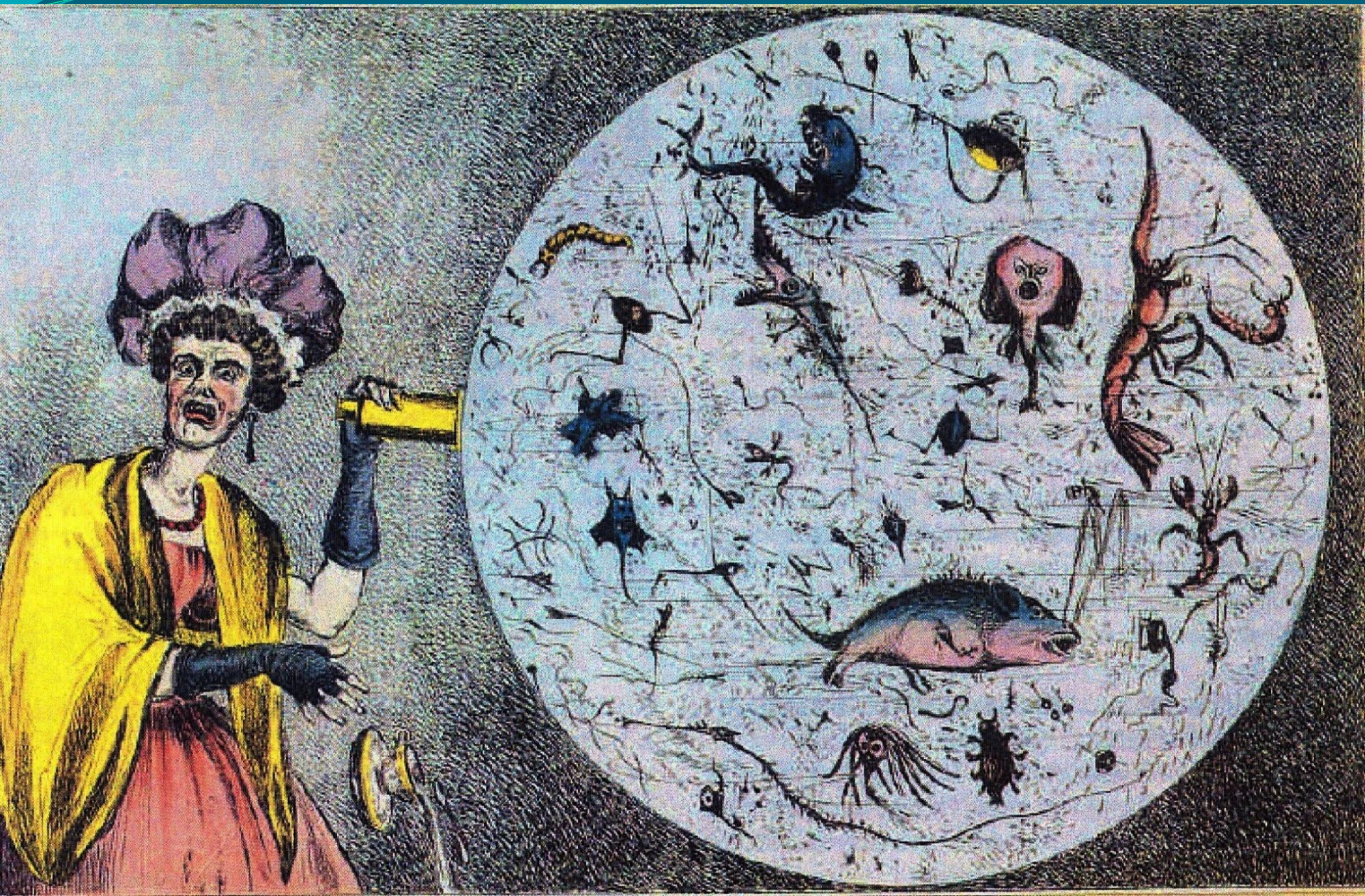
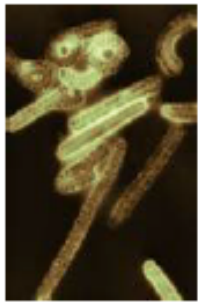
Water Contamination Incidents



Diseases Associated with Water

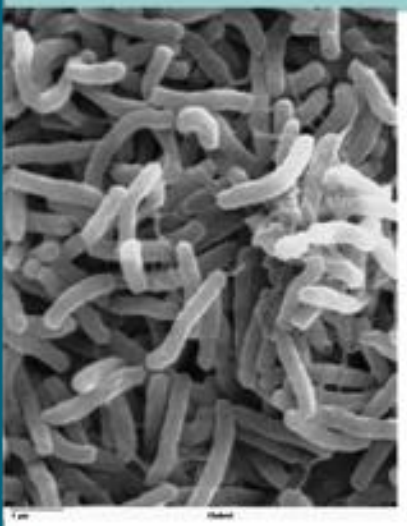


Class	Cause	Disease
Waterborne	Pathogens transmitted by faecal-oral route (sewage or run-off)	Cholera, hepatitis, cryptosporidiosis E. coli 0157:H7
Water-based	Pathogens naturally present in water	Schistosomiasis, Legionnaires' disease
Water-related	Pathogens associated with mosquitoes	Yellow fever, Ross river virus, Dengue, Malaria

John Snow Detailed Epidemiological Study of a Cholera Outbreak - Proving it to be Waterborne

- Outbreak of cholera in London (1848) > 500 deaths in 10 days
- Investigated and mapped deaths - central was the Broad Street water pump
- Pump handle removed, outbreak controlled
- Subsequently experimented with Chlorine to purify water

Cholera Epidemic in Hamburg 1892, Elbe River, 10,000 deaths in 6 weeks

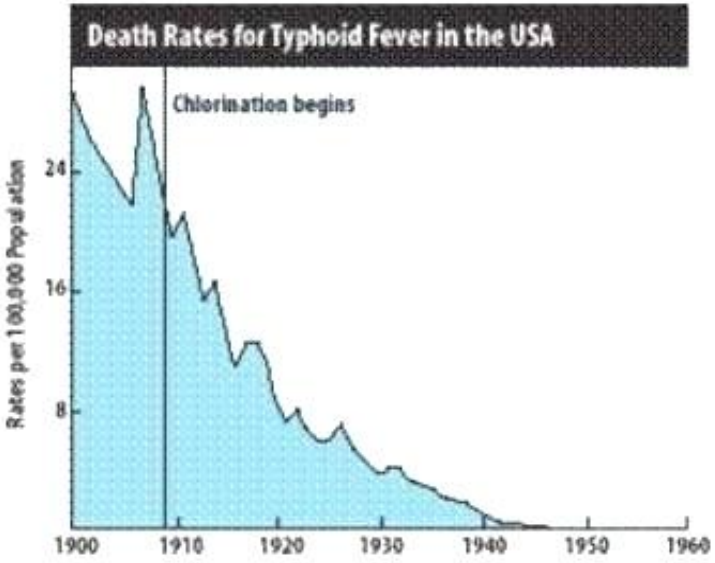


More cases in Hamburg than downstream in Altona where Elbe river water was treated by sand filtration

Robert Koch "germ" disease theory led to a water filtration plant and sewerage system

Typhoid City

	Chicago	Milwaukee
Intake from Shore (m)	1070	210
Sewage Discharge	Re-located	Lake Michigan
Chlorine (1914)	Continuous	Stopped
Typhoid Deaths	30 (10 x lower)	60 (10 x higher)



Rules for Managing Pathogens

- Pathogens are the greatest threat to water safety
- Robust multiple barriers are essential
- Require procedures written by experienced operators
- Trouble is often preceded by change
- Need people able to make good decisions under pressure

Washington County Fair
Albany NY (1999)

Analysis

- Largest *E. coli* O157:H7 outbreak in United States
- Washington County Fair, August 23-29, 1999, Albany NY
- Up to 5000 people developed gastrointestinal illness
- 781 confirmed cases, 71 hospitalized , two deaths
- Septic system approximately 10 metres from a well
- Un-chlorinated well water used to make drinks and ice

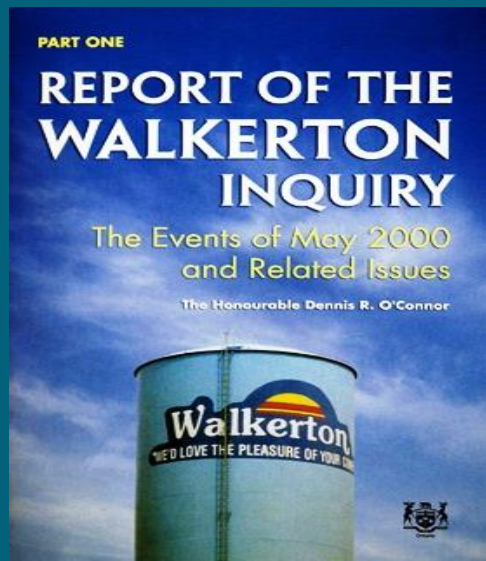
Walkerton

- This was the largest *E. coli* O157:H7 outbreak in Canada
- Walkerton is a prosperous community of 5000 people
- Starting May 15 2000, people began to experience diarrhoea
- There were an estimated 2300 cases of gastroenteritis
- Seven people died, 65 people were hospitalized

Walkerton, Ontario, Canada

Analysis

- Heavy rain, 134 mm in five days with 70 mm falling on 12 May
- On April 22nd 70 tons cattle manure spread at a nearby farm
- Water sourced from a shallow ground water wells
- No treatment plant, operators fail to chlorinate the water
- Manager and Foreman jailed for:
  - drinking on the job
  - failing to use adequate doses of chlorine
  - failing to monitor chlorine residuals daily
  - falsifying operating records



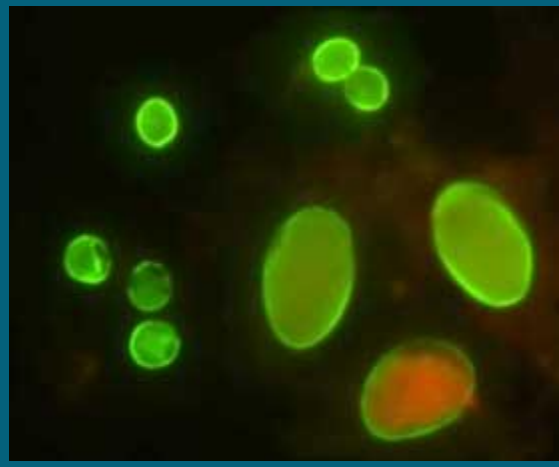
Contamination Site

North Battleford

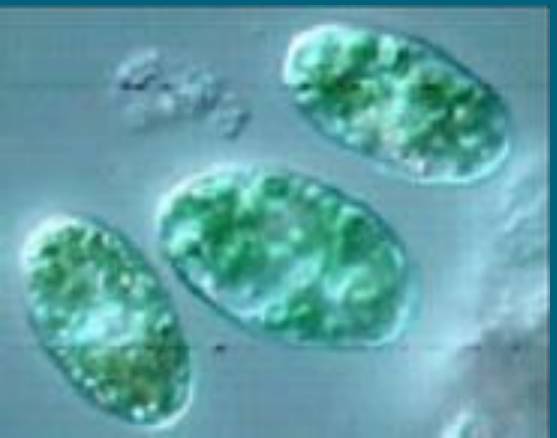
- Battleford is a prosperous community of 15,000 people
- Starting March 2001, people experienced severe diarrhoea
- This was the largest parasitic outbreak in Canada
- There were an estimated 6500 cases of gastroenteritis
- 1st positive case of cryptosporidiosis confirmed on April 4

Cryptosporidium

Left emerging
Cryptosporidium sporozoite
Right Giardia (8 to 12µm)
Cryptosporidium (4 to 6 µm)



First identified in animals (1907) but not in water until 1984 (Braun Station, Texas)



Chlorine resistant but inactivated by O_3 or UV

Issues

- North Saskatchewan River poses challenges at times of spring run-off, rapid changes in turbidity (1 to > 1,000 NTU)
- Sewage treatment plant discharge only 3.5 km upstream
- Conventional water treatment plant (10 ML/d) built in 1950
- Judged 'not a capable plant' based on design and operation
- In 2000, coliform detections in distribution samples , chlorine residuals below the standard, turbidities > 1 NTU
- A relative lack of training and education of operators

North Battleford Canada

Analysis

- Raw water turbidities 2.5 to 7 NTU (ie low) coagulation problems
- March 20 the up-flow blanket clarifier was emptied for repair
- No sludge blanket, no effective clarification for 5 weeks
- Filtration the only barrier to cryptosporidium
- Low demand 3.1 ML/day, plant operation 6 to 8 hours per day
- Stop/start filters returned to service next day without backwash
- Treated water turbidity > 0.5 NTU on 9 days (0.2 to 1 NTU)

Milwaukee

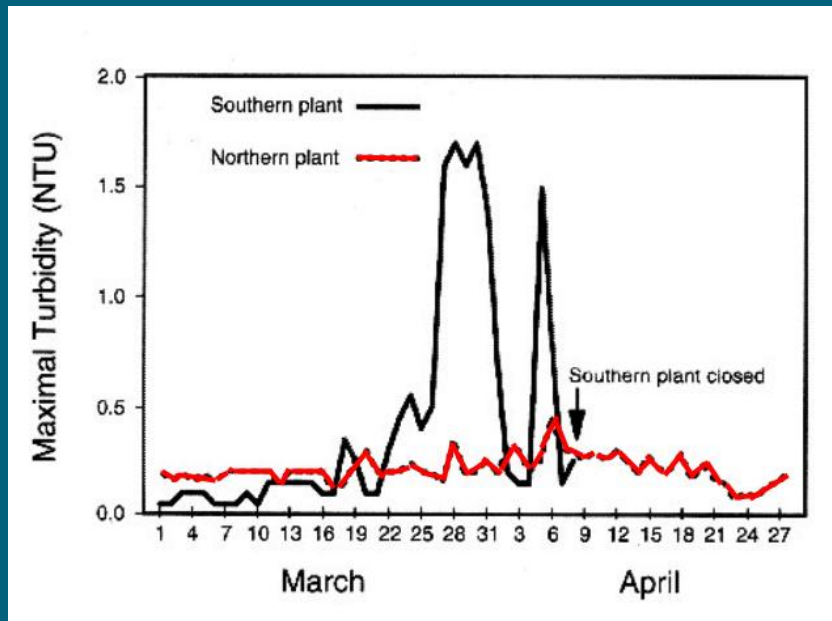
- Milwaukee, Wisconsin, population 880,000 people
- In 1993 the largest waterborne disease outbreak in U.S.
- March 23 to April 8 more than 400,000 people infected
- 4400 people were hospitalized with cryptosporidiosis
- 100 persons are believed to have died from the illness

Milwaukee

Water Treatment Plant Intakes

Sewage Plume

Plant Turbidities



Background

There were two contributing factors:

- A contaminated source water (Lake Michigan) and
- Sub-optimised coagulation allowing cryptosporidium to pass through the filters at the Howard water treatment plant
- The water treatment plant was commissioned in 1962
- It has a capacity of 100 mgd (400m^3/day) with eight filters
- Its intake is 13 metres deep, 2.3 km from the shore-line
- Raw water quality is usually good but with variable turbidity
- However, the water intake was within a sewage plume

Operating Data

- *Changed* to poly-aluminium chloride after 30 years using alum
- Settled water turbidities increased from 2 to 6 NTU on the 24th
- Filtered water turbidity increased from about 0.2 to 0.5 NTU
- Jar tests showed more cloudiness at higher PACl doses and therefore operators reduced dosing rates on the 26th
- This resulted in inadequate coagulation and an increased filtered water turbidity of 2.1 NTU (potentially 0.1 to 10 NTU)
- Changes in dose rate had no immediate affect with similar high turbidity readings of 2.1 NTU on the 28th and 29th
- On 2nd April PACl dosing was stopped and Alum used
- Turbidity Levels eventually stabilised at 0.2 NTU on the 7th April

Notes

- E-coli counts were zero and the treated water complied with both State and Federal standards for turbidity and water quality
- 7 other treatment plants used water from Lake Michigan at the same time and had turbidity problems but not cryptosporidium
- The start of the outbreak can be correlated with a critical turbidity value of 0.5 NTU on 24th March and high for the next 7 days
- Cryptosporidium oocysts are very small (4 to 6 µm)
- During the outbreak:
  - the filtration rate was very low (1 m/hour)
  - the sand media was very fine (0.35 mm)
  - filters were rested after backwashing
- These factors did not compensate for ineffective coagulation

North Thames Cryptosporidium

- Feb to April, 1997, 746,000 boil water advisory notices issued
- 345 confirmed cryptosporidiosis cases
- 26 people were hospitalized , two died

- The largest cryptosporidium outbreak from a ground water supply
- The first reported outbreak caused by filtered bore water
- Only six of 605 boreholes in a UK survey had earlier tested positive for cryptosporidium (maximum level of oocysts was 1 per 1000 ml)

North Thames Cryptosporidium

- A 2 year drought followed by rainfall 162% above February average
- Well water supplied from a chalk aquifer 50-70 metres (m) deep
- Well head 17 m from a river with sewage discharged 8 km upstream
- River water samples at sewage works revealed few or zero oocysts
- 3 other clusters near by at the same time - possible cattle grazing links
- Water treatment plant with ozone and granular activated carbon filters designed to remove pesticides but not cryptosporidium

Clay Lane Water Treatment Plant

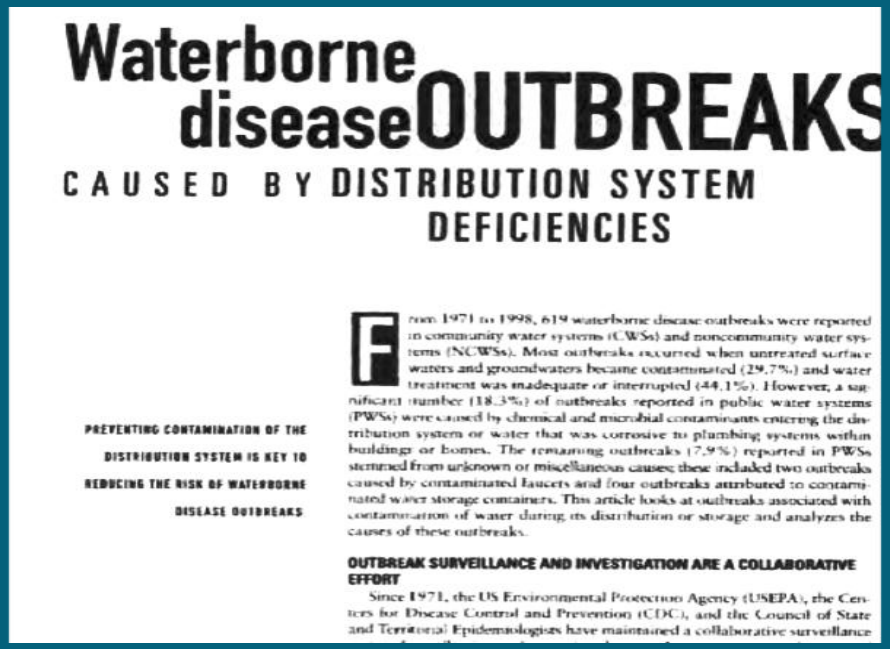
- Built in 1953, Ozone and rapid GAC filters, chlorination , 160 ML/day
- Good quality source water , eight deep wells in a chalk aquifer
- Oocyst load too great for coarse GAC filter media (oocyst 4 to 6 µm)
- Filter to waste following backwash practiced
- Recycled backwash supernatant may have contributed to outbreak

Maximum Cryptosporidium Oocysts per 1000 ml			
Raw Water	Backwash	Filtered Water	Distribution
0.2	0.2	0.3	0.3

More Facts for Managing Pathogens

- 50% of outbreaks linked to wet weather
- 40 % of incidents relate to source water quality
- 40 % of incidents relate to treatment operation
- 80 % of protazoan incidents - caused by ineffective filtration
- 95 % of bacterial incidents - due to ineffective (or zero) chlorination
- 60 % of incidents caused by faults in storage or distribution system

Preventing Contamination of the Distribution system is the Key to reducing Waterborne Disease Outbreaks



Waterborne disease OUTBREAKS CAUSED BY DISTRIBUTION SYSTEM DEFICIENCIES

PREVENTING CONTAMINATION OF THE DISTRIBUTION SYSTEM IS KEY TO REDUCING THE RISK OF WATERBORNE DISEASE OUTBREAKS

From 1971 to 1998, 619 waterborne disease outbreaks were reported in community water systems (CWSs) and noncommunity water systems (NCWSs). Most outbreaks occurred when untreated surface waters and groundwaters became contaminated (29.7%) and water treatment was inadequate or interrupted (44.1%). However, a significant number (18.3%) of outbreaks reported in public water systems (PWSs) were caused by chemical and microbial contaminants entering the distribution system or water that was corrosive to plumbing systems within buildings or homes. The remaining outbreaks (7.9%) reported in PWSs stemmed from unknown or miscellaneous causes; these included two outbreaks caused by contaminated faucets and four outbreaks attributed to contaminated water storage containers. This article looks at outbreaks associated with contamination of water during its distribution or storage and analyzes the causes of these outbreaks.

OUTBREAK SURVEILLANCE AND INVESTIGATION ARE A COLLABORATIVE EFFORT

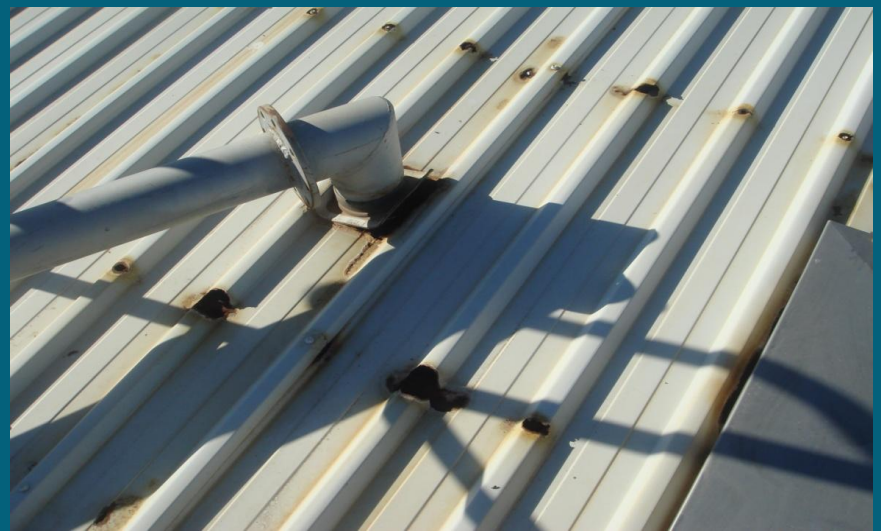
Since 1971, the US Environmental Protection Agency (USEPA), the Centers for Disease Control and Prevention (CDC), and the Council of State and Territorial Epidemiologists have maintained a collaborative surveillance

This platform was used to access inside of standpipe for purposes of removing bird carcasses and adding sodium hypochlorite solution in order to disinfect with free chlorine.

Procedures for Flushing and Replacing Hydrants

Procedures for New Mains and Breaks

Procedures for Reservoir Maintenance



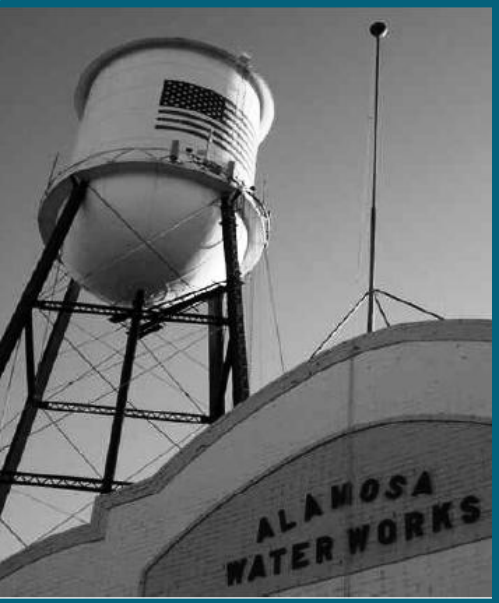
Gideon , Missouri

- Location - Gideon, an unremarkable mid-west town of 1100 people
- A large waterborne salmonella outbreak between Nov and Dec 1993
- In November, seven cases of Salmonella confirmed
- There were an estimated 650 cases of acute gastroenteritis
- 15 people were hospitalized and there were 7 deaths

Analysis

- Two bores 390 metres deep constructed mid-1930s
- 500 KL/day <u>un-chlorinated supply</u>
- Coliforms detected in water and sediment samples
- Water storage tower had corroded roof vents and an uncovered hatch
- <u>Bird feathers were observed in the tank</u>
- Contaminated sediment most likely pulled into the distribution system by an extensive flushing program

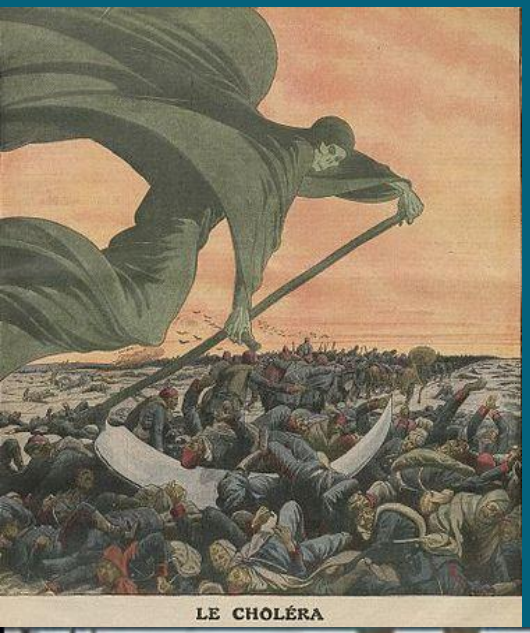
Alamosa, Colorado



- Alamosa, population 8900 people
- A large waterborne Salmonella outbreak, 2008
- Almost 2000 people reported gastrointestinal illness, 442 confirmed salmonella cases, one death
- Unchlorinated bore-water supply
- A new membrane and chlorination treatment plant was in commissioning stage – but to meet new 10 µg/L EPA standard for Arsenic

- Good quality bore water from a low risk confined aquifer (300 to 550m)
- 98% coliform compliance and all positive results negative in re-samples
- Contamination event started March 3 to 5, peak March 17 to 21, 2008
- One positive coliform result on March 17 (a poor indicator)
- Salmonella found in water samples and Weber Reservoir on March 20
- Weber reservoir in poor condition (last cleaned in 1984)
- No active distribution system maintenance and no flushing program
- Contamination of reservoir by one or a small group of animals

Those who cannot change the past are condemned to repeat it



1 billion people lack access to safe water

2 million deaths per annum caused by unsafe water

120,000 cholera deaths each year in > 50 countries