EMERGING ENVIRONMENTAL ISSUES
Contamination of Drinking Water

- Disinfection by-products
- Environmental contaminants (e.g., arsenic, radon)
- Animal-derived contaminants
  - Non-point source contamination
  - Concentrated animal feeding operations
- Human-derived contaminants
  - Wastewater and pathogens
  - Inorganics (e.g., heavy metals, nitrates)
  - Organics (volatile, non-volatile)
    - Pesticides, herbicides, solvents
  - Pharmaceuticals and personal care products
U.S. Drinking Water Systems

- Aging water and wastewater infrastructure
  - Plants, distribution systems long overdue for replacement
  - $> 1$ trillion estimate cost
  - Source water protection, water development

- Risk to public health
  - CSO’s, SSO’s
  - $\sim 250,000$ annual water main breaks
  - Leaks, breaks, low pressure events open systems to contamination and health effects
U.S. Drinking Water Systems

- Private wells, small water systems not under SDWA
- Serve ~45 million people (15.6 million households; ~12% of households)
- Prone to poor construction, operation, maintenance, water quality
  - WA 2003: most small systems had > 1 system deficiencies that posed a potential public health hazard
  - AL 2005: 40% of private wells failed bacteriologic testing
  - NJ 2002-8: 12.5% failed testing (2.2% fecal test positive, 2.7% nitrates)
Building Issues

- Building distribution systems—premise plumbing
  - Regulation, in practice, stops at the street
  - Biofilms everywhere
  - Pathogens exploiting human-made habitats
    - Niches for thermophiles
      - *Legionella*, *Mycobacterium avium* complex, *Acanthamoeba*, *Naegleria*
    - Aerosolization via shower heads, taps

- Cooling systems create hot water via heat exchange
  - Aerosolization of *Legionella*
Naegleria fowleri in tap water

- US Virgin Islands, 2012
- 47 year-old Muslim male from St. Thomas, USVI died
- The patient had no recreational water exposure and practiced ritual ablution including nasal rinsing
- Water sources
  - Home
    - Untreated groundwater from well
    - Untreated rainwater from cistern
    - Both connected to premise plumbing system
  - Mosque
  - Treated municipal water (desalinated and chlorinated)
N. fowleri, Louisiana 2013

- 4 year old boy died in southern Louisiana
  - No recreational water exposure reported; boy did not like to dunk his head in water
  - Likely water exposure was during long day of playing on a backyard “slip-n-slide” irrigated with public drinking water

- Environmental Investigation
  - N. fowleri cultured from
    - One soil sample
    - Both garden hoses
    - Hot water heater
    - Toilet tank
    - Outside hose bib [negative in 1 L, positive in 158-L ultrafiltration (UF) sample] (No chlorine residual detected in hose bib water)

- N. fowleri detected in other parts of distribution system---in areas with low residual disinfection
Louisiana: 2011

- Two cases in different areas
  - Both cases were regular users of neti pots for nasal irrigation
  - *Naegleria fowleri* found in premise plumbing at both residences
  - Hot water heaters set to low temperature settings

- Cases associated with different drinking water systems
  - St. Bernard Parish (near New Orleans) & DeSoto Parish (near Shreveport)
  - Both water utilities performed chloramination for 2° disinfection
  - 1-L samples from municipal water systems negative

Conclusions: *Naegleria fowleri* and Tap Water

- Geographic range shifting northwards as anticipated with water temperature increases
  - Also seen with other climate sensitive pathogens such as *Vibrio*, harmful algal blooms
- Moderate chlorine resistance is challenging for water treatment
- Ability to colonize premise plumbing and biofilms, similar to other thermophilic, environmental organisms (*Legionella, Pseudomonas, NTM/MAC*)

Other Uses of Water: Challenges

- **Food production**
  - Agriculture: production, irrigation, processing is one of the major uses of water in the world
    - Eat the food and drink the water from around the world
    - Water suspected in *Cyclospora* outbreaks 1995+
    - Spinach and *E.coli* O157:H7, CA 2007
  - Drawing from decreasing water resource that may be more prone to contamination

- **Increasing re-use of wastewater & graywater**
Recreational Water: Natural Waters

- EPA regulates
- EPA validating new fecal indicators
  - Critical issue is the lack of differentiation between animal and human fecal contamination
  - Many beaches likely closed due to bird contamination
  - Link to human illness is unclear compared to human sewage contamination
Climate Change and Water Impacts

- Increased water availability
  - Moist tropics and high latitudes
- Decreased water availability
  - Mid-latitudes, semi-arid low latitudes
- Water stress for hundreds of millions
- Extreme weather events
  - Droughts, floods, increased temperatures
- Water quantity as well as water quality becomes issue
Drought

- **Surface water**
  - Concentration of contaminants
  - Decreased dilution factor in outflows, runoff

- **Groundwater**
  - Increasing groundwater recharge
  - Surface water used to recharge
  - Changing soil/geology increases potential for contamination
  - Saltwater intrusion into groundwater as levels drop

- **Water re-use**
  - “Toilet-to-Tap”
  - ~10% of wastewater in US is “reused”
Floods

- Potential infrastructure failures of drinking/wastewater treatment
- Sewer overflows (combined and sanitary)
  - >1 trillion gal of sewage & storm water discharged annually during CSO’s
- Agricultural and livestock areas rinsed into surface water---”first flush”
- Water quality
  - Surface & ground water contamination w/pathogens, chemicals
Higher Temperatures

- Increasing water temperatures and/or nutrients
  - Movement of pathogens to more northern regions
    - *Vibrio paraheamolyticus* in Alaska
  - Enhanced growth of pathogens
    - *Naegleria, Vibrio*, harmful algal blooms, *Pseudomonas*
    - Recreational water climate change indicators
    - Increased water use resulting in increased infections, health effects
Summary

- Environmental issues
  - Premise plumbing/biofilm pathogens
  - Increases in recreational water assoc. outbreaks
  - Aging drinking water infrastructure
  - Increasing complexity of chemical contamination
  - New pathogens, changing epidemiology
  - Climate change: floods, drought, and re-use
  - Water used in food production

- Water jurisdictions generally spread across public health groups or separate agencies

- How can we prepare to meet these challenges?
THANK YOU
Conclusions: *Naegleria fowleri* and Tap Water

- Recent cases associated with tap water are challenging for water utilities
  - FLA in premise plumbing common (~79% of 467 households in OH study); *N. fowleri* occurrence largely unknown
  - Need for communication about not using tap water for nasal rinsing?
  - How to balance risk vs preparedness?

- Ecological and engineering knowledge gaps
  - How to develop predictive capacity? What kind of monitoring?
  - What are water quality risk factors? (e.g., temperature, disinfectant residual; HPC? Other indicators?)
  - What are water system risk factors? (e.g., chloramination? nitrification? water age? elevated storage tank stratification?)
  - What are premise plumbing risk factors? (hot water heater setting/maintenance? pipe material?)