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The Public Health Response to Large Scale Water Contamination

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PEHSU Pediatric Environmental Health Specialty Units

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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

McKay, C. & Scharman, E. (2015)

Emerg Med Clin N Am 33

Water Contamination

- ~ 84% of US population is served by public water systems
- Public drinking water systems
  - 2/3 surface water
  - 1/3 groundwater
  - Serve $\leq$ 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

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

Water Contamination

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

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

Pieper, K., et al. (2015)

Journal of Water and Health 13.3

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 led 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

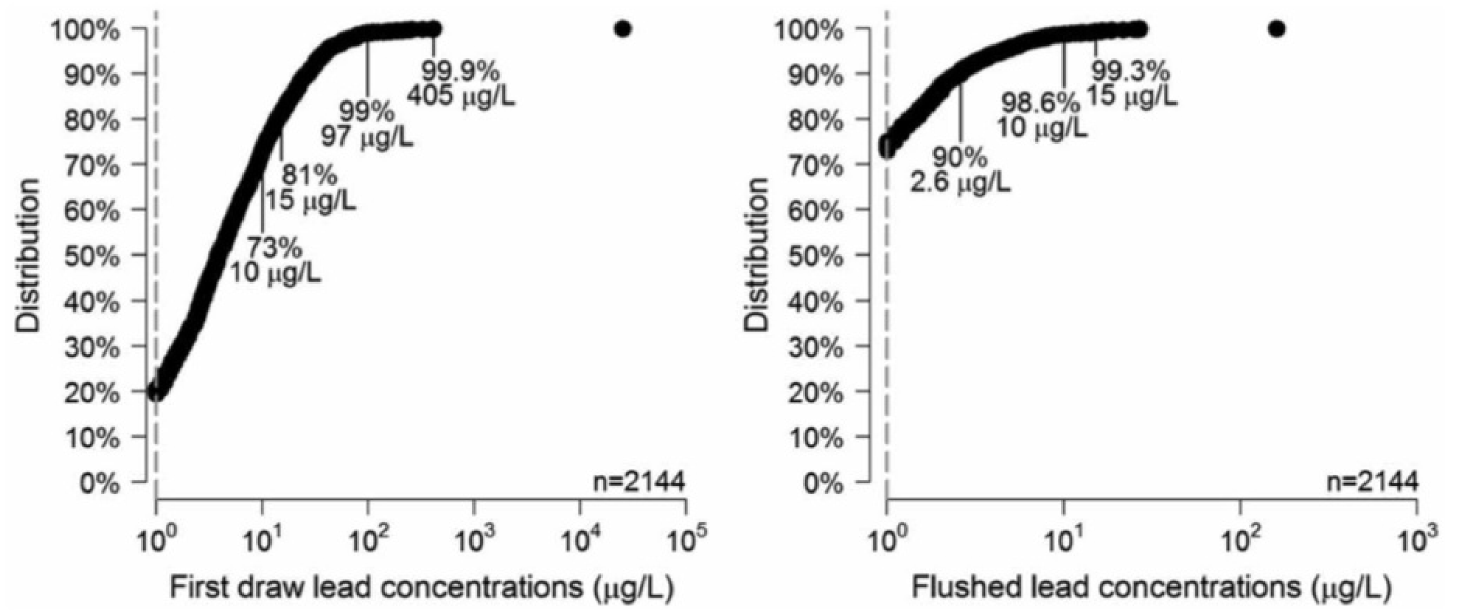


Figure 1 | Lead concentrations in (a) first draws and (b) flushed samples collected during the 2012 and 2013 VAHWQP drinking water clinics. Dashed lines represent the detection limit (1 μg/L).

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*

Hanna-Attisha, M., LaChance, J., Sadler, R., & Schnepp, A. (2016)
AJPH Vol 106, No. 2

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%

Background

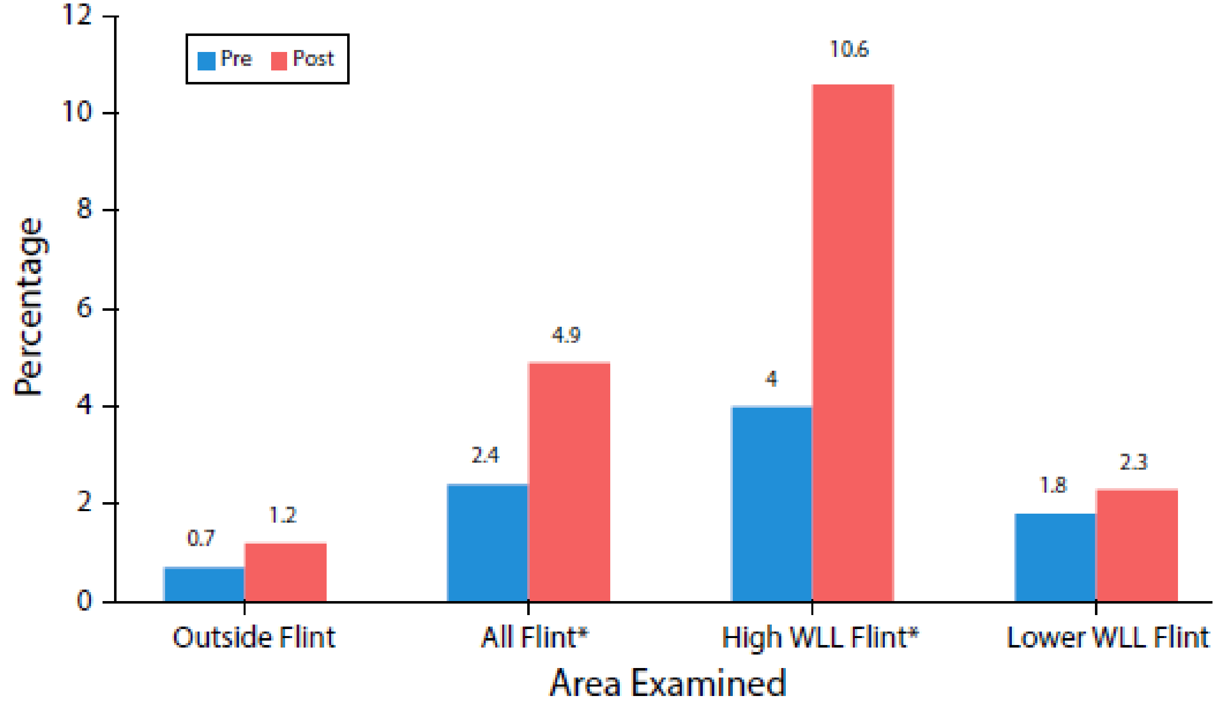
- Flint, Michigan
  - Postindustrial region
  - Lost 77% manufacturing employment since 1980
  - Childhood poverty
  - Unemployment
  - Domestic violence
  - Preterm births
  - Infant mortality
  - Negative health outcomes
  - Racial discrimination

Methods

- Retrospective study
- ≤ 5 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 BBL 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



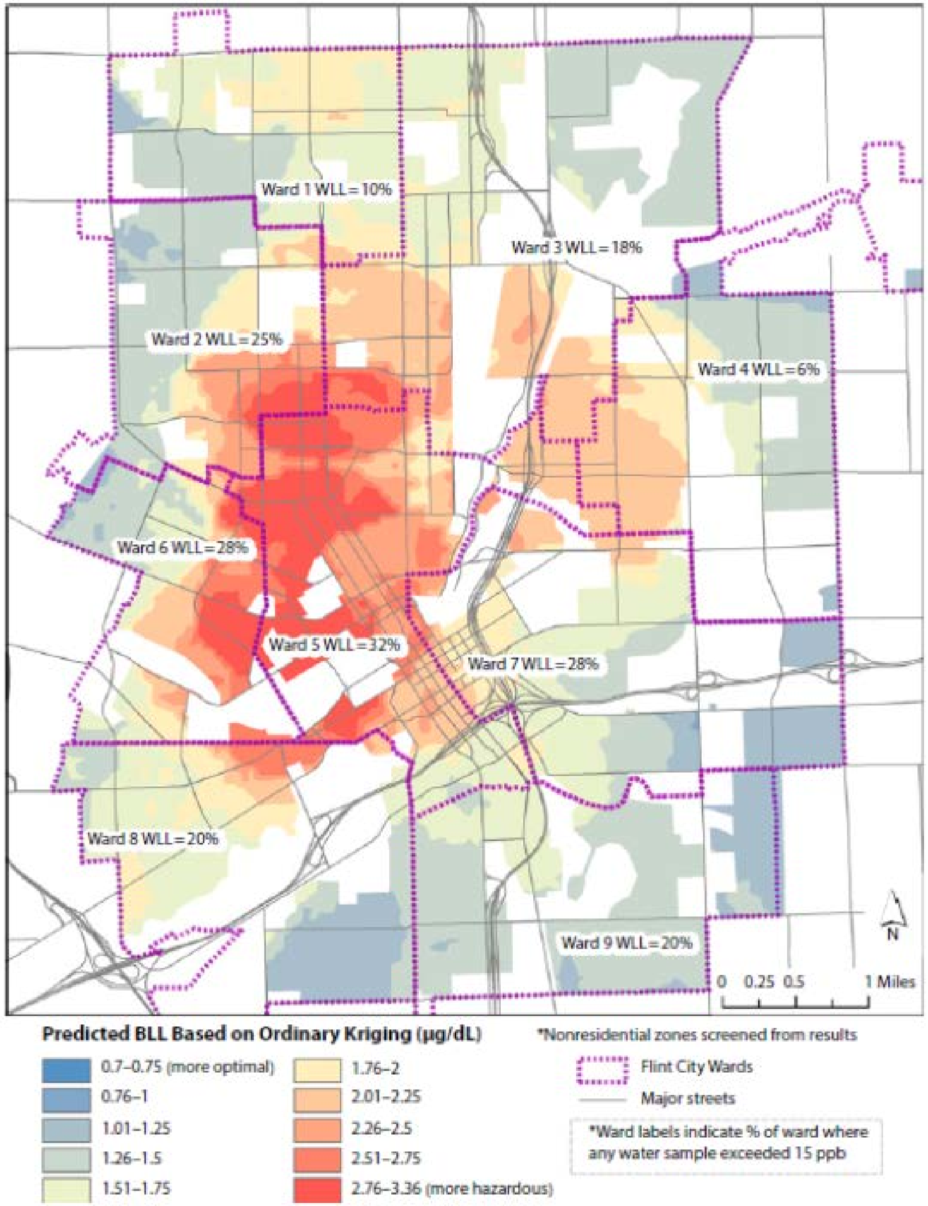
Note. WLL = water lead level.

**P* < .05.

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

Results

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



Note. BLL = blood lead level; WLL = water lead level.

FIGURE 2—Predicted Surface of Child Blood Lead Level and Ward-Specific Elevated Water Lead Level After (Post) Water Source Change From Detroit-Supplied Lake Huron Water to the Flint River: Flint, MI, 2015

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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