Webinars
- Series of scientific webinars that provide a forum for discourse on scientific issues.
- Live and On-Demand
- Case Conferences
- Journal Clubs
- Grand Rounds
- CE Available

Online Courses
- Evidence-based online courses on a variety of children's environmental health topics.
- Interactive and Self-Paced
- CE Available

Resource Catalog
- Fact sheets, journal publications, reports, and other resources for parents, community members, patients and healthcare professionals
- Topics included: Air Quality, Pesticides, Natural Disasters, BPA, Mold, Lead, Mercury
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Learning Objectives

- Identify major water contamination incidents in the US
- Describe potential water contamination related risks
- Evaluate the public health response to large scale water contamination
Articles to Review

- Intentional and Inadvertent Chemical Contamination of Food, Water, and Medication
- Incidence of Waterborne Lead in Private Drinking Water Systems in Virginia
- Elevated Blood Lead Levels in Children Associated with the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response
Intentional and Inadvertent Chemical Contamination of Food, Water, and Medication

Water Contamination

~ 84% of US population is served by public water systems

Public drinking water systems
- 2/3 surface water
- 1/3 groundwater
- Serve ≤ 3300 people up to 100,000 people
Distribution Network

- Pipes placed 30 to 100 years ago
- Vulnerable to leaking and contamination
Contamination Identification

National Primary Drinking Water Regulation
Safe Drinking Water Act

- Maximum contaminant levels for 80 + elements and chemical compounds
- Municipal and Private water companies are required to test and report
- EPA does not regulate the testing methodology

FDA

- Regulates bottled water
Reporting

- CDC monitors water-borne illness outbreaks
  - Biological
  - Chemical
- Many unreported/unrecognized
- Public health implications
  - Knowledge is lacking
Impact of Site of Contamination

Ideal agent of water contamination

- Odorless and tasteless
- Colorless
- Resistant to water treatment procedures
- Water stable
- Water soluble
- Low LD$_{50}$
## Water Contamination

### Table 2
Examples of chemical contamination of the water supply

<table>
<thead>
<tr>
<th>Bow-Tie Site of Introduction</th>
<th>Chemical Exposure</th>
<th>Site/Date</th>
<th>Number of People Affected</th>
<th>Health Effects</th>
<th>Acute vs Chronic Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw material: Yippie political theater threat to introduce LSD into drinking water supply at 1968 Democratic National Convention</td>
<td>LSD(^{43}) (and other intentional threats(^{44}))</td>
<td>Lake Michigan, Chicago, IL/1968</td>
<td>None directly; large security presence at convention with riots</td>
<td>None; threat only</td>
<td>None</td>
</tr>
<tr>
<td>Raw material: Elk River contamination from above-ground storage tank</td>
<td>4-Methylcyclohexane methanol(^{45}) (inadvertent)</td>
<td>Charleston, WV/2014</td>
<td>300,000 no-use water warning</td>
<td>Odor, skin rashes, nonspecific complaints</td>
<td>Acute</td>
</tr>
<tr>
<td>Raw material: 4.1 million cubic meters of wet ash released into Tennessee River tributaries</td>
<td>Coal ash(^{46}) (inadvertent)</td>
<td>Harriman, TN/2008 (and other sites: North Carolina(^{47}))</td>
<td>22 residents evacuated; 165 properties sold to TVA</td>
<td>None; concern about heavy metal contamination and particulate-related respiratory irritation</td>
<td>—</td>
</tr>
<tr>
<td>Production: waste off site: dry cleaning plant. On site: industrial spills, leaking underground storage tanks, waste disposal sites</td>
<td>Trichloroethylene, perchloroethylene, vinyl chloride, benzene, multiple other chemicals (VOCs)(^{48}) (inadvertent)</td>
<td>Camp Lejeune Marine Corps Base, North Carolina/1953–1987 (investigation started in 2009)</td>
<td>Up to 750,000 (service members and families exposed to contaminated tap water</td>
<td>Concerns for higher cancer rates, birth defects (neural tube defects), amyotrophic lateral sclerosis</td>
<td>Chronic with delayed identification of contamination</td>
</tr>
</tbody>
</table>
## Water Contamination

<table>
<thead>
<tr>
<th>Processing: security fence cut at 12 million gallon reservoir</th>
<th>Unknown(^{49}) (intentional)</th>
<th>Seattle, OR/2002</th>
<th>None; cost of emptying reservoir; increased water security</th>
<th>None identified</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution: 60 gallons of foam accidentally pumped into hydrant</td>
<td>Fire retardant foam(^{50}) (inadvertent)</td>
<td>Charlotte, NC/1997</td>
<td>40,000 households; no water use for 1.5 d</td>
<td>None</td>
<td>NA</td>
</tr>
<tr>
<td>Distribution: (cross-connection): water for soup contaminated by boiler additive</td>
<td>Nitrites(^{51}) (inadvertent)</td>
<td>New Jersey/1992</td>
<td>49 children; 14 with MetHb &gt;20%</td>
<td>Cyanosis, nausea, abdominal pain, vomiting, dizziness</td>
<td>Acute</td>
</tr>
<tr>
<td>Distribution: possible plot to introduce 4 kg (9 pounds) of a cyanide compound into US embassy water supply</td>
<td>Potassium ferrocyanide(^{52}) (intentional)</td>
<td>Rome, Italy/2002</td>
<td>None</td>
<td>None; plot disrupted</td>
<td>NA</td>
</tr>
</tbody>
</table>
Large Scale Contamination – Elk River

- Charleston, West Virginia
- January 2014
- 10,000 gallons of a coal flotation product
  - 88.5% 4-methylcyclohexane methanol (MCHM)
  - 7.3% propylene glycol phenyl ether (PPH)
- 300,000 people in 9 counties
Public Health Response

- Do-not-use order
- Cleared for use: 4 – 8 days
- 2 weeks
  - 369 hospital visits
  - 2000 reported exposures by Poison Center
  - 22% of households – symptoms of water contamination
  - No hospital admissions were related to contamination
Distrust / Fear

- Water odor and taste
- State of Emergency
  - 42 days after zones were opened
- Consequences
  - National Guard water distribution
  - Water sample testing
  - School/Business closures
  - Public awareness of chemical proximity to public water system
  - Fear
Potential Vulnerability

- Available filtration systems may be overwhelmed by a large volume of contaminant.
- Backup storage capacity in a water system is essential.
- Odor and taste of a contaminant can be a serious public health issue.
- Unregulated above-ground storage tanks near public water supplies.
Incidence of Waterborne Lead in Private Drinking Water Systems in Virginia

Water Contamination Prevention Efforts

- Eliminating elevated blood lead levels in children by 2020 will be challenging

- Primary focus on leaded gasoline and leaded paint, leaves secondary focus ‘other’ as likely underestimated
USEPA Lead and Copper Rule (LCR)

- Implemented to identify and control corrosion in municipal drinking water systems

- Rule: If >10% of high-risk households have lead concentrations above ‘action level’ of 15ug/L, the utility must take action to control corrosion and educate the public about risk

- 10-15% of US households are not required to follow LCR because they are on private drinking water systems
Private Drinking Water Systems

- Well Types: Drilled wells, bore/dug wells, spring water sourced
- Some states have regulations controlling new wells, but do not monitor after placement
  - Monitoring & maintenance is homeowner responsibility
  - Monitoring is rare and inconsistent
- Cause for concern: Corrosion of internal plumbing causing contamination is rarely assessed at point of use (POU)
Previous Research on POU and Private Systems

- 1970s: 9.2% samples exceeded 50ug/L
- 1985: 20% of first draws exceeded 50ug/L
- 1988: 34% samples exceeded 10ug/L
- 1992: 19% exceed 15ug/L
Soluble versus Particulate Lead

- Soluble lead is defined as passible through a 0.45um pore size filter

- Previous research focused primarily on soluble lead, potentially underestimating actual total lead levels and exposure by 6 to 18ug/L
Study Focus

- Document lead in POU of private drinking water households
- Quantify relative amounts of soluble and particulate lead in samples
- Identify characteristics in system or environment that associate high lead concentrations
- Evaluate homeowner perception of water quality versus high lead concentrations
Methods

- 2,146 samples collected via Virginia Household Water Quality Program
- All volunteers; required purchase of a sampling kit
- **Sampling procedure:**
  - Non-swivel faucet, aerator removed, 6 hours stagnation, first draw at pencil-thin flow, three more samples after 5 minute flush/running water
  - Samples iced, mailed, and tested within 8-12 hours of collection
Methods

- Water quality analyses processed for pH, bacteria, metals, soluble and particulate lead, and hardness.

Statistical Analysis

- Correlation of lead and other metals
- Lead concentration comparison to categorical household characteristics
- Calculated odds of having ELL based upon perception of water quality
Results

Demographics:
- 51% income greater than $65,000
- 69% at least a college degree
- 81% older than age 50
- 89% reported White/Caucasian

Samples: 94.5% private well, 3.6% spring, 1.7% other
Well type: 79% drilled, 12% dug/bored, 9% unknown
Well age: average year 1988 (range 1850 to 2013)
Well depth: mean depth 77.7m (range 1.2m to 381m)
Results: Water Quality

- 58% samples exceeded at least one Maximum Contaminant Level (MCL) using Safe Drinking Water Act standards
- 46% positive for total coliforms
- 19% had ELL above 15ug/L
- 12% had copper above 1.3mg/L
- 26% had pH value outside 6.5-8.5 range
Results: Lead Concentration

- First draw: range <1ug/L to 24,740ug/L
- 80% had detectable lead concentrations above 1ug/L
- Flushing system for 5 minutes reduced lead concentrations to recommended levels for most households
- 74% had non-detectable levels after flushing
Results: First Draw versus Flushing

Figure 1 | Lead concentrations in (a) first draws and (b) flushed samples collected during the 2012 and 2013 VA-HWPQ drinking water clinics. Dashed lines represent the detection limit (1 μg/L).
Soluble versus Particulate Lead

- Particulate lead ranged from non-detectable to 99% total composition.
- First draw did not show difference in particulate lead compared to subsequent draws after flushing.
- Homeowners who identified signs of corrosion (blue-green staining, metallic taste) were 1.7 to 2.8 times more likely to have ELL.
Conclusion

- 60% of samples exceeded recommended levels of one health-based standard for municipal water systems
- 19% of households had ELL above 15ug/L
- Dug/bored wells had significantly higher ELL versus drilled wells
- Increased ELL were associated with obvious signs of corrosion which may be area of public health focus
- Flushing for 5 minutes reduced ELL below 15ug/L in all but 2% of samples
Elevated Blood Lead Levels in Children Associated with the Flint Drinking Water Crisis: A Spatial Analysis of Risk and Public Health Response

Background

- April 2014
- Flint, Michigan
- Water supply changed from Detroit supplied Lake Huron water to the Flint River
- Reported concerns
  - Color
  - Taste
  - Odor
  - Health complaints
    - Rashes
Background

- Safe Drinking Water Act violations
  - Bacteria – E-Coli
  - Disinfection byproducts - Trihalomethane levels
- High chloride
- High chloride-to-sulfate mass ratio
- No corrosion inhibitor
- High % of lead pipes and plumbing
  - 10% - 80%
Flint, Michigan

- Postindustrial region
- Lost 77% manufacturing employment since 1980
- Childhood poverty
- Unemployment
- Domestic violence
- Preterm births
- Infant mortality
- Negative health outcomes
- Racial discrimination
Methods

- Retrospective study
- \(< 5 \text{ years old}\)
- BLL processed by Hurley Medical Center
- Pre time period: 1/1/13 – 9/15/13
- Post time period: 1/1/15 – 9/15/15
- Flint (n=1473); Outside of Flint (n= 2202)
- Highest BLL recorded as pre or post timing
  - Reference: 5 micrograms per deciliter
- Chi square analysis / ANOVA / Spatial analysis
Results

- Flint children – significant change
  - Pre period: 2.4% had EBLL
  - Post period: 4.9% had EBLL

- Outside of Flint – no significant change

- High WLL Flint – significant change
  - Pre period: 4.0% had EBLL
  - Post period: 10.6% had EBLL
FIGURE 1—Comparison of Elevated Blood Lead Level Percentage, Before (Pre) and After (Post) Water Source Change From Detroit-Supplied Lake Huron Water to the Flint River: Flint, MI, 2013 and 2015

Note: WLL = water lead level.

*P<.05.
Results

- Spatial analysis
  - Significant clustering of EBLLs
  - Highest WLLs coincide with highest EBLLs
    - Wards 5, 6, & 7
Discussion

- Increase in % of Flint children with EBLL before and after the change in water sources
- Greatest EBLL increase in specific wards of Flint that correspond to areas of high WLLs
- No environmental confounders noted
- Pre-existing disparities to lead poisoning
- Spatial analysis – guide relief efforts for priority distribution of resources
Limitations

- Underestimated water-based lead exposure
- Lead screening not completed for all children
  - Poverty-focused
  - One lab
- Previous environmental exposure
Conclusions

- Unchecked lead exposure for more than 18 months
- “Dramatic failure of primary prevention”
- Money “saving” changes
- Need for more state and federal oversight
- Public health must be a priority
Future Research

- Detailed geospatial analyses of lead service line locations
- Examine long term effects even after water source is returned
- Feeding type for children (breastfed/formula)
- Newborn BLLs
- Lead testing in homes
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