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
  - ~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**

Yoder JS et al (2012) *Clin Inf Dis*, **54**:805-809

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)

Donlan RM. Biofilms: microbial life on surfaces. Emerg Infect Dis2002; 8:881–90
Marciano-Cabral F, Jamerson M, Kaneshiro ES. Free-living amoebae, Legionella and Mycobacterium in tap water supplies by a municipal drinking water utility in the USA. J Water and Health 2010; 8:71–82
Marciano-Cabral F, MacLean R, Mensah A, LaPat-Polasko L. Identification of Naegleria fowleri in domestic water sources by nested PCR. Appl Environ Microbiol 2003; 69:5864–9.

Other Uses of Water: Challenges

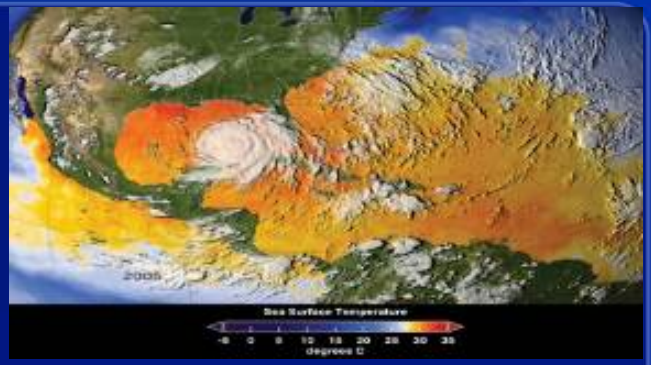
- **Food production**
  - **Agriculture: production, irrigation, processing is one of the major uses of water in the world**
    - **Eat the food and drink the water from around the world**
    - **Water suspected in *Cyclospora* outbreaks 1995+**
    - **Spinach and *E coli* O157:H7, CA 2007**
  - **Drawing 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

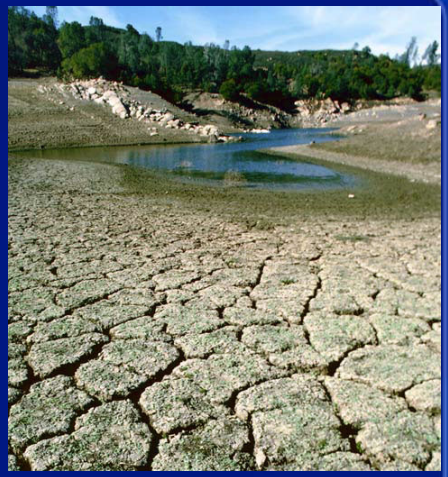
Climate Change and Water Impacts

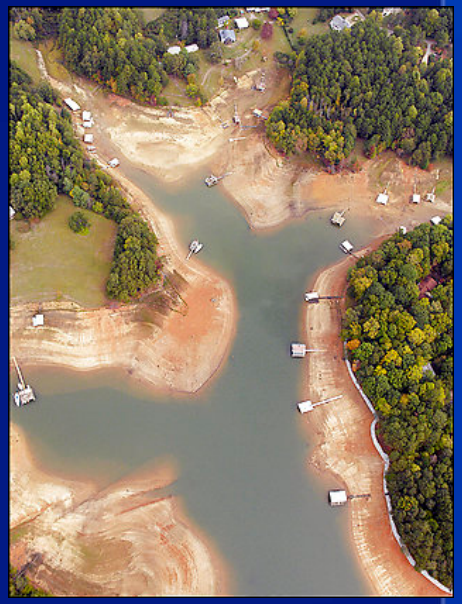


- Increased water availability
  - Moist tropics and high latitudes
- Decreased water availability
  - Mid-latitudes, semi-arid low latitudes
- Water stress for hundreds of millions
- Extreme weather events
  - Droughts, floods, increased temperatures
- Water quantity as well as water quality becomes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

Drought

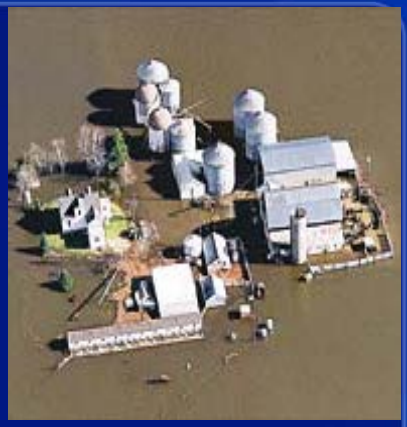
- Surface water
  - Concentration of contaminants
  - Decreased dilution factor in outflows, run-off
- Groundwater
  - Increasing groundwater recharge
  - Surface water used to recharge
  - Changing soil/geology increases potential for contamination
  - Saltwater intrusion into groundwater as levels drop
- Water re-use
  - “Toilet-to-Tap”
  - ~10% of wastewater in US is “reused”





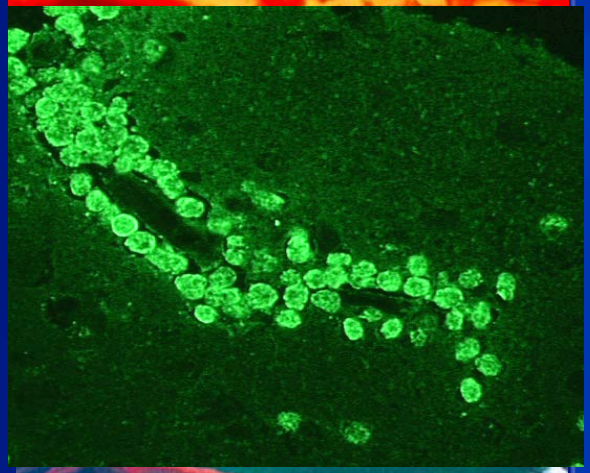
Floods

- 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?)**