Public Health
Risk Assessment of Waterborne Disease

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## Risk Assessment

- **4 basic steps** (NAS, 1983)

<table>
<thead>
<tr>
<th>Hazard identification</th>
<th>Characterization of innate adverse toxic effects of agents</th>
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</thead>
<tbody>
<tr>
<td>Dose-response assessment</td>
<td>Characterization of the relation between doses and incidences of adverse effects in exposed populations</td>
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<tr>
<td>Exposure assessment</td>
<td>Measurement or estimation of the intensity, frequency, and duration of human exposures to agents</td>
</tr>
<tr>
<td>Risk characterization</td>
<td>Estimation of the incidence of health effects under the various conditions of human exposure</td>
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</tbody>
</table>
Evaluation of Waterborne Disease

- Epidemiological Studies
  - Variable
  - Site specific

- Occurrence Data
  - Extrapolation of data
  - "guess"-timate of risk

- Risk Assessment
  - Lack occurrence and exposure data
Identification of Relevant Health Impacts

- Water Industry Data
- Consumer Surveys
- Risk Assessment
- Epidemiological & Health Effects Studies
Health Effects Studies: Contributing Water Quality Data

**Water Treatment Data**
- Water system types
- Water sources
- Water treatments
- Storage

**Distribution System Data**
- Residual disinfectants/Alternative barriers
- Water system operations/terminology
- Premise Plumbing
- Distribution system management

**Overview**
- Quality Assessment

**Interpretation**
- Public Health Study Influence

**Study Influence**
- Water Quality Monitoring
- Customer Complaints/Consumer Surveys
Mixed Messages
What is the True Impact of Waterborne Disease?

- 2,760 cases, 4 deaths (2003-2004: 36 OB CDC, 2006)
- 7 M cases, 1,200 deaths (Morris & Levin, 1995)
- 11.7 M cases (Colford et al., 2006)
- 16 M cases (Messner et al., 2006)
- 19.5 M cases (Reynolds, et al., 2008)

- Agents significant for endemic infections may be different than those targeted from outbreak data.
- Relative few outbreaks detected/reported
Acceptable Risk

- USEPA suggests a 1:10,000 per year acceptable risk of infection from potable water
- Guidance used to conduct mathematical modeling of human health risk from various agents
- Exposure standards
  - Numerical exposure levels in various media that must not be exceeded OR Preventative measures to reduce exposures
- For QMRA, key pieces of information are required (known or predictable):
  - Infectious dose–response of the pathogen of interest
  - Concentration at which the agent can be found in water
  - Impact of various water treatment strategies on the reduction in infectivity of the pathogen of interest
  - Pathogenicity factors
Point Estimate

- Single numeric value of risk
  - May correspond to best estimate of risk
  - May be maximum reasonable exposure
- Use values of exposure and dose response parameters corresponding to point estimate of interest
Interval Estimate

- Range of values, probability distribution
- Considers uncertainty and variability
  - Uncertainty
    - Error in estimate
      - Measurement error
      - Reporting error
      - Physical limitation (small n)
  - Variability
    - Intrinsic heterogeneity
      - Systematic differences in consumption
      - Ethnic cultural differences
      - Dose-response sensitivity varies
      - Immune function
Benefits of Distribution Analysis

- Provides range of possible outcomes
- Determine if uncertainty matters
- Determine key data contributors
- Compare range of outcomes under different conditions/mitigations
Monte Carlo

- Most widely applied tool for risk distribution analysis
- Evaluates known and assumed distribution inputs
  - Variability assessment
  - Uncertainty assessment
  - Combination of both
- Uses random numbers in computational process
- Determines a desired output as a function of changing variables (dose, exposure, survival, etc.)
- Repeat for large number of “trials” (i.e., 1,000)
Risk Characterization

- What is the magic number?
  - May be conservative or worst-case
  - May be a point or interval estimate
  - May collapse distribution to most likely number (or conservative, protective number)

- How will the number inform decisions?
  - Acceptable risk
  - Realized risk
  - Risk reduction potentials
  - Risk management
  - Subpopulations
MRA and Drinking Water: What have we learned?

- Water quality variability effects long-term risk
- No threshold for infectivity
- Low-level exposure over time can have a significant impact
- Sensitive populations at greatest risk
- Sequelae are common
- Greatest uncertainty in models is exposure
- Monitoring is essential to estimate risk
- Plausibility of models demonstrated by epidemiological data
- Need to understand mechanisms (host and pathogen)
- Goal to establish and quantify cause and effect relationships
- More data needed to minimize uncertainty in risk characterization
Future Considerations
Distribution System Issues

- 2003-2004 outbreaks 35% due to distribution systems
- Pipes in U.S.:
  - average life expectancy, 75-120 yrs
  - average replacement rate, 200 yrs.
  - 26% in poor condition
- Main breaks:
  - 250 in 1970; 2,200 in 1989; ~237K breaks per yr in U.S.
  - ~25-30 breaks/100 miles of piping/yr
  - 10-20% produced water unaccounted for…..
  - 20% of pipes below water table
  - 90% of nodes draw negative pressure during power outages

Reviewed by Reynolds et al., 2008
“Average” Dose

- Illnesses occur with:
  - “Average” dose to low number of organisms
  - Widespread exposure to low doses
  - Limited exposures to large doses

- Need improved exposure data
  - Factors effecting the spectrum of severity
Risk Indicators

- Increased monitoring of pathogens
  - Inadequate indicators
  - Improved evaluation of treatment needs
- Fecal/coliforms
  - Indicate treatment efficacy
  - Fecal contamination
  - Poor correlation with risk
  - Absence not indicative of no risk
- Need for real-time monitoring
  - Automated
  - In-line
  - Post distribution
Water Vending Machines

- Ubiquitous throughout major cities
- Post-distribution monitoring
- Large volume/long time period analysis
- Poor virus retention
- Poor recovery
- 45 filters from 41 unique sites
## Field Study Results

<table>
<thead>
<tr>
<th>Organism</th>
<th>% Detection for Total Filters Collected</th>
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<tbody>
<tr>
<td>Total coliforms</td>
<td>27.1</td>
</tr>
<tr>
<td><em>E. coli</em></td>
<td>10.4</td>
</tr>
<tr>
<td>Enterococci</td>
<td>37.5</td>
</tr>
<tr>
<td>Enteroviruses</td>
<td>6.3</td>
</tr>
<tr>
<td>Filters with ≥1 organism</td>
<td>56.3</td>
</tr>
</tbody>
</table>

With a known net negative charge, a virus can be electrophoretically deposited on a positively charged Ge ATR crystal.

After surface deposition, the virus vibrational spectrum can be collected.

The resulting IR spectrum is specific to a certain chemical or biological species.
Viruses: Unique Spectral Features

MS2 and polio electrodeposition on Ge chips

Absorbance (A.U.)

Wavenumber (cm⁻¹)

Applied Environmental Microbiology, 2009
Additional RA Needs

- Use of risk assessment in guiding treatments/applications
- Improved monitoring, exposure assessment, variability analysis
- Evaluation of acceptable risk - what should our risk goal be?
  - Stakeholders
  - Public
  - Scientists
  - Policy makers
- Public perception/acceptance not static
- Management decisions must be cost effective (achievable, applicable)
- Goals set for normal life stages (children, elderly, pregnant) not ill (HIV/AIDS, organ transplants)
- Transparent, science based, universal
- One quantitative value is not standard for all pathogens everywhere
  - Seasonality; Treatment variability; Source contamination differences
- RA training for collaborators
Thank You!

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“And then one day I decided that not taking risks was the greatest risk of all.”