Drinking water

Smart Faucet
- Recognizes user (facial screening)
- Delivers preferred temp, flow

Pure water in antiquity

- 4000 BCE
  - Treatment methods (boiling, filtration) prescribed by Greeks to improve aesthetics
- 1500 BCE
  - Pictures of purifying apparatuses on Egyptian walls (alum addition)
- 400 BCE
  - Hippocrates discussed the link between water maintenance and health
- 1st Century CE
  - Aqueducts and settling reservoirs developed/used

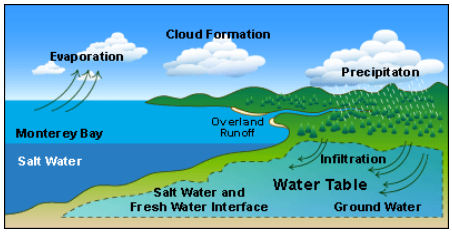
More recently

- 1854
  - John Snow and cholera
- 1892
  - Robert Koch (Germany) identified filtration as mechanism to remove cholera-causing bacteria
- 1908
  - Introduction of chlorination
    - First municipal treatment: Jersey City, NJ
  - Significant reduction in deaths

Water facts and figures

- ~0.8% of water on earth is available for use (held in aquifers, lakes/rivers, plants, etc.)
- Freshwater lakes volume: 3.3×10^{16} gal
- Groundwater volume: 5.5×10^{16} gal
- Of all precipitation…
  - 70% evaporates
  - 20% runs off into lakes, streams, rivers
  - 10% soaks in and becomes groundwater

Hydrologic cycle



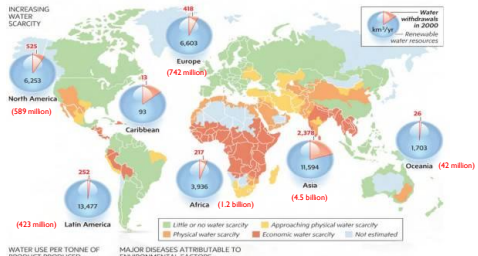
More water facts and figures…

- Daily per capita water requirement
  - 2 - 3 liters per day
- Number of people worldwide who do not have access to safe drinking water
  - 0.66 - 1.7 billion
- 80 % of all diseases and 33 % of all deaths in developing countries result from consumption of contaminated water

Human water usage (US estimates)

- **Personal use**
  - Drinking, cooking, laundering, bathing, etc.
  - Total personal domestic usage: 15 BGD
- **Industrial use**
  - Manufacture of paper, petroleum, chemicals and metals
  - Total industrial usage: 36 BGD
- **Irrigation** (mostly agriculture)
  - Total usage: 100 BGD
- **Other**…including power generation
  - May be significant thermal pollution

Water Scarcity and Usage, 2000



WATER USE PER TONNE OF PRODUCT PRODUCED
(Cubic metres per tonne)

Product	Water use*
Paper	80-2,000
Sugar	3-400
Steel	2-350
Petrol	0.1-40
Soap	1-35
Beer	8-25

* Amount varies with process used

MAJOR DISEASES ATTRIBUTABLE TO ENVIRONMENTAL FACTORS
(Annual global burden attributable to water, sanitation and hygiene)

Disease	Deaths ('000s)	DALY ('000s)**	Environmental pathways
Diarrhea	1,523	52,460	Water supply, sanitation, hygiene
Malnutrition	863	35,579	Water supply, sanitation, hygiene, water resources management
Malaria	526	19,241	Water resources management
Elephantiasis	0	3,784	Water supply, sanitation
Intestinal nematodes	12	2,948	Sanitation
Trachoma	0	2,320	Water supply, hygiene, flies
Schistosomiasis	15	1,698	Water supply, sanitation, water resources management
Japanese encephalitis	13	671	Water resources management
Dengue	18	586	Water supply, sanitation

** Disability Adjusted Life Year, a summary measure of population health. One DALY represents one lost year of healthy life.

SOURCE: THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 3 – WATER IN A CHANGING WORLD

Health Risks

- Water-borne diseases: result from ingestion of water containing pathogens
  - Examples: cholera, cryptosporidiosis
- Water-privation diseases: result from insufficient quantity of water (hygiene)
  - Skin/eye infections, helminths (parasitic worms)
- Water-contact diseases: result from contact with organisms in water
  - Guinea worm disease, schistosomiasis

Health Risks, continued

- Water-insect related diseases: transmitted by insects using water supplies for habitat
  - Malaria, West Nile, Zika
- Toxic chemicals: not all the risks are biological
  - Arsenic from minerals, nitrates from fertilizers

Health Risks, continued

Acceptable daily intake (ADI) and guideline values (GV) for chemicals:

$$ADI = \frac{NOAEL\ (or\ LOAEL)}{UF}$$

$$GV = \frac{ADI \times BM \times P}{C}$$

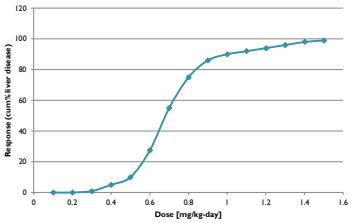
Where,
UF = uncertainty factor
BM = body mass; 10, 40, or 70 kg
P = portion of ADI allocated to drinking water
C = daily drinking water consumption (0.75, 1, 2 L)

Health Risks, Example problem

A recent series of toxicology studies on rats was conducted to examine the relationship between the onset of liver disease and the consumption of drinking water with elevated levels of arsenic. The-dose response curve shown on the following slide is estimated. Assume the following: UF = 10 and 75% of As exposure is from drinking water

a) Determine the most conservative estimate for acceptable daily intake for As in drinking water, and
b) Determine the guideline value

Health Risks, Example problem



$$ADI\ (most\ conservative) = \frac{NOAEL}{UF} = \frac{0.20\ \frac{mg}{kg \cdot day}}{10} = 0.02\ \frac{mg}{kg \cdot day}$$

$$GV = \frac{ADI \times BM \times P}{C} = \frac{(0.02)(70)(0.75)}{2} = 0.53 \frac{mg}{L \cdot day}$$

Source: Craun, et al., 2006, *J. Wat. Health* 4 (Suppl. 2), 19–30.

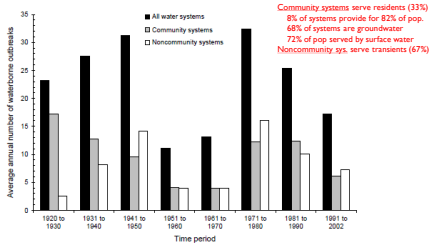


Figure 1. Reported waterborne outbreaks, 1920-2002

"Outbreak" implies ≥2 cases reported
- 1870 total (22.5 per year)
- 42% occurred in *non-community* systems

Source: Craun, et al., 2006, *J. Wat. Health* 4 (Suppl. 2), 19–30.

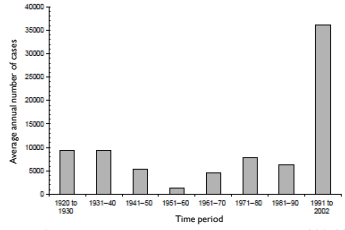


Figure 2. Reported cases in waterborne outbreaks, 1920-2002

"Case" = reported illness
- 884,000 total (10,650 per year)
- 5-20 times more cases in comm. systems

Source: Craun, et al., 2006, *J. Wat. Health* 4 (Suppl. 2), 19–30.

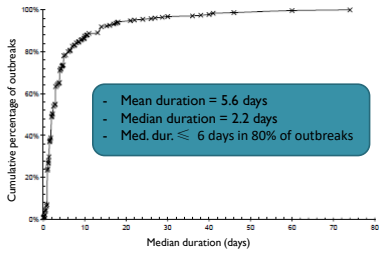


Figure 3. Median duration of illness in waterborne outbreaks, 1971-2002

Source: Craun, et al., 2006, *J. Wat. Health* 4 (Suppl. 2), 19–30.

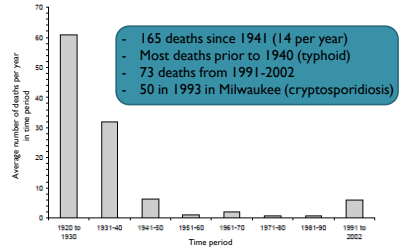
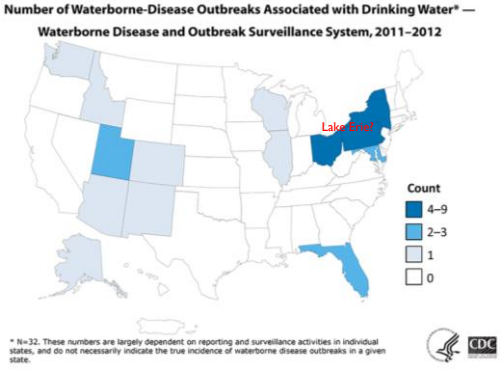


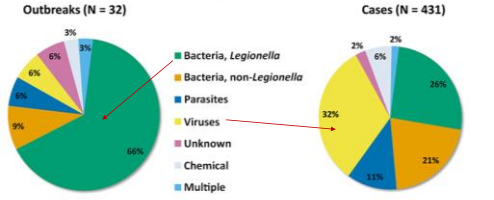
Figure 4. Mortality in drinking water outbreaks, 1920-2002

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html



Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

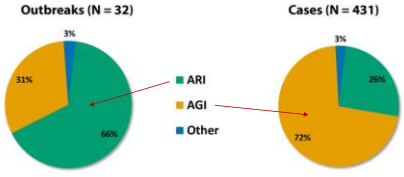
Etiology of Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012



*N=32
†N=431

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

Predominant Illness in Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012

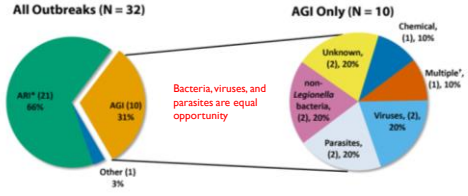


*N=32
†N=431
Abbreviations: AGI: acute gastrointestinal illness; ARI: acute respiratory illness

What's the deal with ARI, you ask? Well, we sometimes get sick when we inhale *aerosolized pathogens* in the water we drink

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

Predominant Illness Reported for all Drinking Water Outbreaks, and Etiologies in Outbreaks of Acute Gastrointestinal Illness (AGI), Waterborne Disease and Outbreak Surveillance System, 2011–2012

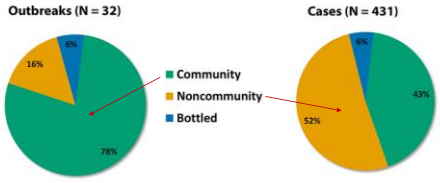


Abbreviations: AGI: acute gastrointestinal illness; ARI: acute respiratory illness

* All acute respiratory illness was attributed to *Legionella* spp.
† The outbreak with multiple etiologies involved bacterial and parasitic agents.

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

Water Systems Associated with Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012

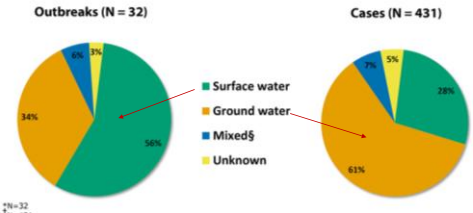


*N=32
†N=431

- More *outbreaks* at community sources
- More *cases* at non-community sources

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

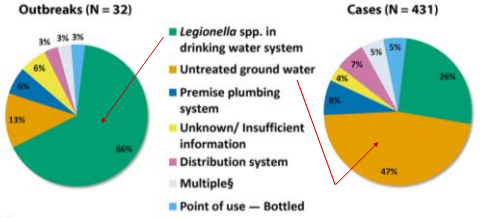
Water Sources Associated with Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012



*N=32
†N=431
§ Includes outbreaks with mixed water sources (i.e. ground water and surface water). Two giardiasis outbreaks were associated with mixed source community water systems.

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-figures.html

Deficiencies Assigned to Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012



*N=32
†N=431
§ Multiple deficiencies were assigned to one giardiasis outbreak which contributed 21 cases: untreated surface water and untreated ground water.

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-tables.html

Drinking Water-associated Outbreaks by Etiology Group, 2011-2012

Etiology	Outbreaks	Cases	Hospitalized	Died
Bacteria, non-*Legionella* spp.	**3**	**90**	**11**	**0**
E. coli O157:H7	1	56	2	0
Pantoea agglomerans	1	12	9	0
Shigella sonnei	1	22	0	0
Bacteria, *Legionella* spp.	**21***	**111**	**91**	**14**
Legionella spp.	→ 21 ←	111	→ 91 ←	→ 14 ←
Virus	**2**	**138**	**0**	**0**
Norovirus	2	→ 138 ←	0	0
Parasite	**2**	**49**	**0**	**0**
Giardia	2	49	0	0
Chemical	**1**	**26**	**0**	**0**
Suspected propylene glycol	1	26	0	0
Multiple[†]	**1**	**7**	**0**	**0**
Unidentified	**2**	**10**	**0**	**0**
Total	**32**	**431**	**102**	**14**

* Hospital information is unknown for two of these outbreaks, and death information is unknown for three of these outbreaks.
[†]One outbreak had multiple etiologic agent types. The etiologies were ***Campylobacter*** spp. (i.e., bacterium) and ***Giardia intestinalis*** (i.e., parasite).

Legionella: bacteria found in natural waters; *inhalation*, mostly
Norovirus: the winter vomiting bug; common cause of gastroenteritis

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-tables.html

Community Water Systems*

Etiology	Ground Water				Mixed Water[‡]				Surface Water			
	Outbreaks	Cases	Hospitalized	Died	Outbreaks	Cases	Hospitalized	Died	Outbreaks	Cases	Hospitalized	Died
Bacteria, non-*Legionella* spp.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**12**	**9**	**0**
E. coli O157:H7	0	0	0	0	0	0	0	0	0	0	0	0
Pantoea agglomerans	0	0	0	0	0	0	0	0	1	12	9	0
Shigella sonnei	0	0	0	0	0	0	0	0	0	0	0	0
Bacteria, *Legionella* spp.	**5**	**29**	**27**	**4**	**0**	**0**	**0**	**0**	**16[§]**	**82**	**64**	**10**
→ *Legionella* spp. ←	5	29	27	4	0	0	0	0	16	82	64	10
Virus	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Norovirus	0	0	0	0	0	0	0	0	0	0	0	0
Parasite	**1**	**28**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Giardia	1	→ 28 ←	0	0	0	0	0	0	0	0	0	0
Chemical	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**26**	**0**	**0**
Suspected propylene glycol	0	0	0	0	0	0	0	0	1	26	0	0
Multiple[†]	**0**	**0**	**0**	**0**	**1**	**7**	**0**	**0**	**0**	**0**	**0**	**0**
Unidentified	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total	**6**	**57**	**27**	**4**	**1**	**7**	**0**	**0**	**18**	**120**	**73**	**10**

*No reported outbreaks in community water systems had unknown water source.
[†]Includes outbreaks with mixed water sources (i.e. ground water and surface water). Two giardiasis outbreaks were associated with mixed source community water systems.
[‡]Hospital information is unknown for two of these outbreaks, and death information is unknown for three of these outbreaks.
[§]One outbreak had multiple etiologic agent types. The etiologies were *Campylobacter* spp. (i.e., bacterium) and *Giardia intestinalis* (i.e., parasite).

Giardia: protozoan parasite that's resistant to Cl_2

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-tables.html

Non-community Water Systems*

Etiology	Ground Water				Mixed Water[‡]			
	Outbreaks	Cases	Hospitalized	Died	Outbreaks	Cases	Hospitalized	Died
Bacteria, non-*Legionella* spp.	**1**	**56**	**2**	**0**	**0**	**0**	**0**	**0**
E. coli O157:H7	1	56	→ 2 ←	0	0	0	0	0
Pantoea agglomerans	0	0	0	0	0	0	0	0
Shigella sonnei	0	0	0	0	0	0	0	0
Bacteria, *Legionella* spp.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Legionella spp.	0	0	0	0	0	0	0	0
Virus	**2**	**138**	**0**	**0**	**0**	**0**	**0**	**0**
Norovirus	2	→ 138 ←	0	0	0	0	0	0
Parasite	**0**	**0**	**0**	**0**	**1**	**21**	**0**	**0**
Giardia	0	0	0	0	1	→ 21 ←	0	0
Chemical	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Suspected propylene glycol	0	0	0	0	0	0	0	0
Multiple[†]	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Unidentified	**1**	**7**	**0**	**0**	**0**	**0**	**0**	**0**
Total	**4**	**201**	**2**	**0**	**1**	**21**	**0**	**0**

*No reported outbreaks in public non-community water systems had surface water or unknown water source.
[†]Includes outbreaks with mixed water sources (i.e. ground water and surface water). Two giardiasis outbreaks were associated with mixed source community.
[‡]One outbreak had multiple etiologic agent types. The etiologies were *Campylobacter* spp. (i.e., bacterium) and *Giardia intestinalis* (i.e., parasite).

E. Coli: large, diverse group of bacteria (diarrhea, UTI, pneumonia,…)

Source: https://www.cdc.gov/healthywater/surveillance/drinking/2011-2012-tables.html

Commercially-bottled Water*

Yes…*bottled* water!

Etiology	Ground Water				Unknown Water			
	Outbreaks	Cases	Hospitalized	Died	Outbreaks	Cases	Hospitalized	Died
Bacteria, non-*Legionella* spp.	0	0	0	0	1	22	0	0
E. coli O157:H7	0	0	0	0	0	0	0	0
Pantoea agglomerans	0	0	0	0	0	0	0	0
Shigella sonnei	0	0	0	0	1	22	0	0
Bacteria, *Legionella* spp.	0	0	0	0	0	0	0	0
Legionella spp.	0	0	0	0	0	0	0	0
Virus	0	0	0	0	0	0	0	0
Norovirus	0	0	0	0	0	0	0	0
Parasite	0	0	0	0	0	0	0	0
Giardia	0	0	0	0	0	0	0	0
Chemical	0	0	0	0	0	0	0	0
Suspected propylene glycol	0	0	0	0	0	0	0	0
Multiple†	0	0	0	0	0	0	0	0
Unidentified	1	3	0	0	0	0	0	0
Total	1	3	0	0	1	22	0	0

*No reported outbreaks in bottled water systems had mixed water or surface water source.
†One outbreak had multiple etiologic agent types. The etiologies were *Campylobacter* spp. (i.e., bacterium) and *Giardia intestinalis* (i.e., parasite).

Shigella: bacteria that cause diarrhea and are closely related to salmonella

Conclusion

- Lack of access to clean drinking water may be the #1 public health concern (globally)
  - Developing world: several of the leading causes of death have a drinking water component
  - Developed world: problem is less severe, but illnesses and deaths happen every year
- The problem isn't going away
  - Population growth
  - Climate change