

Waterborne Diseases

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History of epidemics and pandemics



- 430 BC, the plague of Athens
 - Unknown agents
 - Killed one third of population
 - Ended the Golden Age of Athens
- 166 AD, the Antonine plague
 - Smallpox?, bubonic plague?, measles?
 - Killed 4-7 million
 - Helped to the collapse of Roman Empire
- 1346 to 1350, bubonic plague (Black Death)
 - *Yersinia pestis*
 - Killed one third of the population of Europe
- 16th Century, epidemics in Central and South America
 - Smallpox, yellow fever, malaria, ...
 - Killed one third of the population (10 years)
 - Lead to the collapse of Aztec, Maya, and Inca Empires
- 1817 – 1970, Cholera pandemics
 - *Vibrio cholerae*
 - Killed millions people worldwide
- 1918 -1919, Influenza pandemic
 - Avian influenza A (H1N1)
 - Killed 20 -50 million people worldwide

The Plaque of Athens

- Peloponnesian War (431-404 BC)
- Fortification of Attica
- The plaque (waterborne disease?)
 - Dense population with poor sanitation
 - Typhoid fever?
 - Killed one third of population
 - Ended the Golden Age of Athens

Cholera

- Endemic in India, Pakistan, and Bangladesh.
- Seven (eight?) pandemics
 - 1st: 1817-1823, 2nd: 1829-1851, 3rd: 1852-1859, 4th: 1863-1879, 5th: 1881-1896, 6th: 1899-1923, 7th: 1961-1970, 8th: 1991-present?
- Pathology
 - very virulent
 - 40-60 % mortality if untreated (< 1% with oral rehydration therapy)
 - death after 12-48 hours

Sir John Snow



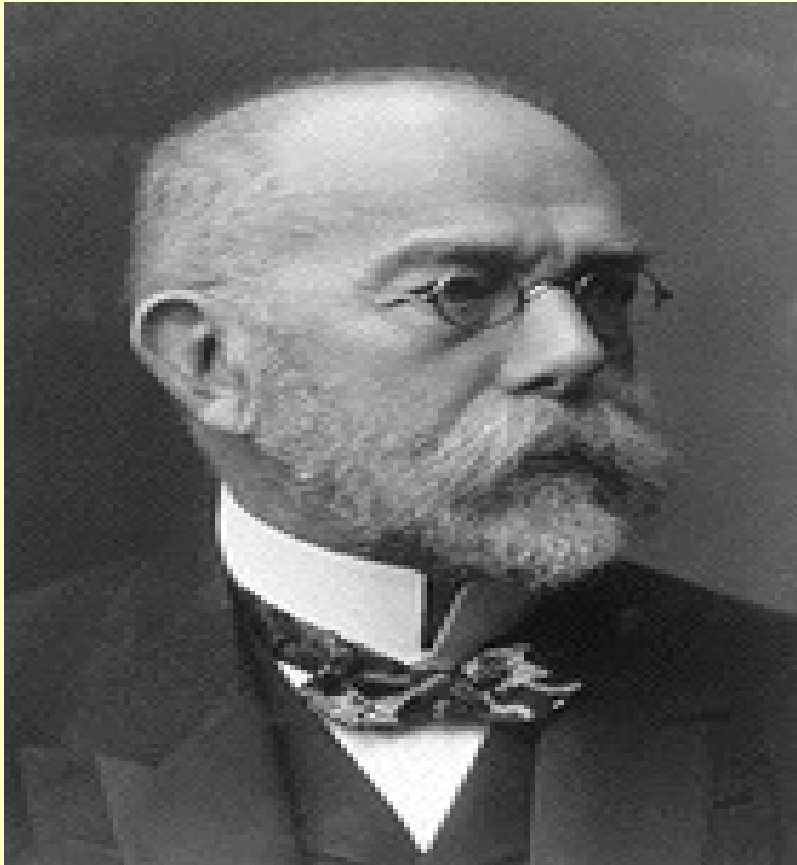
- 1813-1858
- Published “On the Mode of Communication of Cholera”
 - 1st edition in 1849
 - 2nd edition in 1855,
 - the effect of the water supply on certain districts of South London (Soho) during the 1854 Cholera epidemic.
- One of the founding fathers of epidemiology

Cholera from drinking water?



- marked and plotted the deaths on a map
- realized that 197 people died (in 2 days) and 500 people died (in 5 days) within an area only 250 yards across
- found out that those people shared an well on Broad Street as their source of drinking water
- examined the well-site and concluded that the well was contaminated by a cesspool nearby
- ordered to remove the handle on the pump, which ended the local epidemic
- first to suggest drinking water is the source of the cholera

Dr. Robert Koch



- 1843-1910
- Proposed “the germ theory of disease”
- Developed techniques for culturing bacteria
- Identified the cause of anthrax, tuberculosis, wound infection and cholera
- One of the founding fathers of Microbiology

Water as a mode of transmission of infectious disease?

- discovered *Vibrio cholera* in Egypt in 1883 (as leader of the German Cholera Commission)
- investigated an incidence of cholera in two adjacent German Cities (Hamburg and Altonia) in 1892
 - pumped their water from the Elbe River (Altonia: downstream of Hamburg)
 - serious cholera outbreak in Hamburg, but mild outbreak in Altonia
 - 19,891 cases in 580,000 total population in Hamburg
 - 572 cases in 143,000 total population in Altonia
 - slow sand filter in Altonia

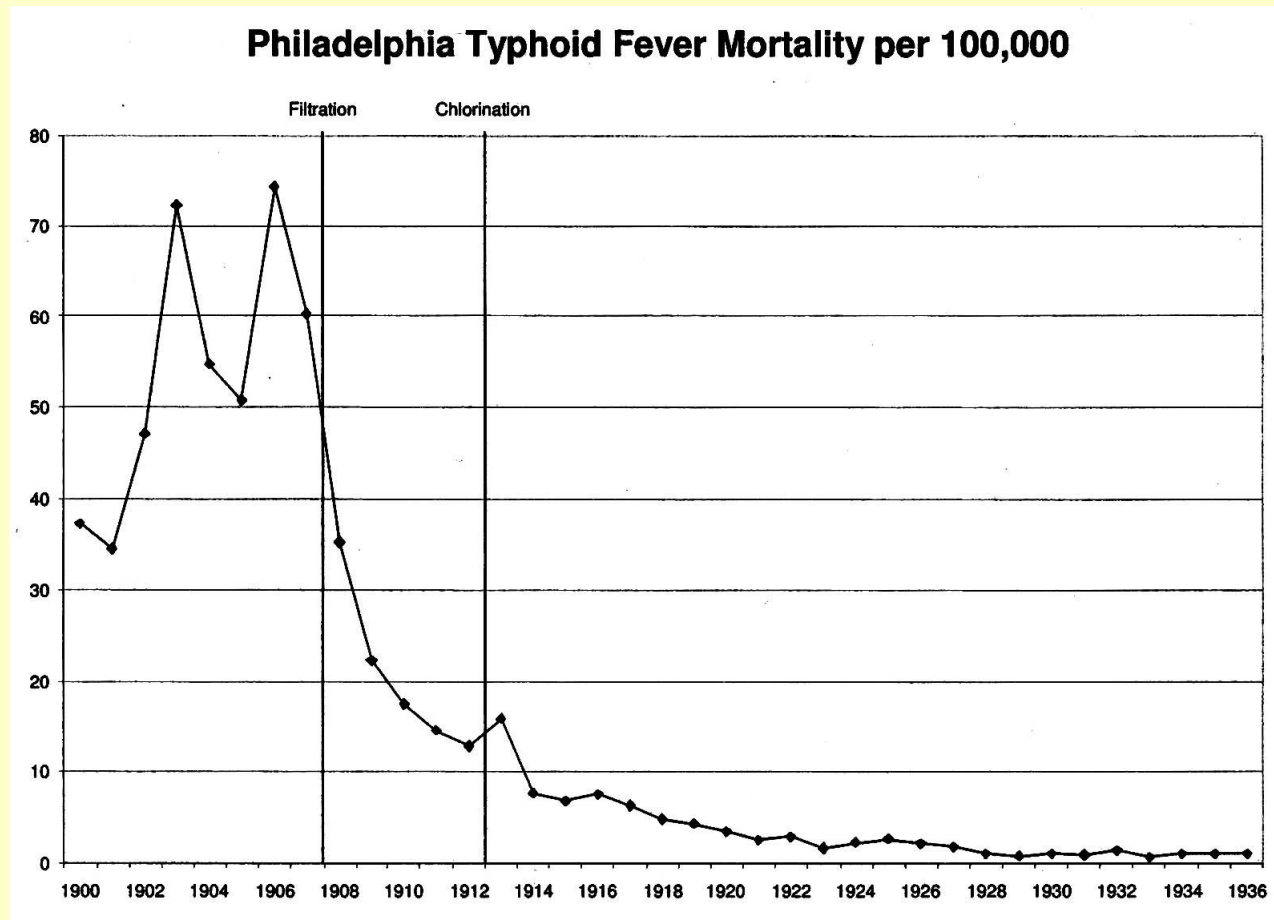
History of modern water treatment

- 1804: Slow sand filtration (Paisley, Scotland)
- 1880-1890: Rapid sand filtration, Coagulation, Flocculation
- 1893: Ozonation (Oudshoon, Netherlands)
- 1905: Chlorination (London, England)
- 1917: Chloramination (Ottawa, Canada)
- 1920-1930: Floc-blanket sedimentation, Solids-contact clarifier, and Dissolved air flotation
- 1962: Membrane technologies (Ultrafiltration, Nanofiltration, and Reverse Osmosis)
- 1960-1970: Chemical precipitation, chemical oxidation, and GAC
- 2000: UV disinfection

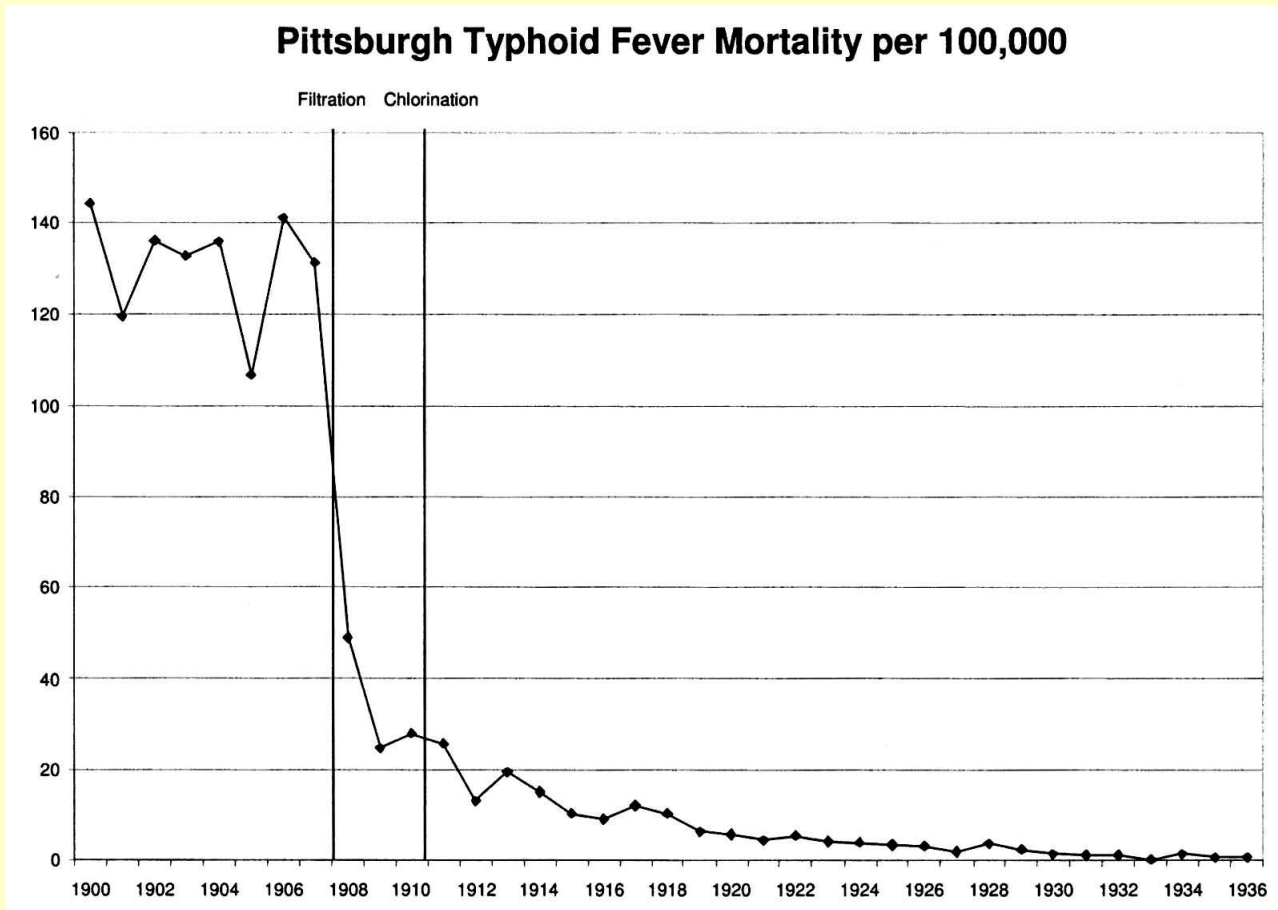
History of modern wastewater treatment

- 1690: Sewers (Paris)
- 1860: Septic tank (Louis Moureas)
- 1868: Trickling sand filter technology (Edward Frankland)
- 1911: Chlorination (London, England)
- 1914: Activated Sludge technology (Arden and Lockett)
- 1960: UV disinfection

Reduction of typhoid fever mortality (I)



Reduction of typhoid fever mortality (II)



Total, infant, child, and typhoid mortality in major cities of USA (1900-1936)

Table 2: The Evolution of Total, Infant, Child, and Typhoid Fever Mortality in Major Cities, 1900-1936

	Deaths per 100,000					
	1900		1920		1936	
	<u>Mean</u>	<u>Std Dev</u>	<u>Mean</u>	<u>Std Dev</u>	<u>Mean</u>	<u>Std Dev</u>
Total Mortality	1,935	316	1,492	222	1,354	287
Infant Mortality	18,931	2,921	11,953	1,752	7,130	2,435
Child Mortality	2,818	1,360	1,260	167	522	267
Typhoid Fever Mortality	47	33	4	2	2	2

Source: United States Census Bureau's *Mortality Statistics*, 1900-1936.

Waterborne outbreaks in the United States (1971-2000)

- 1,010 drinking water outbreaks with 596,177 cases between 1971-2000

TABLE 3.1 Waterborne Outbreaks Reported in the United States by Type of System or Activity, 1971–2000

Water System Type	Outbreaks	Cases of Illness	Emergency Room Visits	Hospitalizations	Deaths
Non-Community	340	54,893	116	868	4
Community	308	517,944	904	1056	65
Recreational	259	21,740	36	206	28
Individual	103	1600	5	93	3
All Water Systems	1010	596,177	1061	2223	100

Definitions

- Community water system: serves year-round residents of a community that has 15 or more connections or an average of 25 or more residents
- Non-community water system: used by the general public for greater than 60 or more days per year and at least 15 service connections or serve an average of 25 or more persons (factories and schools with their own water systems, restaurants, rest stops, parks, etc)
- Individual water system: not owned or operated by a water utility and serve less than 15 connections or less than 25 persons

TABLE 3.2 Waterborne Outbreaks in Drinking Water Systems by Type of System and Water Source, 1971–2000

Water Source	Number of Outbreaks			All Systems
	Community Systems	Non-Community Systems	Individual Systems	
Ground Water ^a	130	272	65	467
Surface Water ^b	142	44	23	209
Mixed	6	1	1	8
Unknown	30	23	14	67
Totals	308	340	103	751

^aSurface water = lakes, reservoirs, rivers, streams.

^bGround water = wells and springs.

TABLE 3.7 Waterborne Outbreaks and Deficiencies in Public Water Systems, 1971–2000

Type of Contamination	Community Systems		Non-Community Systems	
	Outbreaks	Percent	Outbreaks	Percent
Distribution System Contamination	96	31.2	24	7.1
Inadequate or Interrupted Disinfection; Disinfection Only Treatment, Surface Water ^a	64	20.8	22	6.5
Inadequate or Interrupted Disinfection; Disinfection Only Treatment, Ground Water	42	13.6	101	29.7
Untreated Ground Water	34	11.0	140	41.2
Inadequate or Interrupted Filtration, Surface Water	30	9.7	4	1.2
Miscellaneous/Unknown	21	6.8	32	9.4
Inadequate Control of Chemical Feed	11	3.6	4	1.2
Untreated Surface Water	6	1.9	13	3.8
Inadequate or Interrupted Filtration, Ground Water	3	1.0	—	—
Inadequate Control of Disinfection	1	0.3	—	—
Total	308	100	340	100

^aThree outbreaks mixed source.

Cause of outbreaks: water system deficiencies (community systems)

- Untreated surface and groundwater: 12.9%
- Inadequate or interrupted filtration: 10.7%
- Inadequate or interrupted disinfection: 34.7%
- Distribution system contamination: 31.2%

Cause of outbreaks: water system deficiencies (non-community systems)

- Untreated surface and groundwater: 45%
- Inadequate or interrupted filtration: 1.2%
- Inadequate or interrupted disinfection: 36.2%
- Distribution system contamination: 7.1%

TABLE 3.8 Waterborne Outbreaks and Deficiencies in Individual Water System, 1971–2000

Type of Contamination	Outbreaks	Percent
Untreated Groundwater	55	53.4
Untreated Surface Water	19	18.4
Miscellaneous/Unknown	17	16.5
Distribution System Contamination	8	7.8
Inadequate or Interrupted Disinfection; Disinfection Only Treatment of <i>Ground Water</i>	2	1.9
Inadequate Chemical Removal	1	1.0
Inadequate or Interruption of Filtration, <i>Ground Water</i>	1	1.0
Total	103	100

Distribution deficiencies

- Cross-connections
- Backsiphonage
- Corrosion and leaching of metals
- Broken or leaking metals
- Storage deficiencies
- Construction or repair of mains

Cause of outbreaks: Etiology

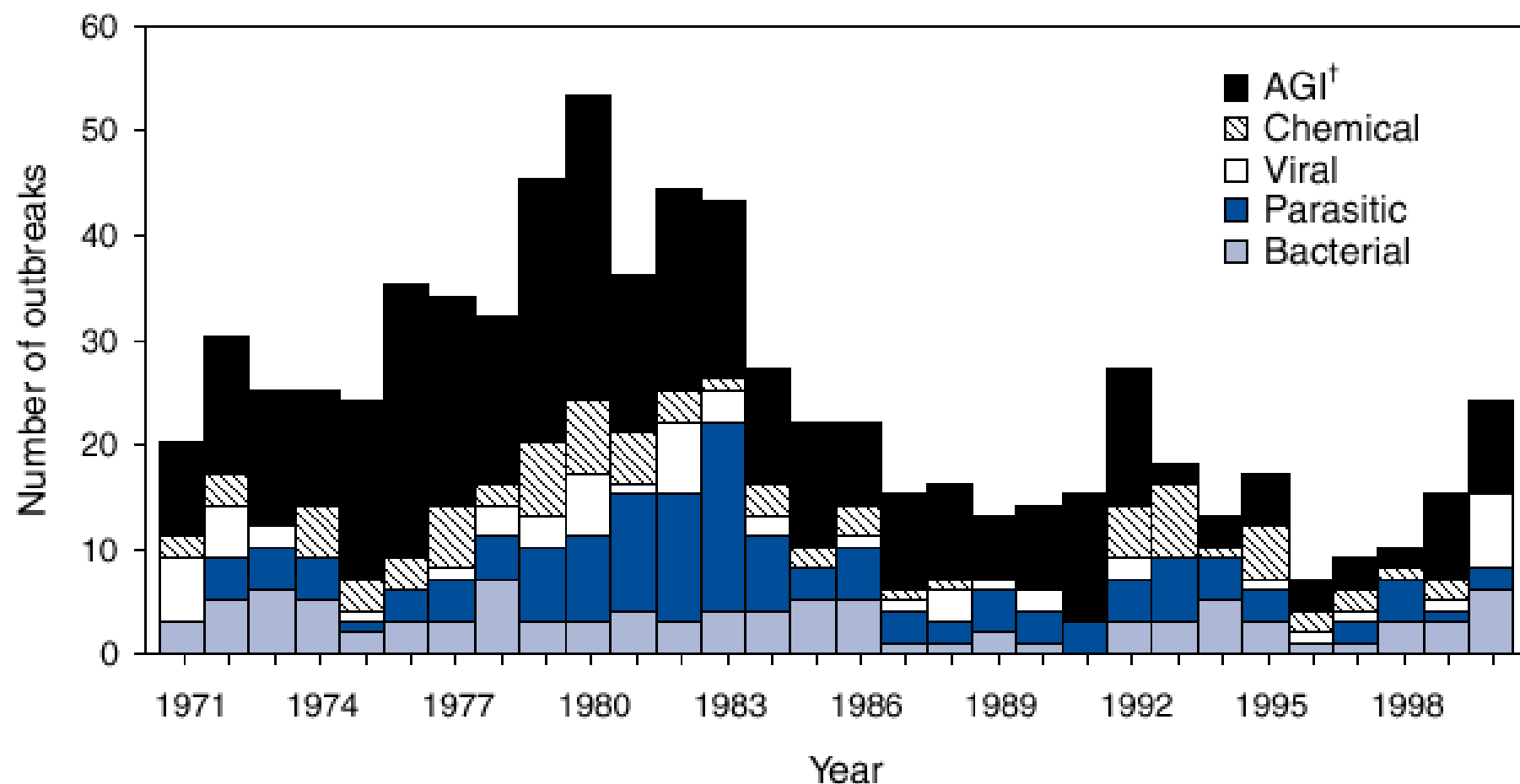
- Chemical poisoning (9%), microbial contamination (51%), and unknown etiology (40%)
- Community system: unknown etiology (32%), protozoa (31%), chemical poisoning (18%), bacteria (13%), viruses (6%)
- Non-community systems: unknown etiology (67%), bacteria (13%), protozoa (9%), viruses (8%), chemical poisoning (3%)
- Recreational waters: Protozoa (37%), bacteria (37%), unknown etiology (15%), viruses (7%), chemical poisoning (2%)
- Individual systems: Unknown etiology (38%), chemical poisoning (20%), bacteria (17%), protozoa (15%), viruses (9%)

TABLE 3.4 Waterborne Outbreaks by Type of Etiology, 1971–2000

Water System Type	Number of Outbreaks of Specified Etiology				
	Unidentified Agents	Protozoa	Viruses	Bacteria	Chemical
Non-Community	228	31	27	43	11
Community	98	96	20	40	54
Recreational ^a	40	97	18	97	5
Individual	39	16	9	18	21
All Water Systems	405	240	74	198	91

^aOne outbreak attributed to algae and one outbreak attributed to bacteria and protozoa not included in 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.

Microbial Etiologies

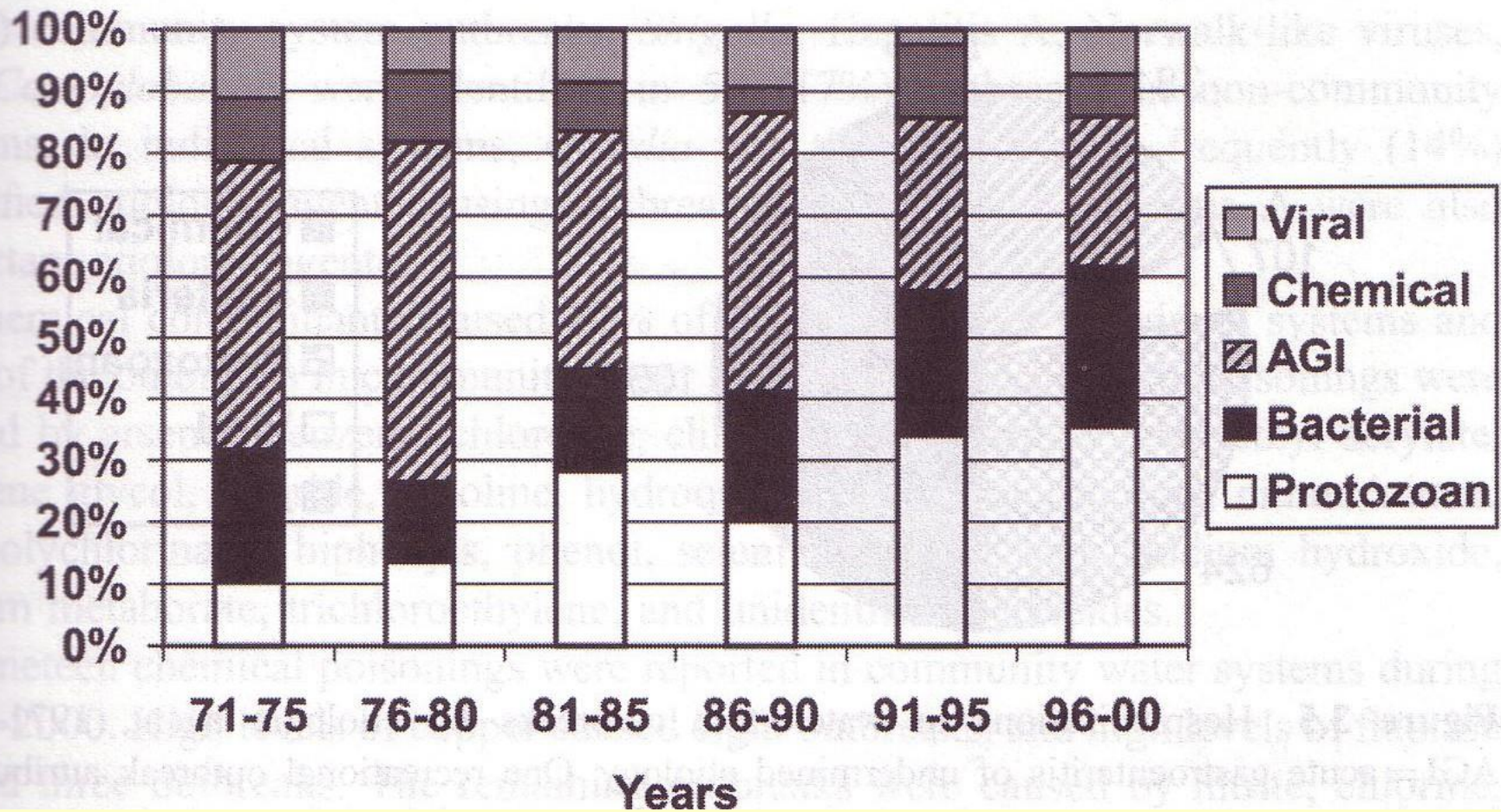


TABLE 3.6 Etiology of Waterborne Outbreaks by Type of Drinking Water System, 1971–2000

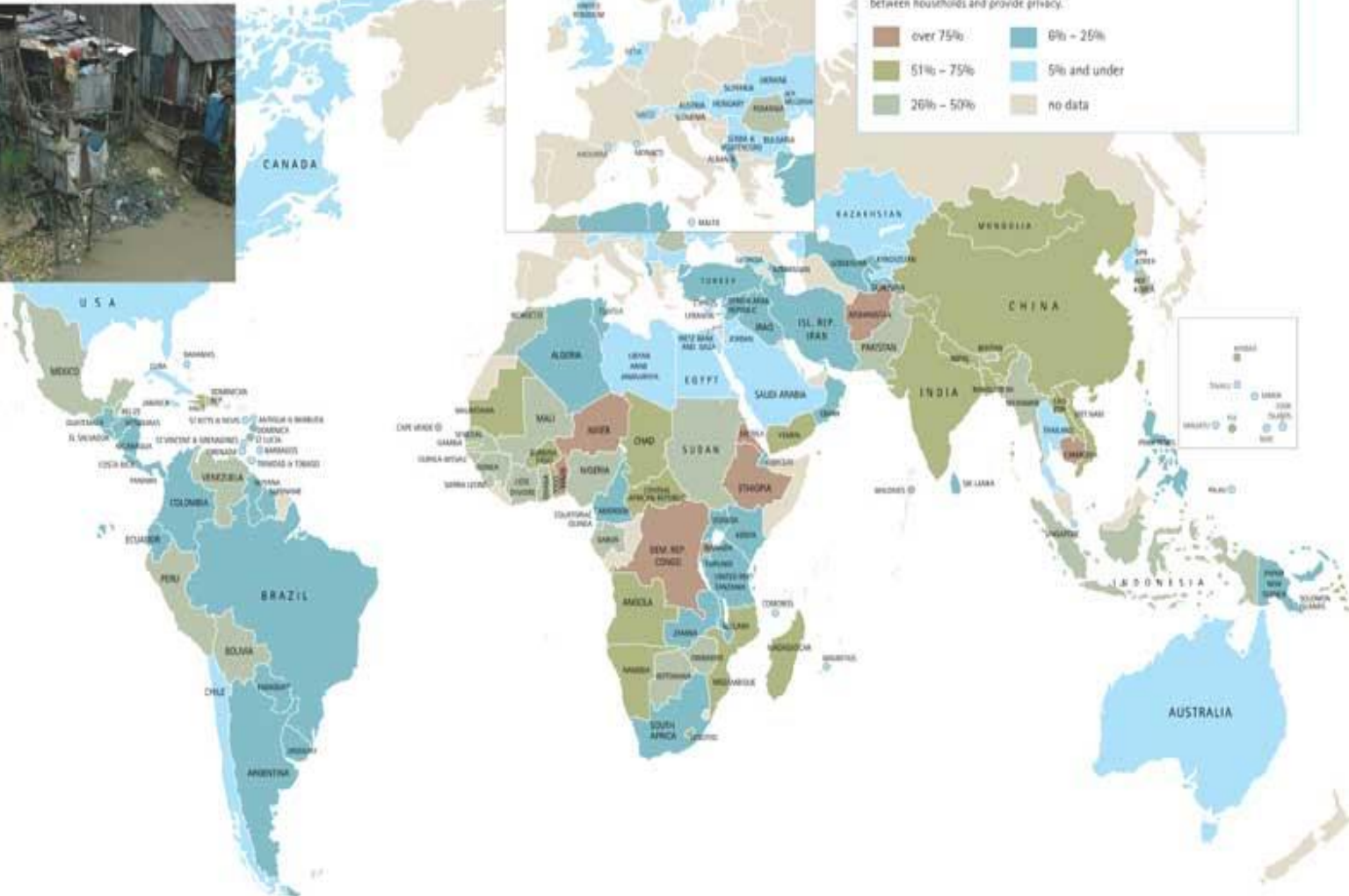
Etiologic Agent	Community Water Systems		Non-Community Water Systems ^a		Individual Water Systems	
	Outbreaks	Illnesses	Outbreaks	Illnesses	Outbreaks	Illnesses
Undetermined	98	48,320	228	34,371	39	800
<i>Giardia</i>	83	25,001	29	3329	14	97
Chemical	54	3674	11	709	21	94
<i>Shigella</i>	14	5715	24	3417	6	64
<i>Cryptosporidium</i>	11	420,856	2	578	2	39
<i>Salmonella</i> , non-typhoid	11	3044	2	72	2	87
Hepatitis A virus	10	241	10	369	8	217
<i>Campylobacter</i>	9	5353	7	120	3	132
Norwalk virus	9	3433	16	9637	1	30
<i>Escherichia coli</i> 0157:H7	4	451	4	66	3	12
Rotavirus	1	1761				
<i>Salmonella</i> , typhoid	1	60	1	210	3	12
Cyclospora	1	21				
<i>V. cholerae</i>	1	11	1	17		
<i>E. histolytica</i>	1	4				
Yersinia			1	8787	1	16
<i>Plesiomonas shigelloides</i>			1	60		
<i>Escherichia coli</i> 06:H16			1	1000		
SRSV			1	70		
Total	308	517,944	339	54,112	103	1600

^aOne outbreak of *Escherichia coli* and *Campylobacter* with 781 cases is not included in this table.

C*t₉₉ Values for Some Health-related Microorganisms (5 °C, pH 6-7)

Organism	Disinfectant			
	Free chlorine	Chloramines	Chlorine dioxide	Ozone
<i>E. coli</i>	0.03 – 0.05	95 - 180	0.4 – 0.75	0.03
Poliovirus	1.1 – 2.5	768 - 3740	0.2 – 6.7	0.1 – 0.2
Rotavirus	0.01 – 0.05	3806 - 6476	0.2 – 2.1	0.06-0.006
<i>G. lamblia</i>	47 - 150	2200	26	0.5 – 0.6
<i>C. parvum</i>	7200	7200	78	5 - 10

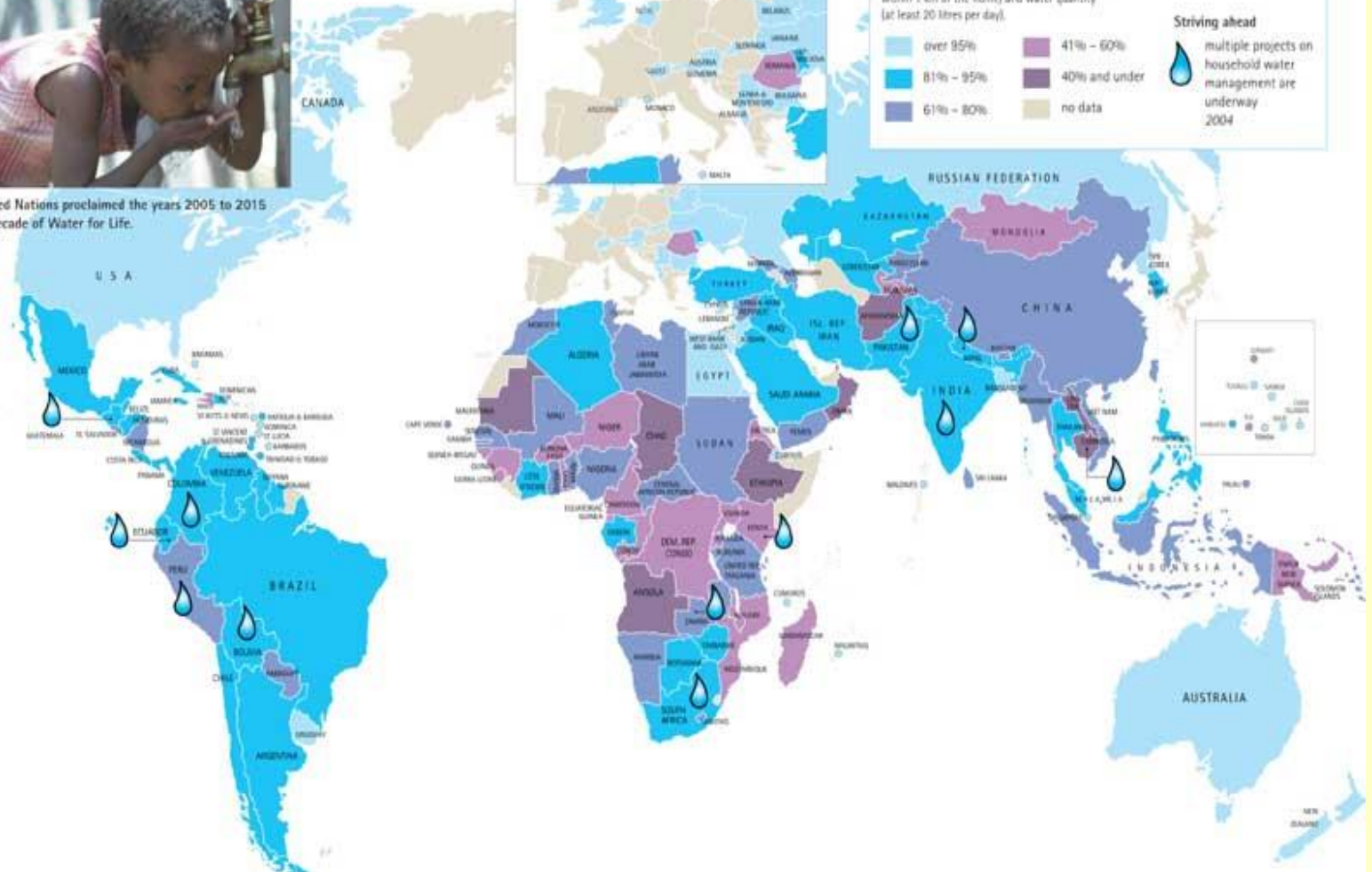
Hurry Up in the Toilet: 2.4 Billion are Waiting



Water for All: Making it Happen



The United Nations proclaimed the years 2005 to 2015 as the Decade of Water for Life.



Overall burden of waterborne diseases: World

- 1 billion cases of diarrhea with 2 million death annually (WHO)
 - 6-60 billion cases, >>2 million death (American Academy of Microbiology)
- 90 % of death in children under 5 years in developing countries

The World's Forgotten Children



Today, 35% of Africa's children are at higher risk of death than they were ten years ago.

