Waterborne Disease Outbreak

- Defined as 2 or more people with similar illness
- Voluntary reporting by local, territorial, tribal, or State health officials
- Test water and patients to verify contaminant
- Estimate # infected, hospitalized, and fatalities
Waterborne Disease Outbreak

- Hard to recognize symptoms
- Symptoms can take days after exposure to a microbial contaminant
- Microbial hard to detect/isolate

- WBDOs are severely underestimated
39 outbreaks associated with drinking water were reported by 25 states.

- One outbreak spanned 10 states (Salmonella Bareilly);
- Caused illness 2,068 persons;
- Linked to 2 deaths;
- The microbe or chemical that caused the outbreak identified for 22 of the 39 outbreaks;
- 20 of the 22 outbreaks associated with pathogens, and 2 were associated with chemical poisoning;
Of the 17 outbreaks involving acute gastroenteritis of unknown etiology, one was a suspected chemical poisoning, and the remaining 16 were suspected as having an infectious cause.

28 of 39 outbreaks were linked to ground water sources; 18 of these 28 ground water outbreaks were associated with private or noncommunity wells that were not regulated by EPA.
FIGURE 1. Number of waterborne-disease outbreaks associated with drinking water, by etiologic agent and month — United States, 1999–2000 (n = 38)*

*One outbreak of *Salmonella* Bareilly was not included.
†Acute gastrointestinal illness of unknown etiology.
**WBDOs associated with drinking water, U.S. 2000 (n=24)**

<table>
<thead>
<tr>
<th>Etiologic agent</th>
<th>Number of cases</th>
<th>Type of system</th>
<th>Deficiency</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norwalk-like virus</td>
<td>147</td>
<td>Ncom</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td><em>Escherichia coli</em> O157:H7</td>
<td>5</td>
<td>Ind</td>
<td>5</td>
<td>River/creek</td>
</tr>
<tr>
<td>AGI**</td>
<td>63</td>
<td>Ind</td>
<td>5</td>
<td>Irrigation system</td>
</tr>
<tr>
<td><em>Giardia intestinalis</em></td>
<td>27</td>
<td>Ncom</td>
<td>3</td>
<td>River</td>
</tr>
<tr>
<td>AGI††</td>
<td>19</td>
<td>Com</td>
<td>3</td>
<td>Well</td>
</tr>
<tr>
<td>AGI</td>
<td>21</td>
<td>Com</td>
<td>3</td>
<td>Well</td>
</tr>
<tr>
<td>AGI</td>
<td>71</td>
<td>Ind</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td>AGI§§</td>
<td>2</td>
<td>Ind</td>
<td>2</td>
<td>Well</td>
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<tr>
<td>AGI</td>
<td>3</td>
<td>Ind</td>
<td>2</td>
<td>Well</td>
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<tr>
<td>AGI</td>
<td>3</td>
<td>Ind</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td>AGI</td>
<td>4</td>
<td>Ind</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td><em>G. intestinalis</em></td>
<td>2</td>
<td>Ind</td>
<td>4</td>
<td>Well</td>
</tr>
<tr>
<td><em>Cryptosporidium parvum</em></td>
<td>5</td>
<td>Com</td>
<td>4</td>
<td>Well</td>
</tr>
<tr>
<td><em>Es. coli</em> O157:H7</td>
<td>4</td>
<td>Ind</td>
<td>5</td>
<td>Irrigation canal</td>
</tr>
<tr>
<td><em>Campylobacter jejuni</em></td>
<td>15</td>
<td>Ncom</td>
<td>2</td>
<td>Spring</td>
</tr>
<tr>
<td>AGI</td>
<td>65</td>
<td>Ncom</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td>Norwalk-like virus</td>
<td>86</td>
<td>Ncom</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td><em>G. intestinalis</em>†</td>
<td>12</td>
<td>Ncom</td>
<td>2</td>
<td>Well</td>
</tr>
<tr>
<td><em>G. intestinalis</em></td>
<td>5</td>
<td>Ind</td>
<td>3</td>
<td>Well</td>
</tr>
<tr>
<td><em>G. intestinalis</em></td>
<td>4</td>
<td>Ind</td>
<td>5</td>
<td>River</td>
</tr>
<tr>
<td><em>Es. coli</em> O157:H7</td>
<td>29</td>
<td>Com</td>
<td>4</td>
<td>Surface water***</td>
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<tr>
<td><em>Ca. jejuni</em>†††</td>
<td>102</td>
<td>Ind</td>
<td>5</td>
<td>Irrigation water</td>
</tr>
<tr>
<td>Norwalk-like virus</td>
<td>123</td>
<td>Ncom</td>
<td>3</td>
<td>Wells</td>
</tr>
<tr>
<td><em>Salmonella Bareilly</em></td>
<td>84</td>
<td>Ind</td>
<td>5</td>
<td>Municipal/spring***</td>
</tr>
</tbody>
</table>
### TABLE 4. Waterborne-disease outbreaks associated with drinking water, by etiologic agent and type of water system, United States, 1999–2000 (n = 39)

<table>
<thead>
<tr>
<th>Etiologic agent</th>
<th>Community</th>
<th></th>
<th>Noncommunity</th>
<th></th>
<th>Individual</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outbreaks</td>
<td>Cases</td>
<td>Outbreaks</td>
<td>Cases</td>
<td>Outbreaks</td>
<td>Cases</td>
</tr>
<tr>
<td>AGI†</td>
<td>6§</td>
<td>57</td>
<td>3</td>
<td>164</td>
<td>8</td>
<td>195</td>
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<tr>
<td><em>Giardia intestinalis</em></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>39</td>
<td>4</td>
<td>13</td>
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<tr>
<td><em>Escherichia coli O157:H7</em></td>
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<td>51</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Norwalk-like viruses (NLV)</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>356</td>
<td>0</td>
<td>0</td>
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<tr>
<td><em>Salmonella</em> species ‡</td>
<td>1</td>
<td>124</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>84</td>
</tr>
<tr>
<td>Campylobacter jejuni</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>15</td>
<td>1</td>
<td>102</td>
</tr>
<tr>
<td><em>Es. coli O157:H7/Ca. jejuni</em></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>781</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Small round-structured virus</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>70</td>
<td>0</td>
<td>0</td>
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<tr>
<td><em>Cryptosporidium parvum</em></td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sodium hydroxide</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>239</strong></td>
<td><strong>11</strong></td>
<td><strong>1,425</strong></td>
<td><strong>17</strong></td>
<td><strong>404</strong></td>
</tr>
<tr>
<td><strong>Percentage</strong></td>
<td><strong>28.2%</strong></td>
<td><strong>11.6%</strong></td>
<td><strong>28.2%</strong></td>
<td><strong>68.9%</strong></td>
<td><strong>43.6%</strong></td>
<td><strong>19.5%</strong></td>
</tr>
</tbody>
</table>
**TABLE 5. Waterborne-disease outbreaks associated with drinking water, by type of deficiency and type of water system United States, 1999–2000 (n = 39)**

<table>
<thead>
<tr>
<th>Type of deficiency</th>
<th>Community</th>
<th>Noncommunity</th>
<th>Individual</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outbreaks</td>
<td>Outbreaks</td>
<td>Outbreaks</td>
<td>Outbreaks</td>
</tr>
<tr>
<td>Untreated surface water</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Untreated groundwater</td>
<td>1</td>
<td>8</td>
<td>8</td>
<td>17</td>
</tr>
<tr>
<td>Inadequate treatment</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Distribution system</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Miscellaneous or unknown</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>11</td>
<td>17</td>
<td>39</td>
</tr>
</tbody>
</table>
FIGURE 5. Number of waterborne-disease outbreaks associated with drinking water, by year and etiologic agent — United States, 1971–2000 (n = 730)*

*The total from previous reports has been corrected from n = 691 to n = 688.
†Acute gastrointestinal illness of unknown etiology.
FIGURE 6. Number of waterborne-disease outbreaks associated with drinking water, by year and type of water system — United States, 1971–2000 (n = 730)*

*The total from previous reports has been corrected from n = 691 to n = 688.
SAFE DRINKING WATER ACT: PROTECTING AMERICA’S PUBLIC HEALTH

RISK

SOURCE WATER & COLLECTION SYSTEM

TREATMENT PLANT

DISTRIBUTION SYSTEM

CONSUMER

PROTECTION BARRIERS

PREVENTION

PROTECTION/CAPACITY

MONITORING/COMPLIANCE

RIGHT-TO-KNOW
Total Coliform Rule
History—1986 Amendments to SDWA

- Proposed Rule: November 3, 1987
- Final Rule: June 29, 1989 [40 CFR Parts 141 and 142]
  - Drinking Water; National Primary Drinking Water Regulations; Total Coliforms (Including Fecal Coliforms and E. Coli); Final Rule
- Currently being reviewed by EPA
Total Coliform Rule (TCR)

- Applies to all regulated public water supplies
- Targets commonly occurring microbial contaminants that may cause acute health effects
- Use coliform as an “indicator” since we can’t test for all known microbials
Types of Microbial Pathogens

- **Bacteria**
  - Single-Celled Organisms
  - Cholera, *E.coli* 0157:H7

- **Viruses**
  - Protein-Packaged DNA or RNA
  - Norwalk, Rotavirus

- **Protozoa**
  - Single-Celled Organisms
  - *Giardia*, *Cryptosporidium*
Why We Use Indicators

- **We Use Indicator Organisms**
  - Indicate Potential Presence of Disease-Causing Organisms
- **Why?**
  - There are Hundreds of Pathogens…
  - Many Cannot be Detected by Existing Tests
  - Others Require Specific Tests Resources
Indicator Organisms

- Must Survive In All Types of Water (Surface and Ground)
- Should Be Present When Pathogens Are Present
- Should Be More Hardy Than Pathogens
Indicator Organisms cont.

- Should Be Absent In Pathogen-Free Water
- Detection Should Be Easy And Affordable
- Obtain results in a timely manner (48 to 72 hours)
Total Coliform as an Indicator

- Advantages:
  - Total Coliform is a General Indicator of a Breach in Water System Integrity
  - Analytical Methods are Simple and Affordable
  - Results available in 48 hours
Total Coliform as an Indicator

- Limitations:
  - Total Coliform May Grow in Distribution Systems (Biofilm)
  - Total Coliform / Fecal Coliform Do Not Indicate all Kinds of Contamination (e.g., Cryptosporidium, Giardia lamblia)
Total Coliform as an Indicator

- Limitations Example:
  - 1993 Milwaukee, WI, *Cryptosporidium* waterborne disease outbreak
  - System did not have coliform positive samples, but *Cryptosporidium* present in water
  - Over 400,000 ill
  - Over 50 deaths
Fecal Coliform Bacteria—Traditional Definition

- **Total Coliform Bacteria**
  - That:
    - Ferment Lactose at an Elevated Temperature When Using Standard (FC) Media
      - 44.5 +/- 0.2 C (Body Temperature)

- **Fecal indicator**

- **Short-Lived outside host**
Escherichia coli

- *E. coli* is a fecal coliform
- May be a better indicator of sewage or fecal contamination than fecal coliform
- Method is good, reliable, and timely
Escherichia coli

- Hundreds of Strains Known
- Most Strains Are Harmless and Live in the Intestines of Healthy Humans and Animals
- Strain O157:H7
  - Produces a Powerful Toxin
  - Causes Bloody Diarrhea and Occasionally Leads to Kidney Failure
E. coli O157:H7

- **Sources of Outbreaks**
  - Undercooked Beef, Dairy Products, Raw Vegetables, Drinking Water

- **Symptoms**
  - Occur in 1-9 Days (3 Average); Recover in ~ 8 Days
  - Watery Diarrhea With Abdominal Pain/
    Bloody Diarrhea; Little or No Fever
  - Some Develop Haemolytic Uremic Syndrome (HUS)
    - Kidney Failure May Occur, Some Cases are Fatal
E. coli O157:H7
New York Fair Outbreak

- Waterborne disease outbreak
- Sept 1999
- 1,000 people affected
- 760 hospitalized
- 2 deaths (3-yr old and 79-yr old)
- Cause: Cattle manure or nearby septic tank impacted shallow well, no chlorination
TCR Update

- EPA is reviewing TCR - could see some changes
- Distribution Rule being considered
- A number of waterborne disease outbreaks (WBDO) attributed to the distribution system
  - Estimated 25% of WBDO 1991-2000 due to distribution system deficiencies
Distribution Concerns

- Backflow/Backsiphonage
  - Cross Connection Control
- Physical openings for contaminant entry
  - Holes in storage tanks
  - Broken pipes
Distribution Concerns

- Leaching, Permeation, Biofilms
- Looking for better indicators for problems
WBDO- Gideon, Missouri

- Gideon, Missouri
- 1993
- Holes in storage tank, birds accessed tank interior
- Bird droppings contained Salmonella
- 625 people ill, 15 people hospitalized, 7 deaths
WBDO- Cabool, Missouri

- Cabool, Missouri
- 1989-90
- Main rupture due to cold weather, water line contaminated with sewage that entered during wet weather, hypochlorination not practiced during repair
- *E. coli* O157 found
- 243 people ill, 32 people hospitalized, 4 deaths
Ground Water Rule
Ground Water Rule

- Proposed May 10, 2000
- Finalized October 2006
- Prompted by deaths associated with unchlorinated well used at New York State Fair - *E. coli* outbreak and deaths
Ground Water Rule (GWR) Background

- GWR passed to address pathogens in ground water
- Some pathogens can
  - Live for long periods outside its host (years) (viruses in particular)
  - Survive in deep aquifers (200 feet)
  - Travel ¼ mile (or more?)
  - And still cause infection
Ground Water Rule (GWR) Background

- New York State fair WBDO
- Island Park, Idaho, 1996 WBDO
  - Broken sewer main contaminated a well
  - *Shigella* outbreak
  - 83 people ill
- GWR documents many other WBDOs
Ground Water Rule

- Sanitary surveys
- Source water monitoring for coliform positive samples from routine TCR monitoring
- Assessment monitoring for high risk systems (State option)
- Corrective action for significant sanitary deficiencies or fecal contamination
Sanitary Surveys

- **Frequency:** Every 3 years for CWS and 5 years for NCWS
- **Key components:**
  - State must address 8 EPA/ASDWA components
  - States must have corrective action authority
  - Systems must fix significant deficiencies
    - 90 days or alternate schedule
    - Treat if uncorrected
  - Systems must provide written certification that correction was completed
Sanitary Surveys – Eight Essential Elements

1. Source
2. Treatment
3. Distribution System
4. Finished Water Storage
Sanitary Surveys – Eight Essential Elements (Cont’d)

5. Pumps/Pump Facilities and Controls

6. Monitoring/Reporting/Data Verification

7. Water System Management/Operations

8. Operator Compliance with State Requirements
Key components:

- If TC-positive, then collect samples at the source unless shown to be distribution specific
- If fecal contamination detected
  - Eliminate source of contamination
  - Develop alternate source
  - 4 logs of virus inactivation/removal
What is Microbial Inactivation?

- Render the Organism Unable to Cause Disease
  - Kill the organism
  - Prevent organism from replicating by disrupting DNA

- Viruses are pathogen of concern for ground water systems

- *Crypto* and *Giardia* present in surface water
Factors Affecting Microbial Inactivation

- Organism Disinfectant Resistance
- Disinfectant Concentration
- Contact Time
- Competing/Shielding of Other Particles
- Water Temperature
- Water pH
Types of Disinfectants

- Chlorine
- Chloramines
  - chlorine and ammonia
- Chlorine Dioxide
  - $\text{ClO}_2$ gas generated on-site
- Ozone
  - $\text{O}_3$ gas generated on-site
- UV Light
Quantifying Microbial Inactivation

- Log Inactivation
  - $\log_{10}$
  - Organism and disinfectant specific

- CT Concept
  - $C =$ chlorine residual concentration
  - $T =$ contact time, function of basin/pipeline size, baffling, and hydraulics
CT (min-mg/L) Values for 4-log Virus Inactivation by Free Chlorine

<table>
<thead>
<tr>
<th>Temperature Celsius</th>
<th>pH 6-9</th>
<th>pH 10</th>
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<td>10</td>
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<td>20</td>
<td>3</td>
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<td>25</td>
<td>2</td>
<td>15</td>
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<td>Giardia</td>
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<td>---------</td>
</tr>
<tr>
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<td>4.0</td>
<td>22</td>
<td>22</td>
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</tbody>
</table>
Other Health Effects – organic and inorganic

- **DBPs** – cause bladder cancer and reproductive effects
  - Stage 1 – 140 million people receiving increased protection from DBPs

- **Lead** – damage to brain, red blood cells and kidneys, esp. children and pregnant women
Other Health Effects – organic and inorganic

- **Copper** – stomach and intestinal distress, liver/kidney damage

- **Arsenic** – bladder and lung cancer

- Other chems in general - nervous system, liver, kidneys, cancer, intestinal problems, bone disease
Summary

- Many microbials present in the environment
- TCR good indicator, but has limitations
- Ground Water Rule attempts to address viruses in ground water supplies
- Systems still vulnerable to contamination
- Look for TCR revisions and Distribution Rule