Cryptosporidium & Giardia Removal in Small Systems

Assessment Procedures & Performance

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OBJECTIVES

- Crypto & Giardia...universal presence
- Summary of data on C & G in Europe
- Measuring treatment performance
- C & G in alternative treatment systems
Crypto & Giardia Global Summary
FACTORS AFFECTING FILTER PERFORMANCE

- Water Quality: turb; DOC; part. no. & type
- Chem. Coag: Chem(Fe;Al); Coag/Filt. aids
- Flocculation -> (Settling)
- Filter Design: media size/profile; media comp.; media depth
- Filter Operation: flow/loading (6->30 m/hr); flowrate contr; term. criteria; backwashing
Overall Physical Removal? (...%; or logs)

Performance of Treatment Components?

Effect on Performance of Differences in:
- design features? (eg. different media size)
- operating features? (eg. different loading rates)
- water quality features? (eg. high vs low turb.)

Note: All questions require statistical ans.
WATER TREATMENT QUESTIONS...CONT.

- Statistical Analysis--Resolve the difference between two measurements...eg. “t” tests
- Ability to Resolve Differences Depends on:
  - Precision (reproducibility) of the assay
  - Number of replicates for each condition
  - Variability in underlying processes
- At Best...Can Resolve Differences ca. 0.2 to 0.5 logs using n=3 (three replicate meas.)
DESIGN OF PERFORMANCE EVALUATION STUDIES

- Organisms (seed): $10^8-10^9$ for most runs
  - Organism condition is important
- Application of Seed
- Sampling: locations; volumes; time; control
- Analysis: control (quality); replication (method precision); nonzero results, minimum relative error
- Full-scale plant performance
TREATMENT PERFORMANCE EVALUATION

\[ C_2 = 0.1C_1 \]
\[ C_3 = 0.001C_1 \]
\[ Q_b = 0.05Q_1 \]
\[ C_5 = 0.1C_4 \]
TREATMENT PERFORMANCE
MEASUREMENTS

\[ Q, C_1 \]
\[ Q_b, C_4 \]
\[ Q_3, C_3 \]
\[ C_1 = 0.23 / L \]
\[ C_{1B} = 0.235 / L \]
\[ C_3 = 0.0005 / L \]
\[ C_4 = 4.9 / L \]
\[ C_5 = 0.37 / L \]
Treatment System Types

- Slow Sand Filtration
- Pressure Filtration-Automatic Backwash
- Package Complete Rapid Sand Filtration
- Complete Rapid Sand Filtration
- Direct Filtration
- In-line Filtration
- Diatomaceous Earth Filtration
## Treatment Facilities Included

<table>
<thead>
<tr>
<th>Location</th>
<th>Filtration Type</th>
<th>Capacity mgd</th>
<th>Seed Organism</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Mi. House, B.C. Canada</td>
<td>Slow sand</td>
<td>1</td>
<td>+</td>
<td>1</td>
</tr>
<tr>
<td>Northern Idaho, USA</td>
<td>Slow sand</td>
<td>0.07-0.29</td>
<td>+</td>
<td>2</td>
</tr>
<tr>
<td>Darrington, WA, USA</td>
<td>Package, direct</td>
<td>0.57</td>
<td>+</td>
<td>3</td>
</tr>
<tr>
<td>Grey Eagle CA, USA</td>
<td>Pressure, auto</td>
<td>4.0</td>
<td>+</td>
<td>3</td>
</tr>
<tr>
<td>Huntington UT, USA</td>
<td>Complete &amp; direct</td>
<td>0.9</td>
<td>+</td>
<td>4</td>
</tr>
<tr>
<td>Seattle WA, USA</td>
<td>Complete &amp; direct, pilot</td>
<td>1 (gpm)</td>
<td>+</td>
<td>5</td>
</tr>
<tr>
<td>Orchard Hills, NSW, Aust.</td>
<td>Complete conventional</td>
<td>15</td>
<td>+</td>
<td>6</td>
</tr>
<tr>
<td>Wellington NSW, Aust.</td>
<td>Complete conventional</td>
<td>5</td>
<td>+</td>
<td>U1*</td>
</tr>
<tr>
<td>Guerie NSW, Australia</td>
<td>Complete conventional, auto</td>
<td>0.2</td>
<td>+</td>
<td>U1*</td>
</tr>
<tr>
<td>Macarthur, NSW, Aust.</td>
<td>Direct, pilot</td>
<td>19.6</td>
<td>+</td>
<td>U2*</td>
</tr>
<tr>
<td>E. Gippsland, VIC, Aust.</td>
<td>Complete conventional</td>
<td>4</td>
<td>+</td>
<td>U3*</td>
</tr>
<tr>
<td>Crystal Mtn, WA, USA</td>
<td>Diatomaceous earth</td>
<td>0.016</td>
<td>+</td>
<td>3</td>
</tr>
<tr>
<td>UNSW, Sydney NSW, Aust.</td>
<td>Diatomaceous earth, pilot</td>
<td>1 ft²</td>
<td></td>
<td>7,8</td>
</tr>
</tbody>
</table>
## C & G Removal Performance

<table>
<thead>
<tr>
<th>Filtration Type</th>
<th>Component</th>
<th>Giardia cyst</th>
<th>Crypto oocyst</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow Sand</td>
<td></td>
<td>0.5-0.7</td>
<td>0.5-0.7</td>
<td>Requires regular maintenance</td>
</tr>
<tr>
<td>Package Pressure</td>
<td></td>
<td>1-1.5</td>
<td>-</td>
<td>On-off between bw limits removal</td>
</tr>
<tr>
<td>Package Complete</td>
<td></td>
<td>1.5-2.5</td>
<td>1.5-2.0</td>
<td>Requires chemical conditioning</td>
</tr>
<tr>
<td>Complete</td>
<td></td>
<td>2-2.5</td>
<td>2-2.75</td>
<td>Removals depend on design &amp; op</td>
</tr>
<tr>
<td></td>
<td>Sedimentation</td>
<td>0.5-1</td>
<td>0.7-1</td>
<td>Pond removals may be &lt; in tanks</td>
</tr>
<tr>
<td></td>
<td>Filtration</td>
<td>1.8-2.2</td>
<td>1.5-2.3</td>
<td>Operation quality affects removal</td>
</tr>
<tr>
<td>Complete Pilot</td>
<td></td>
<td>2.8-3.7</td>
<td>1.9-2.8</td>
<td>To examine design &amp; op’s effects</td>
</tr>
<tr>
<td>Direct</td>
<td></td>
<td>3.8</td>
<td>2.5-2.9</td>
<td>Limited to low turbidity raw water</td>
</tr>
<tr>
<td>Direct Pilot</td>
<td></td>
<td>3.0-3.6</td>
<td>2.7-3.1</td>
<td>Removals ca. 0.5-1 log &gt; full-scale</td>
</tr>
<tr>
<td>Diatomaceous Earth</td>
<td></td>
<td>2-3</td>
<td>-</td>
<td>Removal varies w/ DE grade, but not w/ filter rate @ 1 or 2 gpm/ft²</td>
</tr>
<tr>
<td>DE Pilot</td>
<td></td>
<td>-</td>
<td>4.5-6.5</td>
<td></td>
</tr>
</tbody>
</table>
Summary

- Likely C&G concentrations ca. 10-100/L
- C&G removal
  - Slow sand filtration: < 2-logs
  - Untended rapid sand: ca. 2-logs
  - Optimised rapid sand: 2 to 3-logs
  - DE & Membranes: > 5 to 6-logs
- Confirm performance by direct sampling
Conclusions

- C & G…Always present…require control
- Effective treatment can be provided
- Design must match local capability
- Can measure & monitor performance
Questions?
Information to Limit Outbreak Potential

- Must ASSUME presence of Crypto & Giardia
- Need to know:
  - The concentration of all organisms
    - Live or dead
    - All species
  - Concentration characteristics—level & variability
    - Is concentration high or low?
    - Is concentration constant or variable
Reasons for Monitoring All Species & Live or Dead...Example

Cryptosporidium in sheep

- Prevalence's ranging from <10% to >80%
- At least 10 genotypes identified
- Mean environmental loading rate ~17-145 oocysts/g⁻¹ (0-6,897)
- Significantly associated with diarrhoea and production loss
Why Measure **Concentration**?

- Numbers ≠ Concentration
- Recovery efficiency **varies systematically** over annual cycles...different by location
Water Sampling & Analysis

Protozoan cysts are:
- Discrete particles ca from 2 to 20 µM
- Hardy in the environment...persist for months
- Concentrations in water are low...ca 1 in 10 L ±
- Not growing...must find among $10^6$ other particles

Analysis: *Zeros give no useful information!*
- Samples--volume to give *nonzero* result...$>10$L
- Collect particles $\geq$ organism...e.g. 2µm filter; ppt
- Concentrate organisms...e.g. IMS (Method 1623)
- Identification: e.g. IFA Microscopy
Data Analysis

- Concentration over a typical annual cycle:
  - When high & low

- Cumulative Frequency Distribution:
  - 50%ile → level for comparison
  - Slope or Std Dev. → variability... high = greater risk
Other Possibilities

- Can Discriminate by Species or Type...but not useful for potential outbreak control
  - Various PCR-based schemes

- Can Discriminate by apparent viability...but not useful for potential outbreak control
  - Vital staining--e.g. DAPI
  - Cell culture

- LAMP...can digest particle concentrate w/o separation...but still difficult to quantify
Monitoring Approach

- Analyse monthly samples for a year at a time
- Analyse volumes to give non zero results
- Analyse samples for both Crypto & Giardia
- Use mAb’s for detection of all species...most commercially available mAb’s
- Do not discriminate on apparent viability...all cysts or oocysts present show the real risk potential
- MUST measure recovery efficiency and calculate concentration for each sample
- Analyse data to show both LEVEL and VARIABILITY ...risk depends on both.
- Annual data will show season of high concentration