# Public Health Protection

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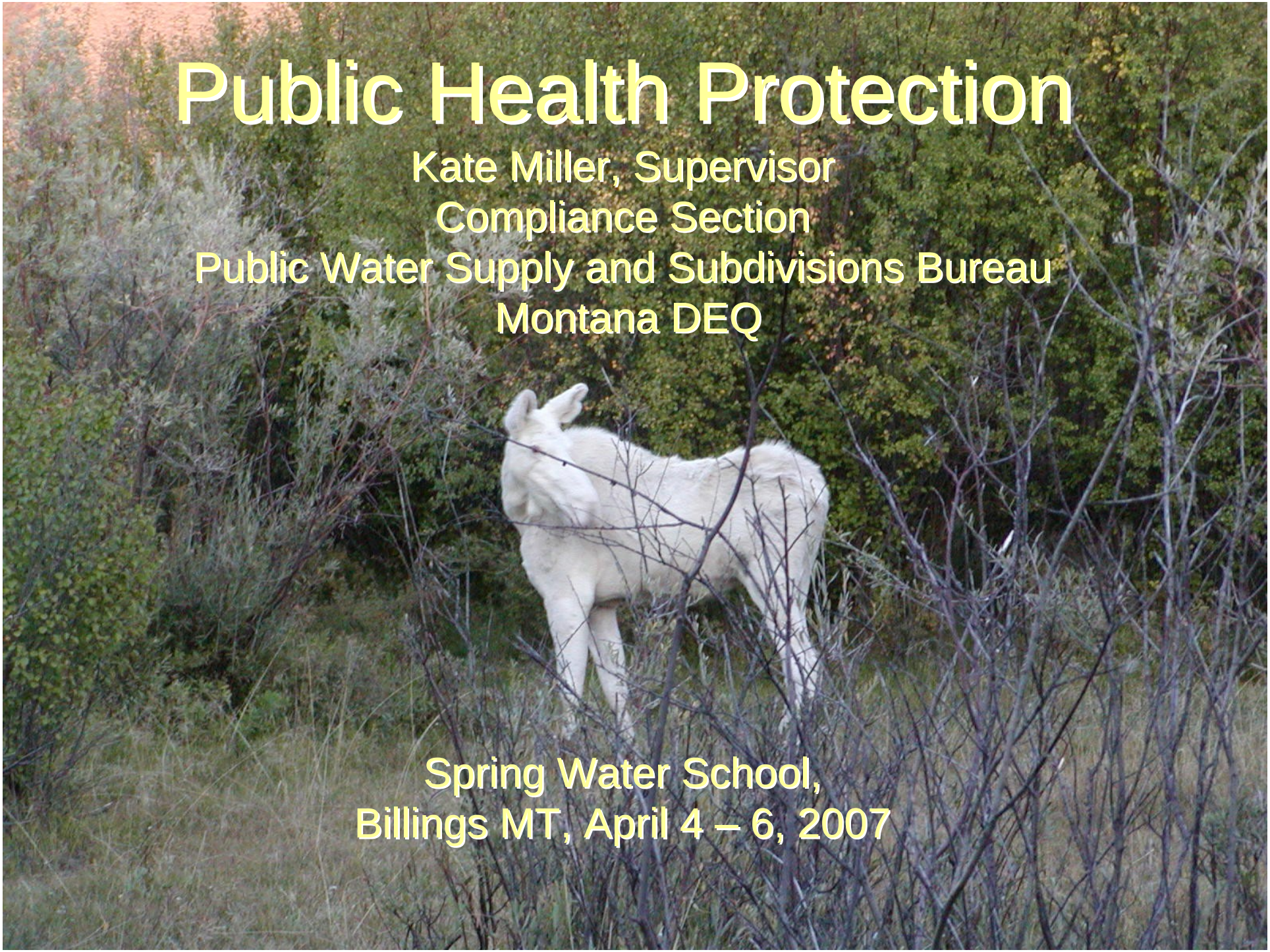


Spring Water School,
Billings MT, April 4 – 6, 2007

# 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**

# WBDOs 1999-2000

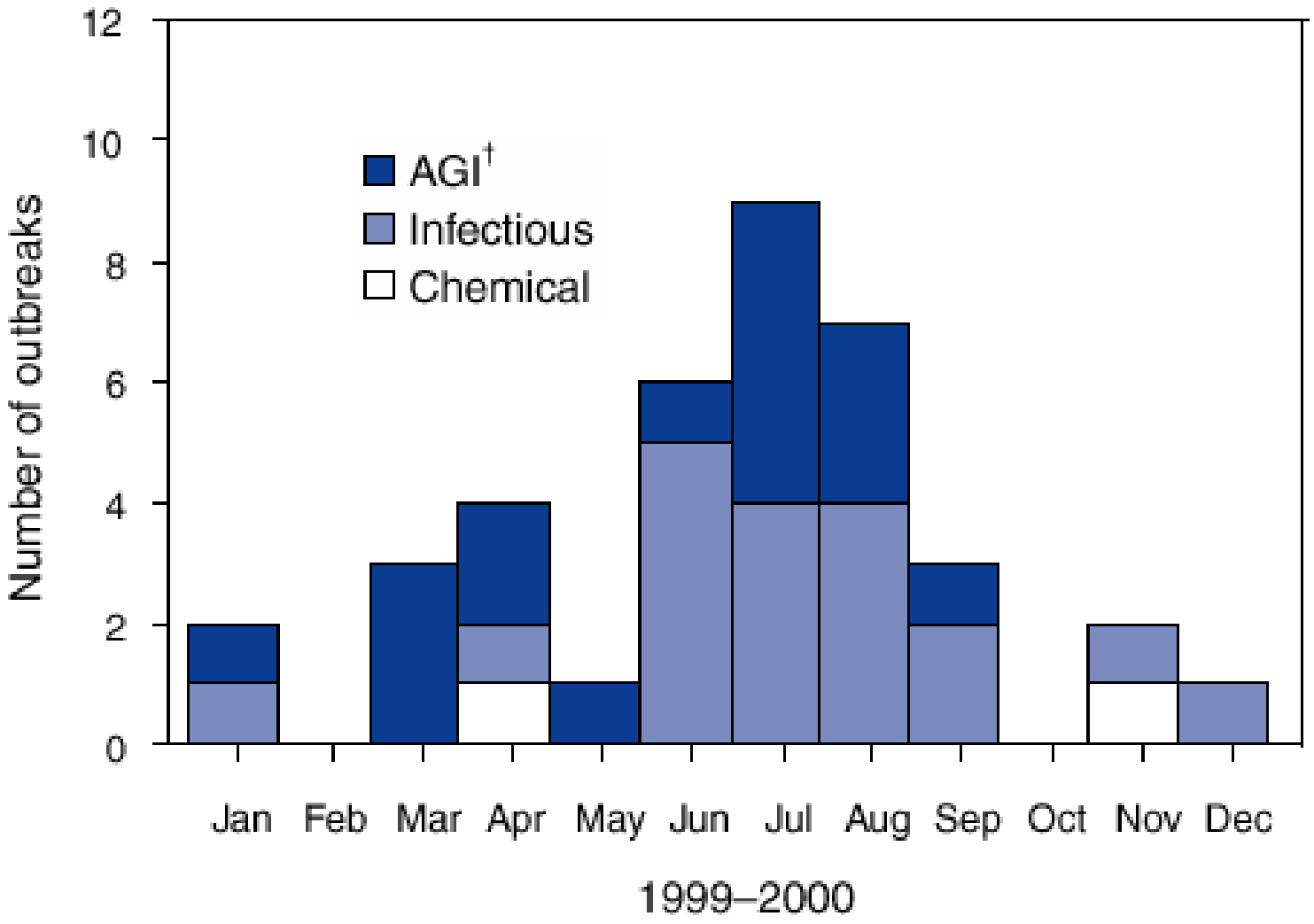
- **39 outbreaks associated with drinking water were reported by 25 states.**
  - one outbreak spanned 10 states (*Salmonella* Bareilly );
  - caused illness 2,068 persons ;
  - linked to 2 deaths;
  - the microbe or chemical that caused the outbreak identified for 22 of the 39 outbreaks;
  - 20 of the 22 outbreaks associated with pathogens, and 2 were associated with chemical poisoning;

# WBDOs 1999-2000, continued

- 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)

| Etiologic agent | Number of cases | Type of system[§] | Deficiency[¶] | Source |
|---|---|---|---|---|
| Norwalk-like virus | 147 | Ncom | 2 | Well |
| *Escherichia coli* O157:H7 | 5 | Ind | 5 | River/creek |
| AGI** | 63 | Ind | 5 | Irrigation system |
| *Giardia intestinalis* | 27 | Ncom | 3 | River |
| AGI†† | 19 | Com | 3 | Well |
| AGI | 21 | Com | 3 | Well |
| AGI | 71 | Ind | 2 | Well |
| AGI§§ | 2 | Ind | 2 | Well |
| AGI | 3 | Ind | 2 | Well |
| AGI | 3 | Ind | 2 | Well |
| AGI | 4 | Ind | 2 | Well |
| *G. intestinalis* | 2 | Ind | 4 | Well |
| *Cryptosporidium parvum* | 5 | Com | 4 | Well |
| *Es. coli* O157:H7 | 4 | Ind | 5 | Irrigation canal |
| *Campylobacter jejuni* | 15 | Ncom | 2 | Spring |
| AGI | 65 | Ncom | 2 | Well |
| Norwalk-like virus | 86 | Ncom | 2 | Well |
| *G. intestinalis*¶¶ | 12 | Ncom | 2 | Well |
| *G. intestinalis* | 5 | Ind | 3 | Well |
| *G. intestinalis* | 4 | Ind | 5 | River |
| *Es. coli* O157:H7 | 29 | Com | 4 | Surface water*** |
| *Ca. jejuni*††† | 102 | Ind | 5 | Irrigation water |
| Norwalk-like virus | 123 | Ncom | 3 | Wells |
| *Salmonella* Bareilly | 84 | Ind | 5§§§ | Municipal/spring§§§ |

# WBDOs by etiologic agent

**TABLE 4. Waterborne-disease outbreaks associated with drinking water, by etiologic agent and type States, 1999–2000 (n = 39)**

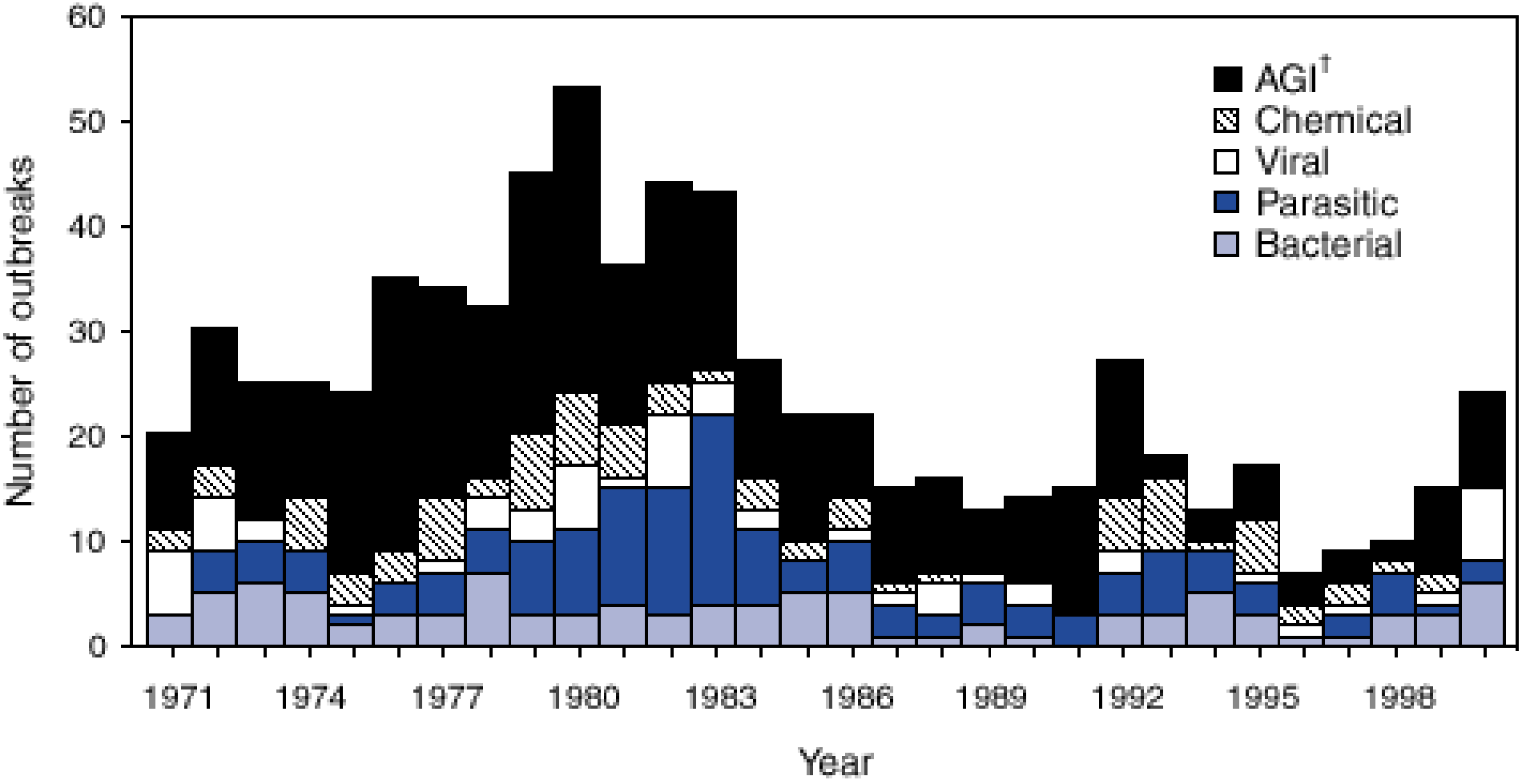
| | Type of water system[a] | | | | | |
|---|---|---|---|---|---|---|
| | Community | | Noncommunity | | Individual | |
| **Etiologic agent** | **Outbreaks** | **Cases** | **Outbreaks** | **Cases** | **Outbreaks** | **Cases** |
| AGI[†] | 6[§] | 57 | 3 | 164 | 8 | 195 |
| *Giardia intestinalis* | 0 | 0 | 2 | 39 | 4 | 13 |
| *Escherichia coli* O157:H7 | 2 | 51 | 0 | 0 | 2 | 9 |
| Norwalk-like viruses (NLV) | 0 | 0 | 3 | 356 | 0 | 0 |
| *Salmonella* species[¶] | 1 | 124 | 0 | 0 | 1 | 84 |
| Campylobacter jejuni | 0 | 0 | 1 | 15 | 1 | 102 |
| *Es. coli* O157:H7/*Ca. jejuni* | 0 | 0 | 1 | 781 | 0 | 0 |
| Small round-structured virus | 0 | 0 | 1 | 70 | 0 | 0 |
| *Cryptosporidium parvum* | 1 | 5 | 0 | 0 | 0 | 0 |
| Sodium hydroxide | 1 | 2 | 0 | 0 | 0 | 0 |
| Nitrate | 0 | 0 | 0 | 0 | 1 | 1 |
| **Total** | **11** | **239** | **11** | **1,425** | **17** | **404** |
| **Percentage** | **28.2** | **11.6** | **28.2** | **68.9** | **43.6** | **19.5** |

# WBDOs by type of deficiency

**TABLE 5. Waterborne-disease outbreaks associated with drinking water, by type of deficiency and type of water system United States, 1999–2000 (n = 39)**

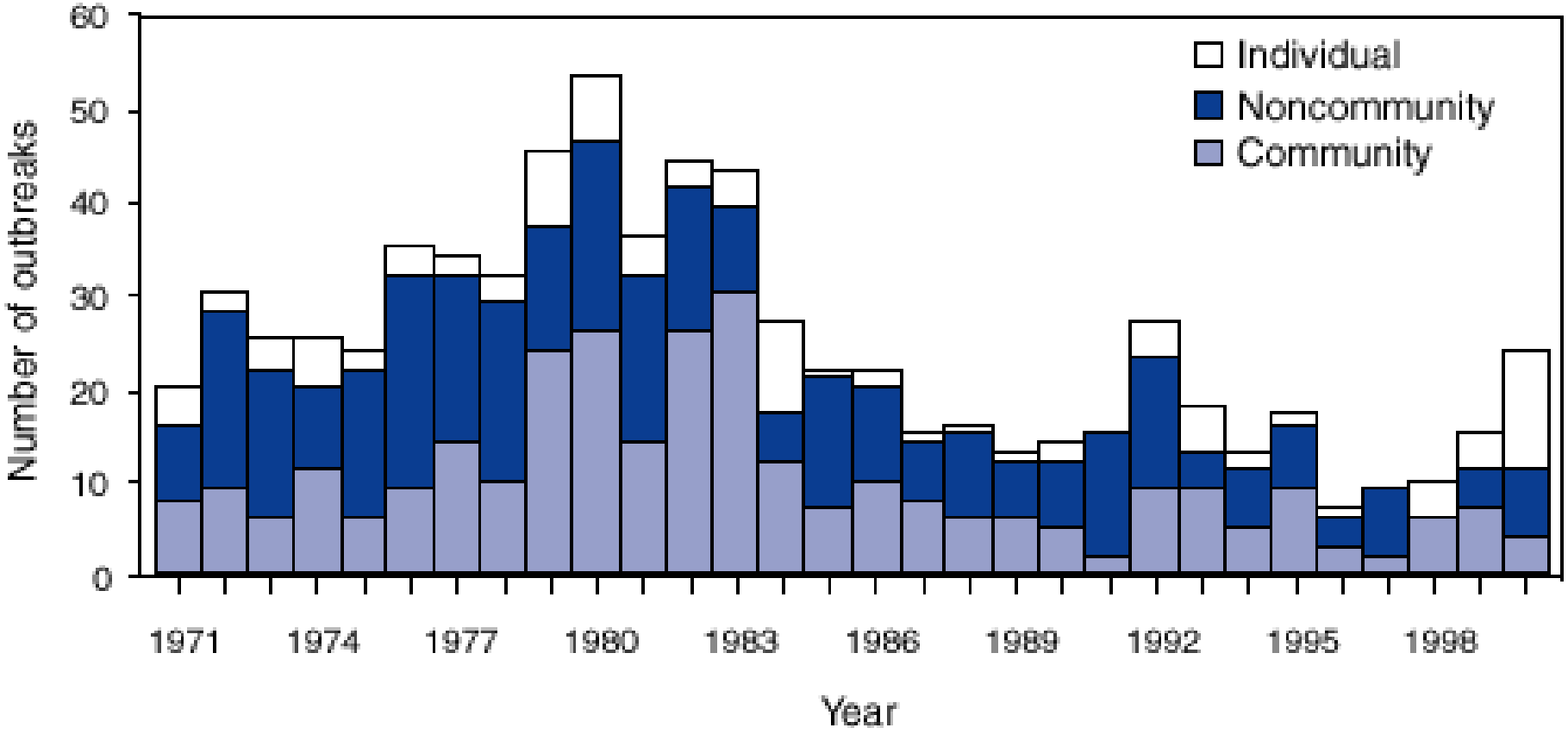
| | Type of water system* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Community | | Noncommunity | | Individual | | Total | |
| **Type of deficiency†** | **Outbreaks** | **%** | **Outbreaks** | **%** | **Outbreaks** | **%** | **Outbreaks** | **%** |
| Untreated surface water | 0 | 0 | 0 | 0 | 1 | 5.9 | **1** | **2.6** |
| Untreated groundwater | 1 | 9.0 | 8 | [illegible] | 8 | [illegible] | **17** | **43.6** |
| Inadequate treatment | 5 | [illegible] | 3 | [illegible] | 1 | 5.9 | **9** | **23.1** |
| Distribution system | 5 | [illegible] | 0 | 0 | 1 | 5.9 | **6** | **15.4** |
| Miscellaneous or unknown | 0 | 0 | 0 | 0 | 6 | 35.3 | **6** | **15.4** |
| **Total** | **11** | **100.0** | **11** | **100.0** | **17** | **100.0** | **39** | **100.0** |

**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.

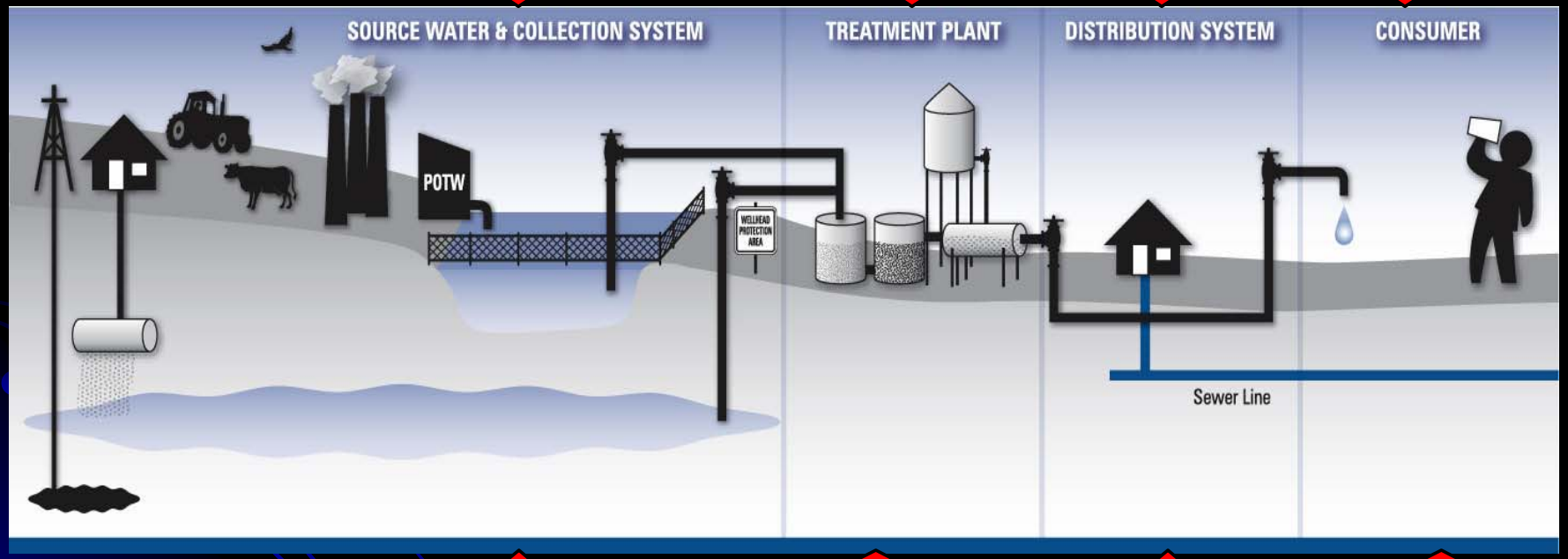
**FIGURE 6. Number of waterborne-disease outbreaks associated with drinking water, by year and type of water system — United States, 1971–2000 (n = 730)***




* The total from previous reports has been corrected from n = 691 to n = 688.

# SAFE DRINKING WATER ACT: PROTECTING AMERICA'S PUBLIC HEALTH

RISK RISK RISK RISK




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

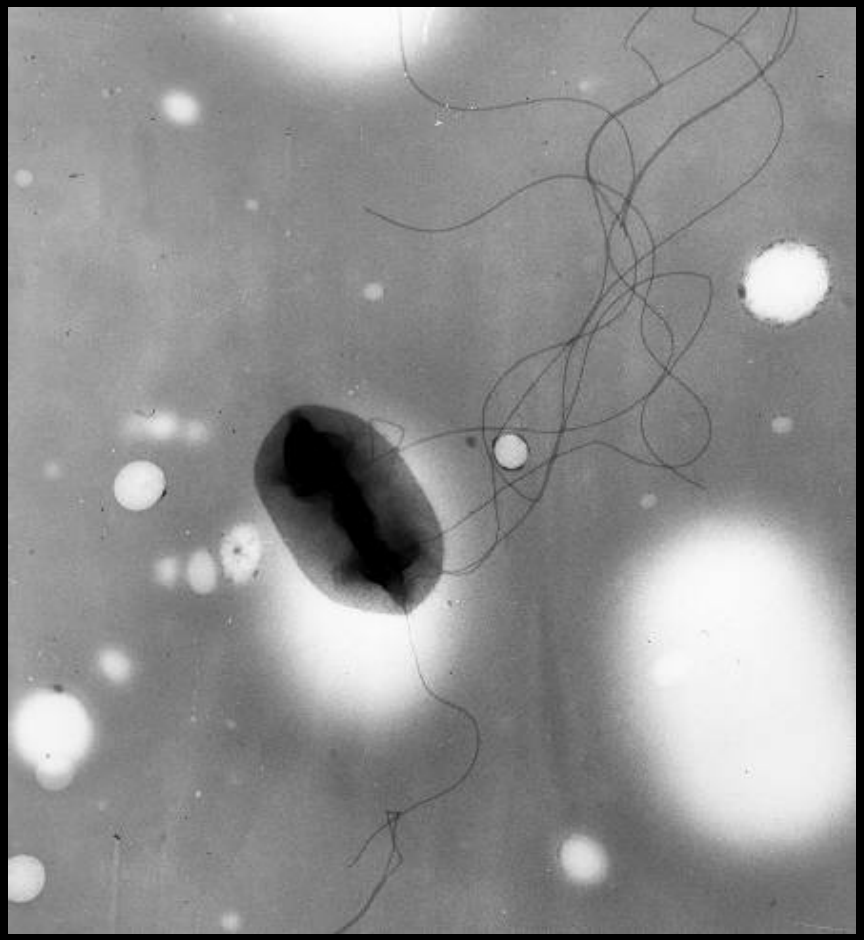
- Total Coliform Bacteria That:
  - Ferment Lactose at an Elevated Temperature When Using Standard (FC) Media
    - 44.5 +/- 0.2 C (Body Temperature)
- Fecal indicator
- <u>Short-Lived outside host</u>

# *Escherichia coli*

- *E. coli* is a fecal coliform
- May be a better indicator of sewage or fecal ccontamination 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

# Source Water Monitoring

- 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
  - $ClO_2$ gas generated on-site
- Ozone
  - $O_3$ 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

| Temperature Celsius | pH 6-9 | pH 10 |
|---|---|---|
| 0.5 | 12 | 90 |
| 5 | 8 | 60 |
| 10 | 6 | 45 |
| 15 | 4 | 30 |
| 20 | 3 | 22 |
| 25 | 2 | 15 |

# UV Dose ($mJ/cm^2$) from LT2ESWTR

| Log Credit | *Crypto-sporidium* | *Giardia* | Viruses |
|---|---|---|---|
| 0.5 | 1.6 | 1.5 | 39 |
| 1.0 | 2.5 | 2.1 | 58 |
| 1.5 | 3.9 | 3.0 | 79 |
| 2.0 | 5.8 | 5.2 | 100 |
| 2.5 | 8.5 | 7.7 | 121 |
| 3.0 | 12 | 11 | 143 |
| 3.5 | 15 | 15 | 163 |
| 4.0 | 22 | 22 | 186 |

# 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