Pure water in antiquity

- **4000 BC**
  - Treatment methods (boiling, filtration) prescribed by Greeks to improve aesthetics

- **1500 BC**
  - Pictures of purifying apparatuses on Egyptian walls (alum addition)

- **400 BC**
  - Hippocrates discussed the link between water maintenance and health

- **1st Century AD**
  - 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: \(3.3 \times 10^{16}\) gal
- Groundwater volume: \(5.5 \times 10^{16}\) 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
  - ___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, laundring, 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

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

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>Viruses</th>
<th>Protozoa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cholera</td>
<td>West Nile</td>
<td>Cryptosporidiosis</td>
</tr>
<tr>
<td>Typhoid</td>
<td>Zika</td>
<td>Malaria</td>
</tr>
</tbody>
</table>

Health Risks, continued

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

\[
ADI = \frac{NOAEL \text{ (or LOAEL)}}{UF}
\]

\[
GV = \frac{ADI \times BW \times P}{C}
\]

Where,
- UF = uncertainty factor
- BW = 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)
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

\[ ADI \, (\text{most conservative}) = \frac{\text{NOAEL}}{UF} = \frac{0.25 \, \text{mg/kg/day}}{10} = 0.025 \, \text{mg/kg/day} \]

\[ GV = \frac{ADI \times BW \times P}{C} = \frac{(0.025)(70)(0.75)}{2} = 0.6 \, \text{mg/day} \]
Figure 1. Reported waterborne outbreaks, 1920-2002

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


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

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


- Mean duration = 5.6 days
- Median duration = 2.2 days
- Med. dur. \( \leq 6 \) days in 80% of outbreaks

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


- 165 deaths total (14 per year)
- Most deaths prior to 1940 (typhoid)
- 73 deaths from 1991-2002
- 50 in 1993 in Milwaukee (cryptosporidiosis)
Number of Waterborne-Disease Outbreaks Associated with Drinking Water* — Waterborne Disease and Outbreak Surveillance System, 2011–2012

Lake Erie

Count
- 4–9
- 2–3
- 1
- 0

* N=32. These numbers are largely dependent on reporting and surveillance activities in individual states, and do not necessarily indicate the true incidence of waterborne disease outbreaks in a given state.

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

Outbreaks (N = 32)

- Bacteria, Legionella: 66%
- Bacteria, non-Legionella: 6%
- Parasites: 6%
- Viruses: 3%
- Unknown: 3%
- Chemical: 6%
- Multiple: 6%

Cases (N = 431)

- Bacteria, Legionella: 26%
- Bacteria, non-Legionella: 26%
- Parasites: 6%
- Viruses: 11%
- Unknown: 32%
- Chemical: 21%
- Multiple: 2%
What’s the deal with ARI, you ask? Well, we sometimes get sick when we inhale aerosolized pathogens in the water we drink.
Water Systems Associated with Drinking Water Outbreaks* and Outbreak-related Cases†, Waterborne Disease and Outbreak Surveillance System, 2011–2012

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

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

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* 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.
**Deficiencies Assigned to Drinking Water Outbreaks**
and Outbreak-related Cases, Waterborne Disease and

**Outbreaks (N = 32)**

- **Legionella spp. in drinking water system:** 66%
- **Untreated ground water:** 6%
- **Premise plumbing system:** 3%
- **Unknown/ Insufficient information:** 3%
- **Distribution system:** 3%
- **Multiple:** 3%
- **Point of use — Bottled:** 13%

**Cases (N = 431)**

- **Legionella spp. in drinking water system:** 26%
- **Unknown/ Insufficient information:** 7%
- **Premise plumbing system:** 5%
- **Distribution system:** 4%
- **Multiple:** 4%
- **Untreated ground water:** 4%
- **Point of use — Bottled:** 7%

*\*N=32
\*N=431

† Multiple deficiencies were assigned to one giardiasis outbreak which contributed 21 cases: untreated surface water and untreated ground water.

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

<table>
<thead>
<tr>
<th>Etiology</th>
<th>Outbreaks</th>
<th>Cases</th>
<th>Hospitalized</th>
<th>Died</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria, non-Legionella spp.</td>
<td>3</td>
<td>90</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>E. coli O157:H7</td>
<td>1</td>
<td>56</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Pantoea agglomerans</td>
<td>1</td>
<td>12</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>Shigella sonnet</td>
<td>1</td>
<td>22</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Bacteria, Legionella spp.</td>
<td>21*</td>
<td>111</td>
<td>91</td>
<td>14</td>
</tr>
<tr>
<td>Legionella spp.</td>
<td>21</td>
<td>111</td>
<td>91</td>
<td>14</td>
</tr>
<tr>
<td>Virus</td>
<td>2</td>
<td>138</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Norovirus</td>
<td>2</td>
<td>49</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Parasite</td>
<td>2</td>
<td>49</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Giardia</td>
<td>2</td>
<td>49</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chemical</td>
<td>1</td>
<td>26</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Suspected propylene glycol</td>
<td>2</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Multiple</td>
<td>1</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Unidentified</td>
<td>2</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>32</td>
<td>431</td>
<td>142</td>
<td>14</td>
</tr>
</tbody>
</table>

* 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; **inhalaion**, mostly
**Norovirus**: the winter vomiting bug; common cause of gastroenteritis
Giardia: protozoan parasite that’s resistant to Cl₂

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