Consideration of pathogen risks associated with uncovered finished water reservoirs

Nicholas J. Ashbolt (Ashbolt.Nick@epa.gov)
U S EPA/ORD/Cincinnati

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LT2-ESWTR Uncovered Finished Water Reservoirs Public Meeting
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Pathogen testing of waters

- No ideal indicator
- Not all about Cryptosporidium
- Target < 0.075 oocysts /1000L or < 1 in 10,000 L need to take >>200 50-L samples (noting method recovery generally < 50% and non-normal input/distribution of oocysts in water)
- Key issue: what is the change in relative risk due to an uncovered finished water (UCFWR)
Risk = probability x consequence

- Therefore pathogen risk is based on likelihood of occurrence & consequence of disease endpoint(s); So for LT2 & in UCFWR
  - Interested in gastrointestinal (GI) disease
  - But other endpoints & sequelae possible, e.g.
    - *E. coli* O157:H7 but may also cause HUS
    - *Campylobacter jejuni* causes reactive arthritis & Guillain Barré syndrome
Models provide supporting info

• Quantitative Microbial Risk Assessment (QMRA) to inform change in risk from UCFWR:
  – Need to ID potential sources/routes of concern of pathogen contamination to UCFW reservoirs
  – Model/measure fate & transport to provide relative risk by pathogen that an uncovered reservoir may introduce
Animals identified in UCFWR

Photos: Staff of the California Drinking Water Program

Owl

Rabbit

Rat
Why Model?

• Models help us explore questions that we might not be able to address in the laboratory or field; for example:
  – What is the waterfowl risk to reservoir waters under condition X?
  – What is the impact of reservoir turn-over?
  – When may it be safe to restart service after an event for an UCFWR?
Pathogen hazards: mostly zoonotic

Portland reservoir urination raises a few concerns (Oregon Live.com, 6/15/11)

- 21 year-old’s event led to draining 7.8 MG Mt. Tabor R
- Risk was human access ‘thought it was a sewer plant’

Zoonosis – pathogen from animal-to-human

- A few are viral (HEV wild pigs, H5N1 virus in birds), range of pathogenic bacterial & parasitic protozoa

Which animal groups of concern:

- **Birds** (e.g. H1N1, Cryptosporidium meleagridis, Giardia lamblia, Salmonella enterica, Campylobacter jejuni), **rodents** (most as above) **rabbits** (C. cuniculus)
Understanding (fecal) sources

• Animal surveys / by season / risk periods
• qPCR for various pathogens / indicators
• Microbial Source Tracking (MST)
  – Bacteroidales targets, yet poorly developed for non-ruminants & birds
  – Emerging use whole genome sequencing
• Chemical biomarkers to ID sources
  – Fecal sterols, biomass assays
<table>
<thead>
<tr>
<th>Source (g feces/d)</th>
<th>Pathogens</th>
<th>Counts/gram</th>
<th>D-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birds, e.g. ducks</td>
<td>H5N1, Cryptosporidium meleagrisid, Giardia lamblia, microsporidia*,</td>
<td>P/A, ranges 10^2-10^4/g</td>
<td>H5N1 Sal Campy</td>
</tr>
<tr>
<td>(30-360)</td>
<td>Salmonella, Campylobacter &amp; Mycobacterium spp.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rodents (2-30)</td>
<td>Cryptosporidium parvum, Salmonella, E. coli O157:H7</td>
<td>10^2-10^4/g P/A</td>
<td>?</td>
</tr>
<tr>
<td>Rabbits (20-80)</td>
<td>Cryptosporidium cuniculus, Staphylococcus aureus (+ARG), Francisella tularensis</td>
<td>3000/g P/A</td>
<td>illness</td>
</tr>
<tr>
<td>Feral cats</td>
<td>Toxoplasma gondii,</td>
<td>P/A</td>
<td>-</td>
</tr>
<tr>
<td>Environmental</td>
<td>Schistosoma spp., Mycobacterium avium (↑virulent strains from animals)</td>
<td>P/A</td>
<td>-</td>
</tr>
</tbody>
</table>

P/A presence/absent data only, ARG – antibiotic-resistant genes

*Encephalitozoon hellem, E. intestinalis, & Enterocytozoon bieneusi
Model/measure fate & transport

• Various model components can be estimated with surrogates:
  – Fecal loadings (E. coli, enterococci, MST) & HRT
  – Environmental inactivation (light intensity + temp)
  – Algae-association, reservoir turn-over (re-suspension) of sediment-bound pathogens

• Role of algae?
  – May lead to growth of some bacterial pathogens & indicators
  – Toxins?
Reservoir water QMRA model

Goal: estimate the relative risk increase (for water in vs out of the UC reservoir)

STEP 1 SETTING

Hazard identification & pathways
Describe physical system, selection of reference pathogens & identification of hazardous events

Viruses
Bacteria
Parasitic protozoa

U.S. Environmental Protection Agency
Reservoir QMRA model

STEP 1 SETTING

Hazard identification & its setting
Describe physical system, selection of reference pathogens and identification of hazardous events

For each reference pathogen:

- **Fecal source(s)**
  - Pathogen range

- **Reservoir**
  - Direct deposition or wash-in

- **Fate & Transport (UCFW)**
  - Pathogen removal (appropriate surrogate)

- **Sedimentation & resuspension**
  - Partition/die-off (surrogate)

- **Treatment**
  - (appropriate surrogate)

- **Ingestion**
  - (1 L assumed)

- **Estimated Reference Pathogen conc.**
Reservoir QMRA model

STEP 2
EXPOSURE

Reservoir
Direct deposition or wash-in

Fecal source(s)
Pathogen range

Sedimentation & resuspension
Partition/die-off (surrogate)

Fate & Transport (UCFW)
Pathogen removal (appropriate surrogate)

Treatment (appropriate surrogate)

Ingestion
(1 L assumed)

Estimated Reference Pathogen conc.

Dose-Response \( (P_{inf}) \)
Selection of appropriate model & dose for each pathogen and scenario
Reservoir QMRA model

**STEP 1** SETTING

Hazard identification & its setting
Describe physical system, selection of reference pathogens and identification of hazardous events

**STEP 2** EXPOSURE

- Reservoir
  - Direct deposition or wash-in
- Sedimentation & resuspension
  - Partition/die-off (surrogate)
- Fate & Transport (UCFW)
  - Pathogen removal (appropriate surrogate)
- Treatment (appropriate surrogate)
- Ingestion
  - (1 L assumed)

Fecal source(s)
Pathogen range

**STEP 3** HEALTH EFFECTS

- Estimated Reference Pathogen conc.
- Dose-Response ($P_{inf}$)
  - Selection of appropriate models for each pathogen and scenario examined

**STEP 4** RISK

Characterisation of Risk
Simulations for each pathogen baseline and event infection risks with variability & uncertainty identified
Conclusions

- Uncovered finish water reservoirs are vulnerable to fecal inputs, in decreasing order of likely pathogen risks as follows:
  - Birds
  - Rodent
  - Feral cats (& dogs)
- Additional treatment could negate risks
- Very large numbers of samples required to measure pathogen risk impacts due to UCFWR