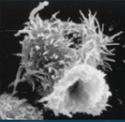


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**MRA Research Activities to Support
Drinking Water Standards**

Nicholas J. Ashbolt

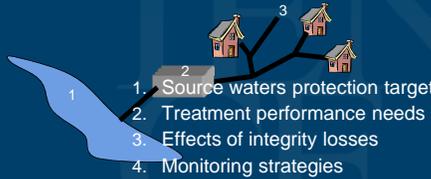

Bethesda North Marriott Hotel and
Conference Center in Bethesda
Maryland, April 8-10, 2008

Office of Research and Development
National Exposure Research Laboratory

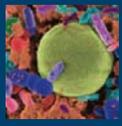
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**Quantitative Microbial Risk
Assessment (QMRA)**

**Provides information
for managing safe water**



1. Source waters protection targets
2. Treatment performance needs
3. Effects of integrity losses
4. Monitoring strategies



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QMRA (continued)

**...and provides information
for identifying/prioritizing
research needs**



- Contaminant sources
- Pathogens of concern
- Characterization of exposures
- Prevention approaches and control technologies

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Research steps for undertaking QMRA

- Describe system conceptual model
 - Including various hazardous events that could be managed and reference pathogens to study
- Compile & use existing data for a tier 1 QMRA
 - If risk appears unacceptable and not immediately manageable, collect new data to reduce uncertainties
- Increase tier of MRA until uncertainties acceptable
- **The above identifies major research gaps to be filled**

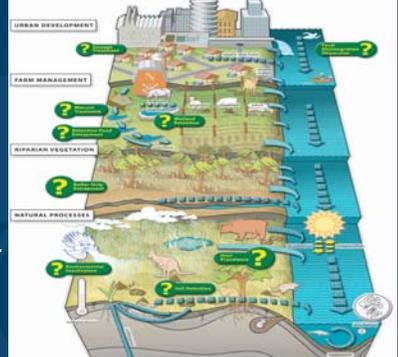
.....for example

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CONCEPTUAL MODEL OF A WATERSHED

Water and Particulates | Particulates | Size proportional to knowledge gap



Ferguson *et al.*
(2003) J.AWWA
95:92-102

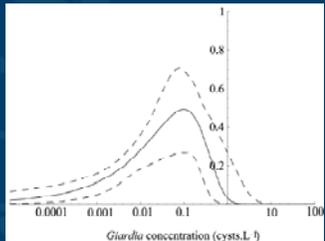
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Count Volume (L)

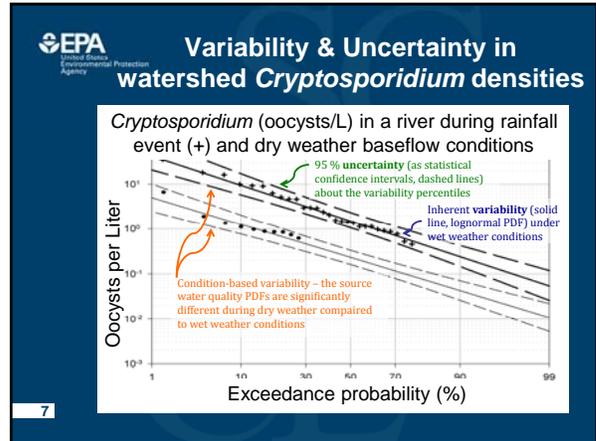
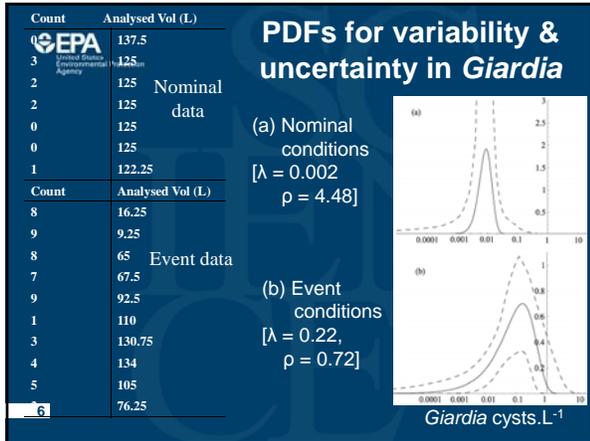
8	16.25
9	9.25
8	65
7	67.5
9	92.5
1	110
3	130.75
4	134
5	105
2	76.25
0	137.5
3	125
2	125
0	125
0	125
1	112.25

**PDF for the *Giardia* cyst
densities in raw water**



Maximum likelihood Gamma distribution
 $\lambda = 0.41$ and $p = 0.24$ (solid line) and 95%
Bayesian credible intervals (dashed lines)
constructed from posterior MCMC samples

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Now that was the straight forward part!

- In full-scale treatment works and distribution, pathogen densities of concern are below current detection limits
 - e.g. < 1 enteric virus per million Liters = 10^{-4} risk
- Hence, surrogates are used to validate treatment performance and integrity of drinking waters
 - E.g. particle-size (1-20µm) removal, C.t disinfectant
- But there is added uncertainty in extrapolating from surrogate to pathogen behavior

Research needs at treatment

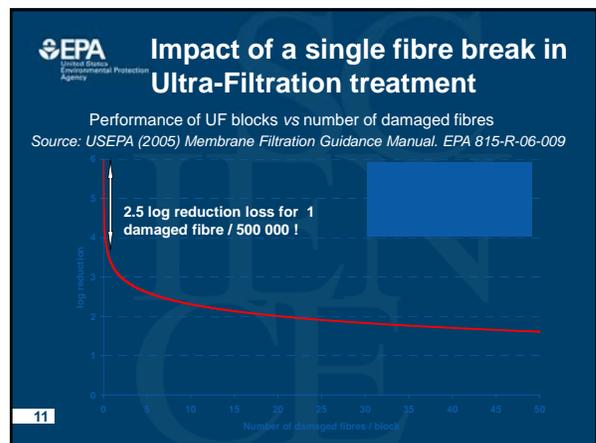
- Very frequent sampling is required to identify events of concern at treatment works
- It is simply not possible to sample sufficient volumes of finished water for microbes
- Hence, we are reliant upon on-line instrumentation to provide action levels
 - QMRA can provide information to support the setting of action levels

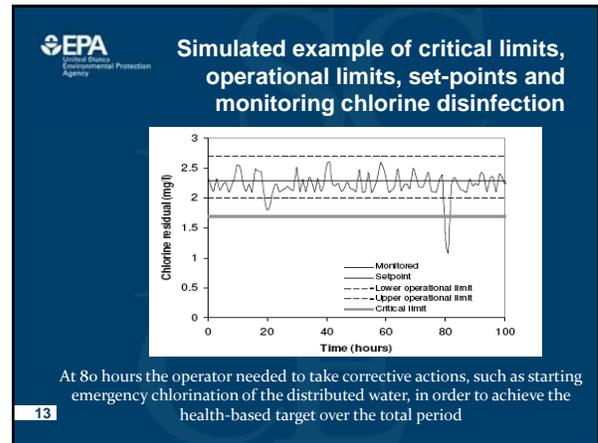
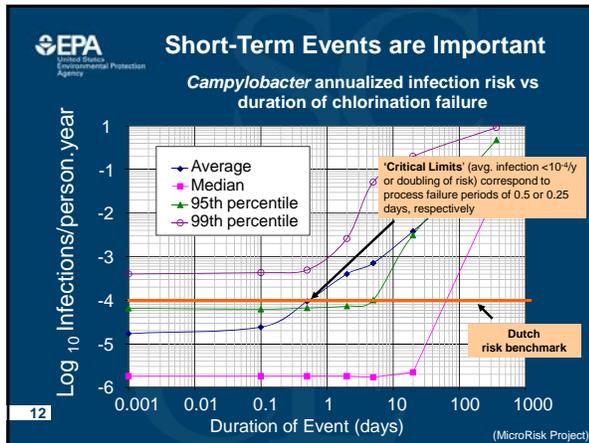
Monitoring required to verify at the 95% confidence level that failure events do not significantly add to risk when compared to nominal treatment performance

Nominal log ₁₀ reduction	#/year	Monitoring interval
0.05	1	1 year
1	30	1 week
2	300	1 day
3	3,000	3 hours
4	30,000	15 min
5	300,000	2 min
6	3,000,000	10 sec
7	30,000,000	1 sec

i.e. a 100,000 m³/d plant treatment with a disinfection system designed for 7 log inactivation of viruses, must monitored every 3 liters to be 95% confident that all water was sufficiently treated

Smeets (2008)





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Research needs for distribution



- How to interpret *E. coli* detects?
- Develop better means to identify the frequency and duration of 'intrusion' events, and to sample associated pathogens
- Understand the occurrence of biofilms & amoeba that promote opportunistic pathogen densities of concern
 - E.g. growth of human-infectious *Mycobacterium* & *Legionella* strains

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Public Health implications of Coliforms in distribution systems



- Various coliforms grow in pipe biofilms
 - Incl. *Citrobacter*, *Enterobacter*, *Klebsiella* species
 - Latter include fecal coliform members
 - Hence importance of using *E. coli* as the fecal indicator in follow-ups
- Of the 3-8% of systems that have MCL non-acute (TC) violations, only 10% have acute violations (*E. coli* present in ~0.5% of Total Coliform Rule samples)

Need to be able to separate growth from an intrusion event ...

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Biofilm pathogen research

Biofilms sequester fecal pathogens and allow the growth of opportunistic pathogens

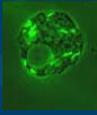


Biofilm-like sampling device

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Opportunistic Pathogens (continued)

- Various *Legionella* strains
- *Mycobacterium avium*, *M. ulcerans*
- *Burkholderia pseudomallei*
- *Helicobacter pylori*
- *Campylobacter* spp.
- *Aetia*, *Bosea* & *Criblamydia* spp.

All grow associated with amoeba in biofilms and may be active but non-culturable

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Conceptual model of *Legionella* in piped water (Lau & Ashbolt)

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SO TO SUMMARIZE THE PROCESS

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Typical QMRA Drinking Water Model

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Iterative tiered approach for undertaking QMRA

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*The risk level of the system should be reviewed at a regular interval according to the relevant risk management protocol

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EPA Research Goals for Biofilms

- Identify the possible significance/occurrence of *Legionella* and novel pathogens in distribution biofilms
 - Specific focus on virulence up-regulation in *Legionella* associated with biofilm/amoeba growth, and
 - Sampling pathogens with a biofilm-like device
- Role of ABNC cells in biofilms using animal dose-response models and disinfection efficacy studies
- Add biofilm/pathogen issues to EPA-Net model and provide missing key QMRA data inputs for piped water

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Acknowledgment

Special thanks to the many international colleagues who have worked with me on distribution system microbiology and EPA post doctorate, Dr. Helen Lau

Disclaimer: This presentation does not necessarily reflect official Agency policy

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