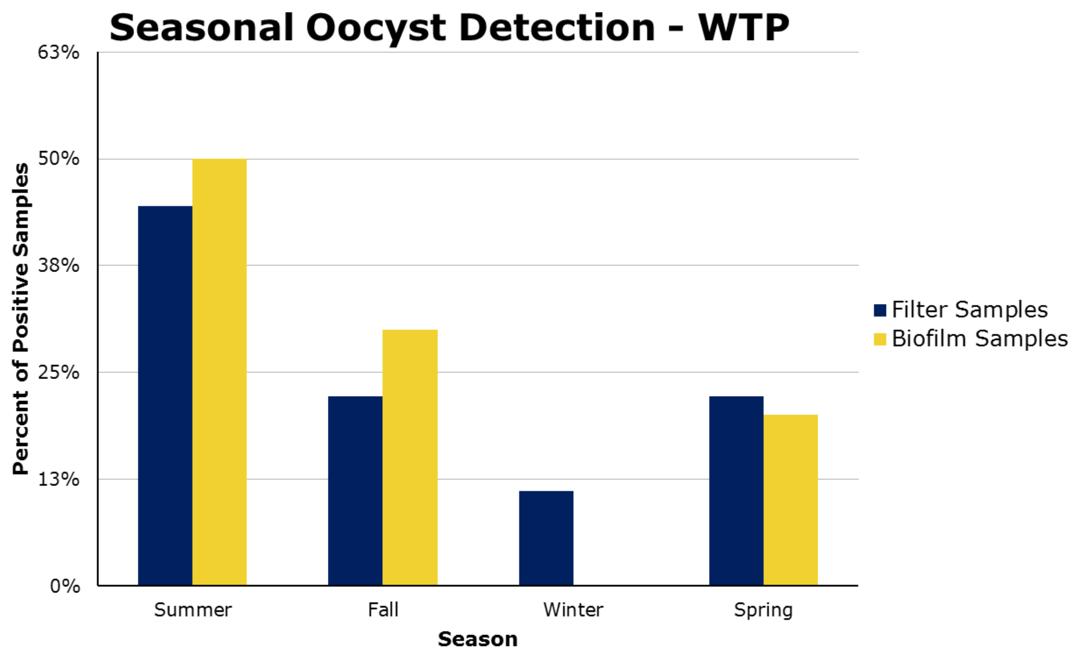
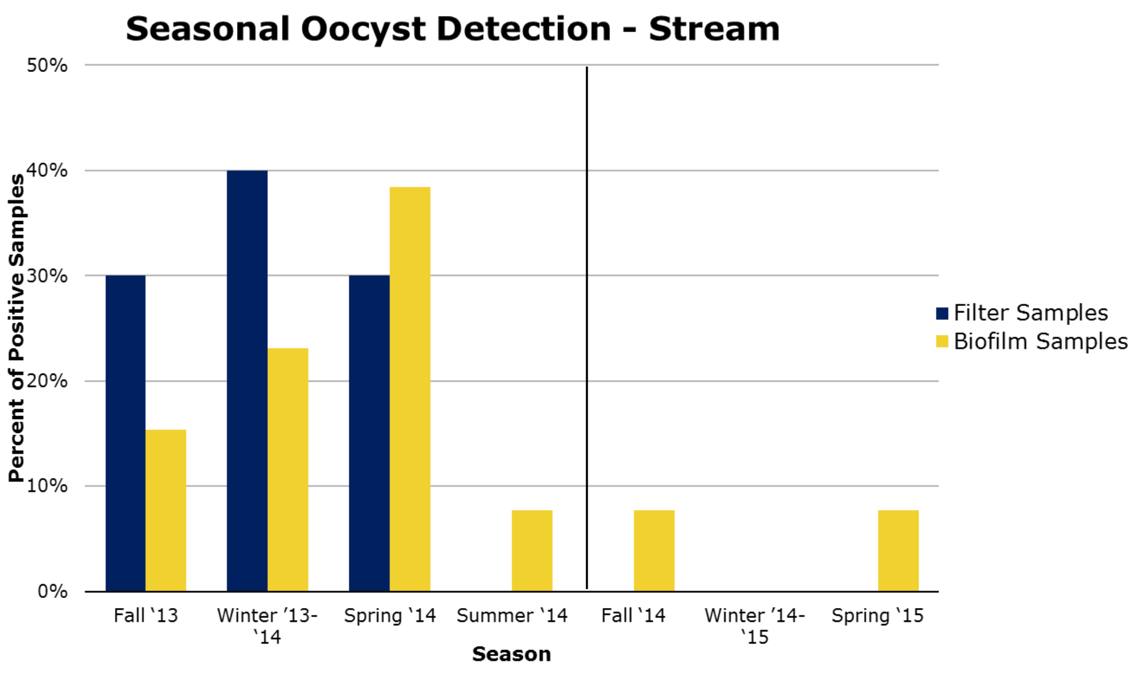
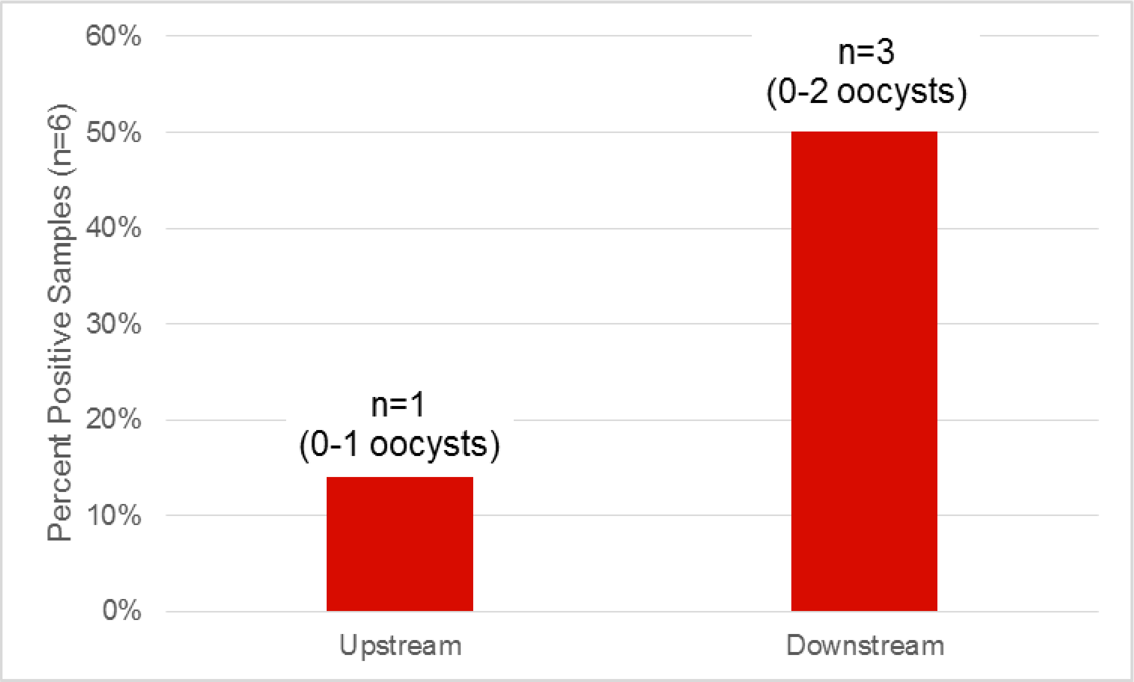
3/9/2015
3/23/2015


Seasonal Oocyst Detection - WTP
63%
50%
38%
25%
13%
0%
Percent of Positive Samples
Summer
Fall
Winter
Spring
Season
Filter Samples
Biofilm Samples


Seasonal Oocyst Detection - Stream
50%
40%
30%
20%
10%
0%
Percent of Positive Samples
Fall '13
Winter '13-'14
Spring '14
Summer '14
Fall '14
Winter '14-'15
Spring '15
Season
Filter Samples
Biofilm Samples

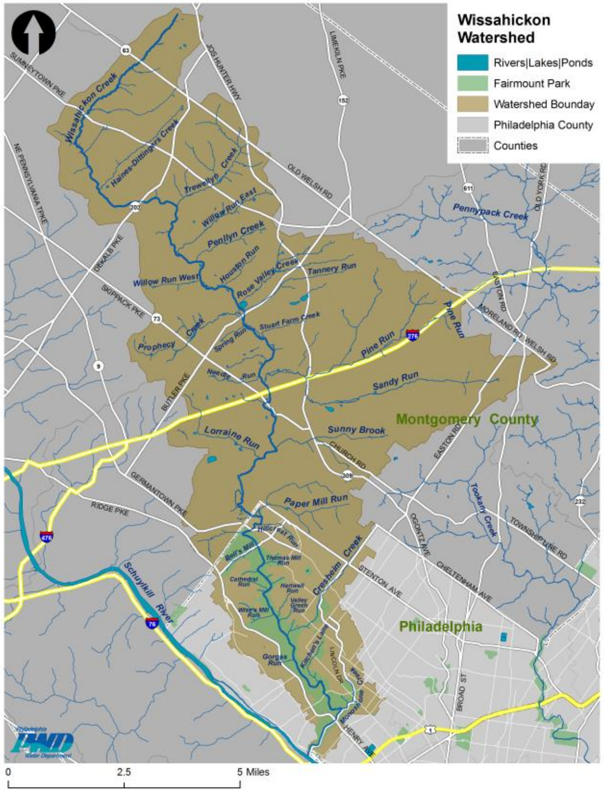
Benthic Rock Biofilms

- Biofilms sampled from benthic rocks collected upstream and downstream of a defective sewer lateral (October 2014-March 2015)



Conclusions

- Benthic rock biofilm sampling may identify point sources of oocysts along the length of a waterway
  - May provide historic look at water quality conditions
- Oocyst detection in slide biofilms is comparable to oocyst detection in filtered water samples
  - Frequency, oocyst numbers



Long-term Significance

- Biofilm monitoring is much less expensive than filtration
  - Filters \$120 each; Slides \$3 per set; Rocks \$0

    For a utility monitoring 3 WTP intakes, 2x/month:

$$filters\text{:}\frac{2\ sample\ dates}{month}\cdot\frac{3\ locations}{sample\ date}\cdot\frac{filter}{location}\cdot\frac{\$120}{filter}\cdot\frac{12\ months}{year}=\$\mathbf{8,640\ \textit{per year}}$$

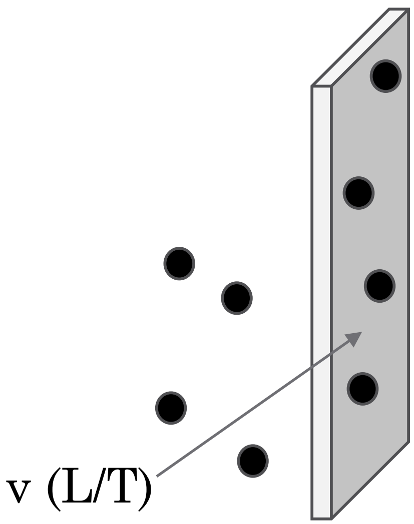
$$slides\text{:}\frac{2\ sample\ dates}{month}\cdot\frac{3\ locations}{sample\ date}\cdot\frac{slide\ set}{location}\cdot\frac{\$3}{slide\ set}\cdot\frac{12\ months}{year}=\$\mathbf{216\ \textit{per year}}$$

$$rocks\text{:}\ \$\mathbf{0\ \textit{per year}}$$

  - Biofilm monitoring could permit more frequent monitoring at more locations in a watershed; may be used to identify oocyst point sources

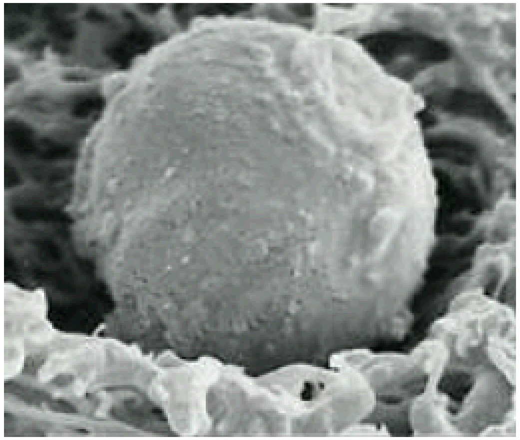
Limitations

- Determination of oocyst concentration depends on **stream velocity** at biofilm surface, **time** of slide deployment, and oocyst **attachment efficiency**
- Oocyst attachment efficiency may not be constant
  - Variability in biofilm composition and architecture in different streams and at different times of year

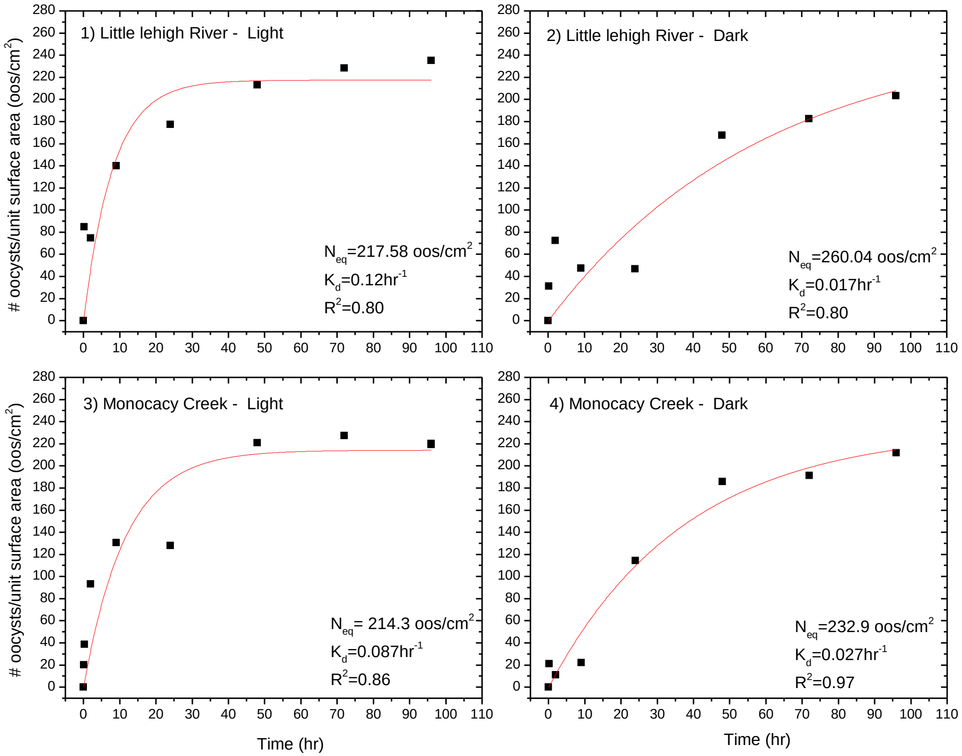


Ongoing Interdisciplinary Work

- Characterization of biofilm surfaces at sites of oocyst attachment
  - Scanning electron microscopy, atomic force microscopy, x-ray photoelectron spectroscopy
  - Modeling oocyst attachment/detachment kinetics



http://www.marvistavet.com/assets/images/single_cryptosporidium_oocyst.gif



Ongoing Interdisciplinary Work

- Development of a biomimetic surface for standardized oocyst detection
  - Antimicrobial (prevent biofilm formation)
  - Inexpensive (sell for <$5)
  - Constant oocyst attachment efficiency over 3-day deployment

- Similar approach could be taken for monitoring other waterborne pathogens

Acknowledgements

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Contact Information

Kristen Jellison, kjellison@lehigh.edu, 610-758-3555