Chemical Contamination of Food, Water, and Medication

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Faculty Disclosure

• Faculty: Charles McKay MD
  – Relationships with commercial interests:
    • Principal Investigator for clinical trial (Alere)
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  – Other: none
Learning Objectives

• Describe how U.S. drinking water is produced as a prototype for the water, food, and medication systems

• Use past incidents of water, food, and drug contamination to identify system vulnerabilities and potential agents of concern

• Describe system-wide changes or legislation resulting from past accidental or terrorist events

• Identify resources detailing measures used to protect the water, food, and drug supplies
Water Treatment

• State / federal EPAs regulate public drinking water safety (Safe Drinking Water Act) in US
• Common treatment steps:
  – Coagulation / Flocculation
  – Sedimentation
  – Filtration
  – Disinfection
Typical Public Drinking Water System

1. **Lake or Reservoir**: Water is collected from a lake or reservoir.
2. **Coagulation**: Coagulants are added to remove dirt, other particles, and to form tiny sticky particles called "floc" which attract the dirt particles. The combined weight of the dirt and the coagulant (floc) becomes heavy enough to sink to the bottom during sedimentation.
3. **Sedimentation**: The heavy particles (floc) settle to the bottom and the clear water moves to filtration.
4. **Disinfection**: A small amount of chlorine is added or some other disinfection method is used to kill any bacteria or microorganisms that may be in the water. Water is placed in a closed tank or reservoir for disinfection to take place. The water then flows through pipes to homes and businesses in the community.
5. **Filtration**: The water passes through filters, some made of layers of sand, gravel, and charcoal that help remove even smaller particles.

Source: AWWA Drinking Water Weekly Blue Thumb Kit
Coagulation/Flocculation

Coagulation removes dirt and other particles suspended in water. Alum and other chemicals are added to water to form tiny sticky particles called "floc" which attract the dirt particles. The combined weight of the dirt and the alum (floc) become heavy enough to sink to the bottom during sedimentation.
Sedimentation:
The heavy particles (floc) settle to the bottom and the clear water moves to filtration.
Filtration: The water passes through filters, some made of layers of sand, gravel, and charcoal that help remove even smaller particles.
Disinfection: A small amount of chlorine is added or some other disinfection method is used to kill any bacteria or microorganisms that may be in the water.

Storage: Water is placed in a closed tank or reservoir for disinfection to take place. The water then flows through pipes to homes and businesses in the community.
Water System Vulnerabilities

The Water System,

• Is essential for health & safety
• Comprises spatially diverse elements
• Is susceptible to intrusion
• Provides numerous attack sites
• Is difficult to protect against backflow attacks
• Contamination is difficult to trace
Maple Leaf Reservoir (Seattle, WA)

- Sept 10th, 2002
- Breach of fence around 60,000,000 gal finished water reservoir reported.
- 15 foot garden hose found near cut in fence.
- First noted 2 days earlier but not reported to supervisors.
Questions

When water supply adulteration is suspected,
– What chemicals should we test for?
– Who can run STAT tests for significant chemical contaminants?
– What criteria do you use to say the water is safe to drink?
Maple Leaf Reservoir (Seattle, WA)

- Tests on hose and reservoir water negative
- No claims of responsibility
- No clusters of illness identified
- Reservoir water disinfected and reprocessed
The Ideal Drinking Water Contaminant

- Resists water treatment
- Is difficult to detect
- Is difficult to clean
  - Pipes, reservoirs, etc
- Causes illness:
  - Delayed onset
  - Difficult to diagnose

- Readily available
- No odor & taste
- Colorless
- Water soluble
- Stable in water (i.e., resistant to hydrolysis)
- Unexpected
- Low LD50
Relative Water Toxicity

$$R = \frac{\text{Solubility}}{\text{Lethal Dose}} \times 1000$$

<table>
<thead>
<tr>
<th>Compound</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Botulinum Toxin</td>
<td>10,000</td>
</tr>
<tr>
<td>VX</td>
<td>300</td>
</tr>
<tr>
<td>Sarin</td>
<td>100</td>
</tr>
<tr>
<td>Nicotine</td>
<td>20</td>
</tr>
<tr>
<td>Cyanide</td>
<td>9</td>
</tr>
<tr>
<td>Amiton (OP)</td>
<td>5</td>
</tr>
<tr>
<td>Na Fluoroacetate</td>
<td>1</td>
</tr>
<tr>
<td>Arsenite, arsenate</td>
<td>1</td>
</tr>
</tbody>
</table>

*Clark: J Contingencies Crisis Management 2000*
Cyanide Calculations

Cyanide salts as potential contaminants:

• Individual:
  – 250 mg Lethal Human Dose (oral)
    (250 mg/0.5 L = 500 mg/L = 0.5 g/L)

• Water System:
  – 0.0005 kg/L x 200,000,000 L = 100,000 kg = 220,000 lb = 110 tons
NaCN Tanker
Botulism Calculations

- 0.00003 µg/kg LD50 Mice
- 70 µg Lethal Human Dose
- 70 µg/0.5 L = 140 µg/L
- 140 µg/L x 200,000,000 L = 28,000 g
- 28 kg for 200,000,000 L Reservoir!
Filtration Spectrum
Cross-Connections

• Mix of non potable with potable water
• Distribution system pressure $\geq 20$ psi
• Backpressure: external$>$system pressure
• 1970-01: 459 events, 12,093 illnesses
  – Avg 1 line break/yr 1,000 person system

(Potential Contamination Due to Cross-connections and Backflow and Associated Health Risks. Issue Paper US EPA OGW & DW Aug 2002)
Cross Connection / Backflow Threats

One sociopath who understands hydraulics and has access to a drum of toxic chemicals could inflict serious damage pretty quickly to a water supply system in a neighborhood or a pressure zone without detection in most communities. - Denileon: JAWWA 2001
Cross Connection Example

North Carolina (1997)
• 60 gal. retardant foam pumped into hydrant
• No local labs for testing
• Water use ban on 40,000 households
• 90 million gallons used to flush system
• No drinking water for 39 hrs

Krouse: Opflow 2001
Drinking Water: Terrorism Detection

Detection Scenarios:

• Caught in the act
  (cameras, security, or eye witness reports)
• Online/Field detection & monitoring
• Water quality observations (odor, color, …)
• Mass Illnesses (often nonspecific)
  – ED/Public Health Surveillance Systems
Early Detection

• Online Phys/Chem Monitors
  – Chlorine, pH, Turbidity, Total Organic Carbon, Pressure, Radioactivity

• Rapid Field Testing Kits

• Online Biosensors
Online Biosensors

- Daphnia Toximeter®
- Algae Toximeter®
- Mosselmonitor®
- Fish Stations
More Information

Available Online at:
www.epa.gov/safewater/security

Response Protocol Toolbox: Planning for and Responding to Drinking Water Contamination Threats and Incidents
Physician Preparedness for Acts of Water Terrorism
An On-Line Readiness Guide

www.waterhealthconnection.org

Practicing healthcare providers are likely to be the first to observe unusual illness patterns resulting from intentional contamination of water and must understand their critical role as “front-line responders” in detecting water-related disease resulting from biological, chemical or radiological terrorism. The primary purpose of *Physician Preparedness for Acts of Water Terrorism: An On-Line Readiness Guide* is to provide healthcare practitioners with streamlined access to resources that will help guide them through the recognition, management, and prevention of water-related disease resulting from intentional acts of water terrorism.

In order to respond to a potential act of waterborne terrorism, the medical and public health community must have immediate access to constantly updated information. The physician on-line readiness guide was developed in order to provide access to *clinically relevant and updated information* in a format that offers easy access to practicing physicians in a clinical setting. The on-line readiness guide provides the following *educational components* to healthcare practitioners and public health specialists faced with addressing the evaluation and management of water-related disease resulting from terrorist activity:

- Review of the threat of water terrorism in the US including water as a vehicle for transmission of biological, chemical, and radiologic agents from either direct or indirect environmental contamination.
- Completion of accurate exposure histories and assessment of multiple exposure pathways and contaminant sources as part of a clinical evaluation to accurately diagnose terrorism-related waterborne disease.
- Clinical resources addressing the accurate diagnosis, appropriate medical management, recommended laboratory evaluation, and prevention guidelines for biological, chemical, and radiologic compounds that may be used as waterborne agents.
- Specific precautionary guidelines for susceptible populations at increased risk for morbidity and mortality resulting from intentional chemical, biological, and radiologic contamination of water supplies.
- Use of epidemiologic clues and syndromic surveillance techniques to detect waterborne terrorism.
- Case reporting mechanisms and surveillance requirements for notification of suspected outbreaks or disease clusters resulting from a potential terrorist water contamination event.
- Effective risk communication strategies and public education procedures for discussing health risks associated with intentional water contamination.

PHYSICIAN PREPAREDNESS FOR ACTS OF WATER TERRORISM
www.WaterHealthConnection.org

Author: Patricia L. Meinhardt, MD, MPH, MA

Section 1: Purpose of Physician Readiness Guide for Acts of Water Terrorism
Section 2: Understanding the Threat of Water Terrorism
Section 3: Chemical, Biological and Radiologic (CBR) Agent Dispersal and Multiple Exposure Pathways
Section 4: Detection and Diagnosis of Waterborne Terrorism
Section 5: Evaluation and Management of Disease Resulting from CBR Agents
  Section 5.1: Clinical approach and medical management of BIOLOGICAL AGENTS
  Section 5.2: Clinical approach and medical management of BIOLOGICAL TOXINS
  Section 5.3: Clinical approach and medical management of CHEMICAL AGENTS
  Section 5.4: Clinical approach and medical management of RADILOGIC AGENTS
Section 6: Clinician Role in Risk Communication and Community Readiness
Section 7: Clinician On-Line Resources Guide and Targeted Search Engine Tools
Section 8: Glossary of Disaster Preparedness Terms

Section 5.1 Biological Agents
Section 5.2 Biological Toxins
Section 5.3 Chemical Agents
Section 5.4 Radiologic Agents
Which of the following statements regarding US drinking water standards is correct?

1. FDA enforces standards set by the EPA
2. EPA sets and enforces standards either directly or through state-run programs
3. USDA enforces standards set by the EPA
4. EPA specifies the methods used to enforce standards
5. EPA enforces standards set by the FDA
Protecting Food: FDA vs USDA Roles

• USDA regulates meat, poultry, eggs, & processed egg products
• FDA regulates all other foods (~ 80% of US food supply)
• FDA & USDA, high risk foods:
  – large batches
  – uniform mixing
  – short shelf life
  – ease of access
Factors Enhancing Food System Vulnerability

- Concentration of primary production in large, monoculture farms/stockyards
- Raw goods from small suppliers combined
- Concentration of commodity food-processing in large centralized facilities
- Quality control not designed to detect unanticipated contaminants/poisons
Botulism Threat

• Potency: “Most Lethal Substance”
  – 70 ug Lethal Oral Dose
  – 70 gm Could Kill 1,000,000 People

• Prolonged ICU Requirement
  – May Exhaust Supply of Ventilators

• Easy to Mass Produce
  – Russia, Iraq, Iran, Syria, North Korea
  – 1991 “Iraqi Stockpile”: 19,000 L
Botulinum toxin inhibits acetylcholine release. [Arnon: JAMA 99]
Analyzing a bioterror attack on the food supply: 
The case of botulinum toxin in milk

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We developed a mathematical model of a cows-to-consumers supply chain associated with a single milk-processing facility that is the victim of a deliberate release of botulinum toxin. Because centralized storage and processing lead to substantial dilution of the toxin, a minimum amount of toxin is required for the release to do damage. Irreducible uncertainties regarding the dose-response curve prevent us from quantifying the minimum effective release. However, if terrorists can obtain enough toxin, and this may well be possible, then rapid distribution and consumption result in several hundred thousand poisoned individuals if detection from early symptomatics is not timely. Timely and specific in-process testing has the potential to eliminate the threat of this scenario at a cost of <1 cent per gallon and should be pursued aggressively. Investigation of improving the toxin inactivation rate of heat pasteurization without sacrificing taste or nutrition is warranted.
Fig. 1. The milk supply chain.
Botulinum Contaminated Milk

- Toxin placed in holding tank at farm, tanker truck from farm or raw milk silo at plant
- Without detection
  - < 1g toxin → 100,000 poisoned persons
  - 10g → 568,000 poisoned persons
- Early symptomatic detection:
  - 2/3 cases avoided yet
  - 10 g → 100,000 poisonings
- Children would form a larger percentage of the victims with lower doses of toxin
Inactivating Botulinum Toxin

• Botulinum toxin cannot be completely inactivated by radiation or any heat treatment that does not adversely affect the milk’s taste.

• Ultrahigh-temp pasteurization (UHT) can inactivate botulinum toxin but has not been embraced by U.S. consumers.
Maine Arsenic Poisonings

- 1 died, 15 others were sickened following Sunday services in 2003
- Next day, maintenance man died of gunshot wound to chest
- Victims shared coffee and food
- Arsenic was found in the coffee pot.
Toxic Oil Syndrome (Spain 1981)

- Illegally marketed cooking oil
- Rapeseed oil denatured with 2% aniline
- 20,000 poisoned, 12,000 hospitalized
- > 340 died
- Toxic Oil Syndrome
  - Pneumonitis
  - Eosinophilia
  - Pulmonary hypertension
  - Scleroderma-like changes
  - 50% Peripheral neuropathy, myopathy

Billions in Compensation for Toxic Oil Poisoning Victims
Impact of Potential Food Terrorism

• Roles of:
  – Threat analysis
  – Identification
  – Response/Mitigation
  – Recovery

• Impact of contamination
  – Beginning vs. end of food production/delivery process

• Multidisciplinary response with active communication needed
How Safe are US Medications?

• Drug production is a complex process
  – Synthesis → Delivery to the patient
  – Multiple steps for interference

• Depending on the circumstances, the results can be devastating:
  – Primary Impact (fatalities, illness)
  – Fear/Uncertainty
  – Economic Impact
Tylenol Murders (Chicago, 1982)

- 7 died from KCN laced Tylenol
- 1-2 bottles per store
- <10 tampered/ deformed looking capsules/bottle
- Capsules filled with KCN (100-150mg)
Copycat (1986)

- Woman in WA state killed her husband with cyanide-laced pain killer
- Attempted to cover her tracks by placing packages of poisoned Excedrin and Anacin capsules on the shelves of 3 stores
- Nickell was sentenced to 90 years in prison.
The Tylenol Bill

1983

"Tylenol Bill” made malicious tampering with consumer products a federal offense.

1989

FDA established a national requirement for tamper-resistant packaging of over-the-counter products.

• Triple-seal, tamper-resistant packaging now the norm.
Diethylene Glycol (DEG)

Mysterious Cases of Renal Failure (Haiti)

- 86 cases of acute renal failure:
  - Nov 1995 to June 1996 (8 months)
  - Children aged 3 months – 13 years
- Traced to DEG-contaminated pain medication
- DEG was used to dissolve an early antibiotic causing >100 deaths
- Led to passage of the Food, Drug, and Cosmetic Act (1938)
- Epidemics of renal failure and death due to DEG still occur
Heparin Contamination

• FDA announced increased allergic reactions and deaths related to the use of heparin in 2008
• Samples contained 5-20% of an inexpensive non-heparin ingredient that mimicked heparin – Oversulfated chondroitin sulfate
• The implicated ingredient originated in China
Other Aspects of Medication Quality Control

• Dietary Supplement Health and Education Act of 1994
  – Excludes supplements from FDA oversight, unless harm shown
  – Issues of safety, efficacy, contents, and purity are responsibility of manufacturer
    • Asian patent medicine and other ethnic medications
    • Ephedra-containing products
    • Examples of raw ingredient mixing errors

• Fraudulent prescription medicines via Internet
  – Particularly from other countries
Conclusions

• Numerous past incidents reveal vulnerabilities
• Potentially very injurious
• Difficult to prevent, detect, mitigate
• Toxicity, availability determine likelihood
Questions