Arsenic and Lead in Drinking Water

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Contact: Stan Hazan, Sr. Director Science & Regulatory Affairs hazan@nsf.org 1-734-769-5105 www.nsf.org

Disclosure

- Stan Hazan, BSc, MPH, MBA
- Employed by NSF International
- Board member:
  - Dean's Advisory Board, University of Michigan, School of Public Health
  - Partnership for Food Safety Education
- No external funding sources

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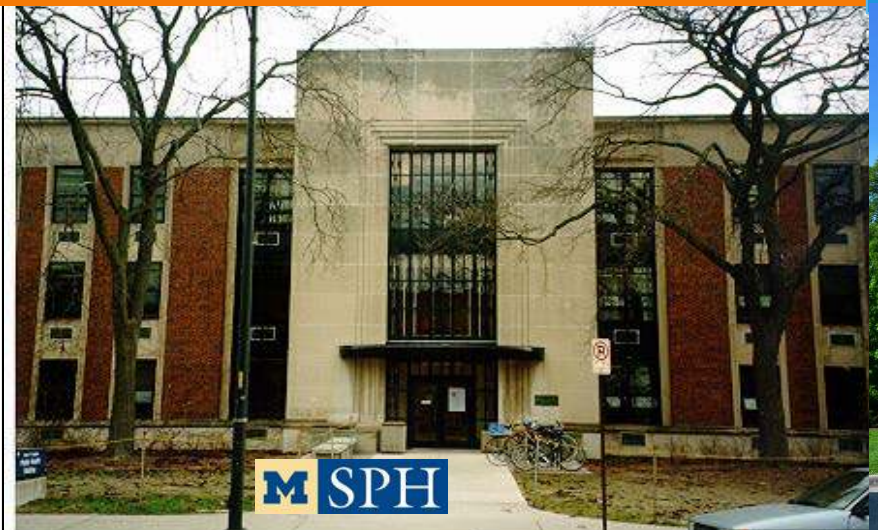

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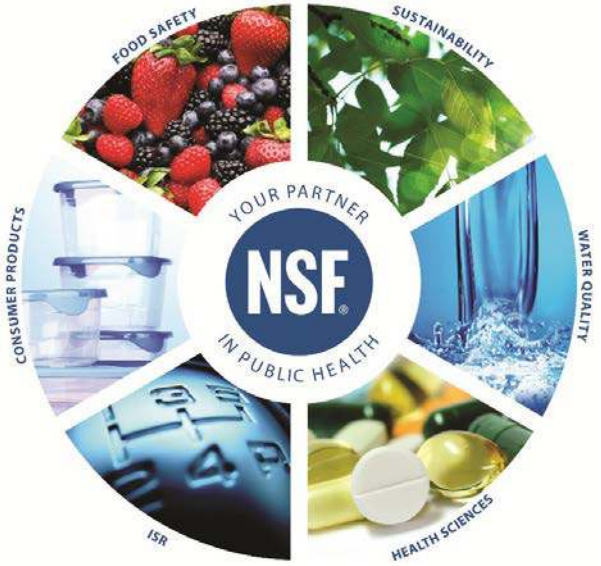

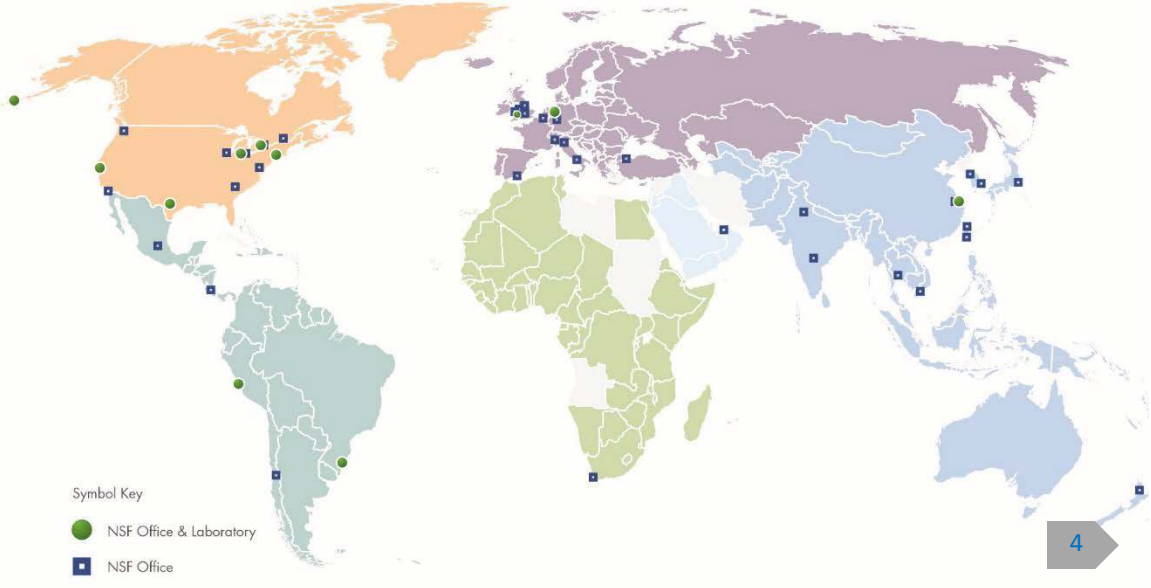

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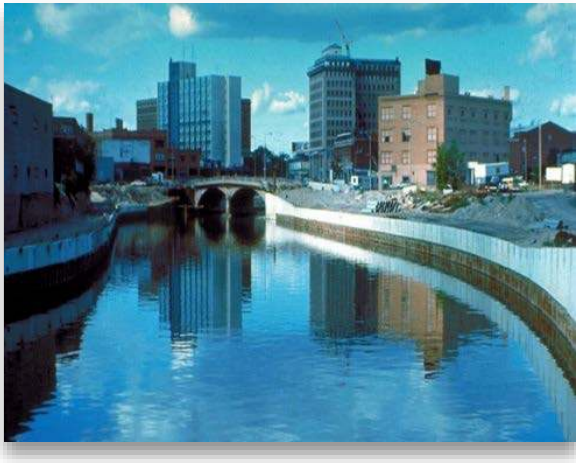
- Drinking Water Treatment Chemicals – Health Effects
- Drinking Water Treatment Units – Aesthetic and Health Effects
- Plastics and Plumbing Components – Performance and Health Effects
- Prevention of Injury and Disease Associated with Building Water Systems
- Municipal Drinking Water Equipment – Performance
- Recreational Water Facilities
- Wastewater Technology
- Legionella / Cooling Towers
- Biofilms
- Microcystin/Algal Blooms
- PFOS and PFOA



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- Food
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- Indoor Environments
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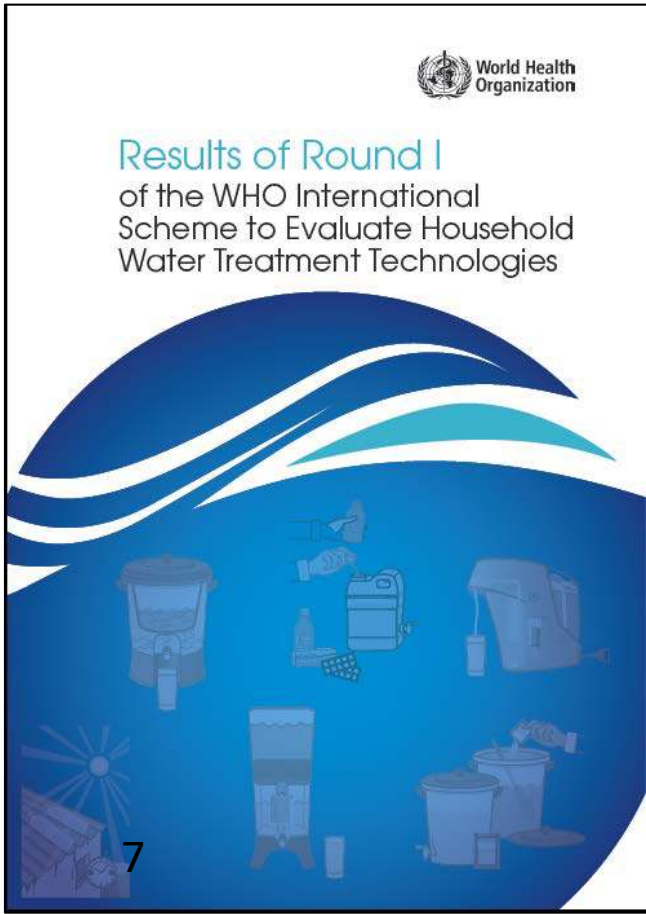
- WHO Chemical Risk Assessment Network
  - Review of Chemical-Specific Adjustment Factors (CSAF)
- Drinking Water Conferences
  - Heterotrophic Plate Count Bacteria in Drinking Water Systems
  - Calcium Magnesium in DW and Cardiac Events (w ILSI)



NSF Environmental Programs

- Wastewater (Septic and Advanced Wastewater Treatment Technology)
- Ballast Water Treatment Technology Verification Program/CG/NRL/EPA
- EPA Safer Choice / Design for the Environment / CleanGredients
- TSCA, FIFRA, GRAS
- CA Proposition 65
- Sustainability
  - Safer Choice (NSF assisted w drafting of Guidelines)
  - Green House Gases (GHG) Certification
  - Water Sense

The Safe Drinking Water Act (SDWA)

- Enacted 1974, Amended 1986 and 1996
- Primacy grants State responsibility for compliance and enforcement
- SDWA addresses >100 drinking water contaminants, including lead and arsenic
- National Primary and Secondary Drinking Water Regulations
- Primary are enforceable, Secondary are not enforceable
  - Microorganisms, Disinfection Byproducts, Inorganic Chemicals, Organic Chemicals, Radionuclides
- Public water systems have >15 service connections, >25 people for 60 days/year.

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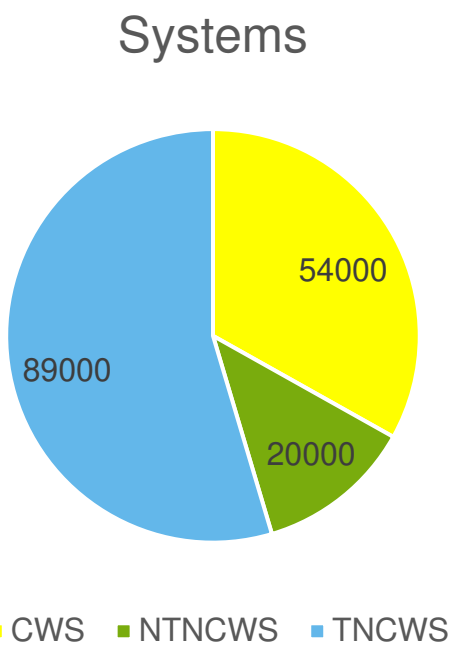
The Safe Drinking Water Act (SDWA)

- Drinking water standards apply to water systems differently based on type and size
- Community Water Systems (~54,000) serve same people year-round.
  - Homes, apartments, condos in cities, small towns, and mobile home parks.
  - Receive Consumer Confidence Reports
- Non-Community Water Systems (~110,000) serve the public but not year-round.
  - Non-Transient Non-Community Water Systems (~20,000) serve same people >6 months/yr but not year-round, i.e. a school with own water supply.
  - Transient Non-Community Water Systems (~89,000) serve the public but not same individuals for more than 6 months, i.e. rest area or campground.



1996 SDWA Amendments - Highlights

- Consumer Confidence Reports, annually.
- Cost-Benefit Analysis for every new standard.
- Drinking Water State Revolving Fund.
- Microbial Contaminants and Disinfection Byproducts Rules.
- Operator Certification.
- Small Water Systems Assistance to Comply
- Source Water Protection & Risk Assessment Programs

Table 2. U.S. drinking water system summary (USEPA, 2012)

System Service Population	Very Small <=500	Small 501–3,300	Medium 3,301–10,000	Large 10,001–100,000	Very Large >100,000	Total
Number of Systems	127,896	19,180	5,176	3,861	426	156,539
% Total Systems	82%	12%	3%	2%	0.3%	100%
Service Population	14,336,173	25,181,127	30,048,390	110,185,765	140,623,820	320,375,275
% Total Population	4.5%	7.9%	9.4%	34%	44%	100%

SDWA Rules, Regulations and Other Unfunded Mandates

1976 – Drinking Water Standards (22 contaminants)
1983 – Total Trihalomethanes (TTHMs)
1987 – Phase 1 Volatile Organic Chemicals
1989 – Total Coliform Rule / Surface Water Treatment Rule
1991 – Phase 2 Synthetic Organic / Inorganic Chemicals
1991 – Lead Copper Rule
1996 – Information Collection Rule
1998 – Stage 1 Disinfection By-Products Rule
1998 - Interim Enhanced Surface Water Treatment Rule
1999 – Unregulated Contaminant Monitoring Rule
2000 – Radionuclides Rule
2001 – Arsenic Rule
2002 – 9/11 - Vulnerability Assessments, Emergency Response Plans
2003 – Stage 2 Disinfectants and DBP Rule
2003 – Long Term 2 Enhanced SWT Rule
Cybersecurity Requirements, and more

Violations and Compliance by System Type

System Type	Health-Based Violations	Systems in Violation	Population (M) in Violation	Total Systems by Type	Total Population (M) by Type	GPRA-System Basis	GPRA-Population Basis
CWS	9,906	4,682	22.90	50,808	303.36	91%	92%
NTNCWS	2,184	1,354	0.40	18,225	6.34	93%	94%
TNCWS	5,494	4,076	0.55	84,105	12.76	95%	96%
Total	17,584	10,112	23.85	153,138	322.45	93%	93%

- https://echo.epa.gov database contains info on Public Water Systems by Size, Type, Source, State, City, Violations, Enforcements, Inspection, Sanitary Survey)

Source: SDWIS Pivot Tables (2014) per AWWA

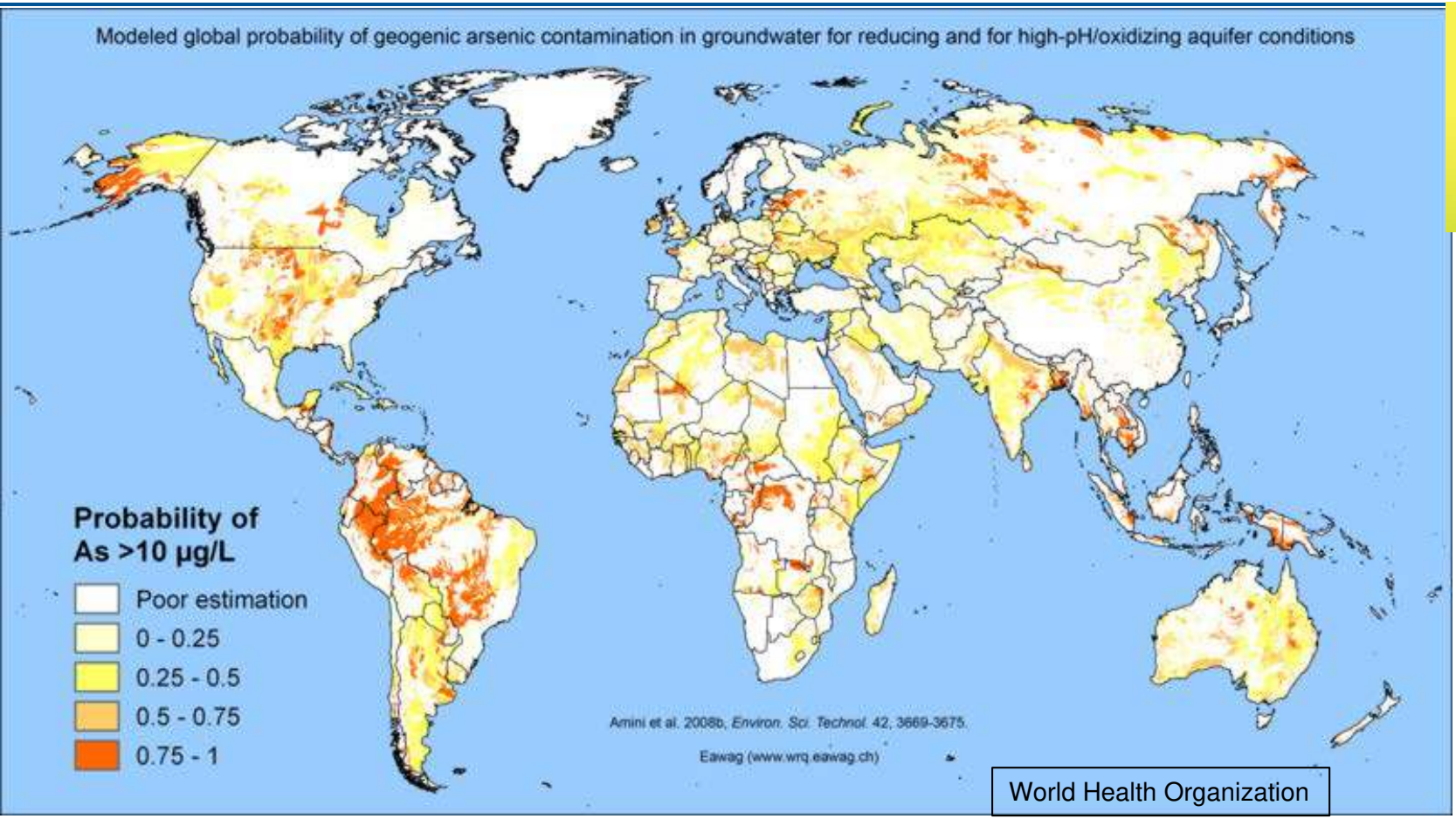
Arsenic in Drinking Water

Arsenic in Drinking Water

33
As
Arsenic
74.922

- Arsenic comprises 0.00015% of the Earth's crust
- 53rd most abundant element
- Common valence forms III and V
- Toxicity = skin, lung and bladder cancer risk, neuropathies
- Found in surface & ground waters, rice, apples and other Ag foods
- US EPA DW MCL = 10ug/L, MCLG = 0ppb
  - Drop from 50ug/L in 2001 resulted in significant SDWA non-compliances
- Surface waters less contaminated with As
- Centralized systems use Coag/Floc (Fe, Al) for >90% reduction
- Decentralized and individual wells have greater challenges
  - Breakeven point ~ 120/200 connections for RO / Alumina Mn POUs
- POU RO and manganese coated activated alumina effective for As(V)
- POU RO not effective for As(III) which must be oxidized to As(V)

Arsenic in Drinking Water



World Health Organization

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Arsenic in Bangladesh Drinking Water

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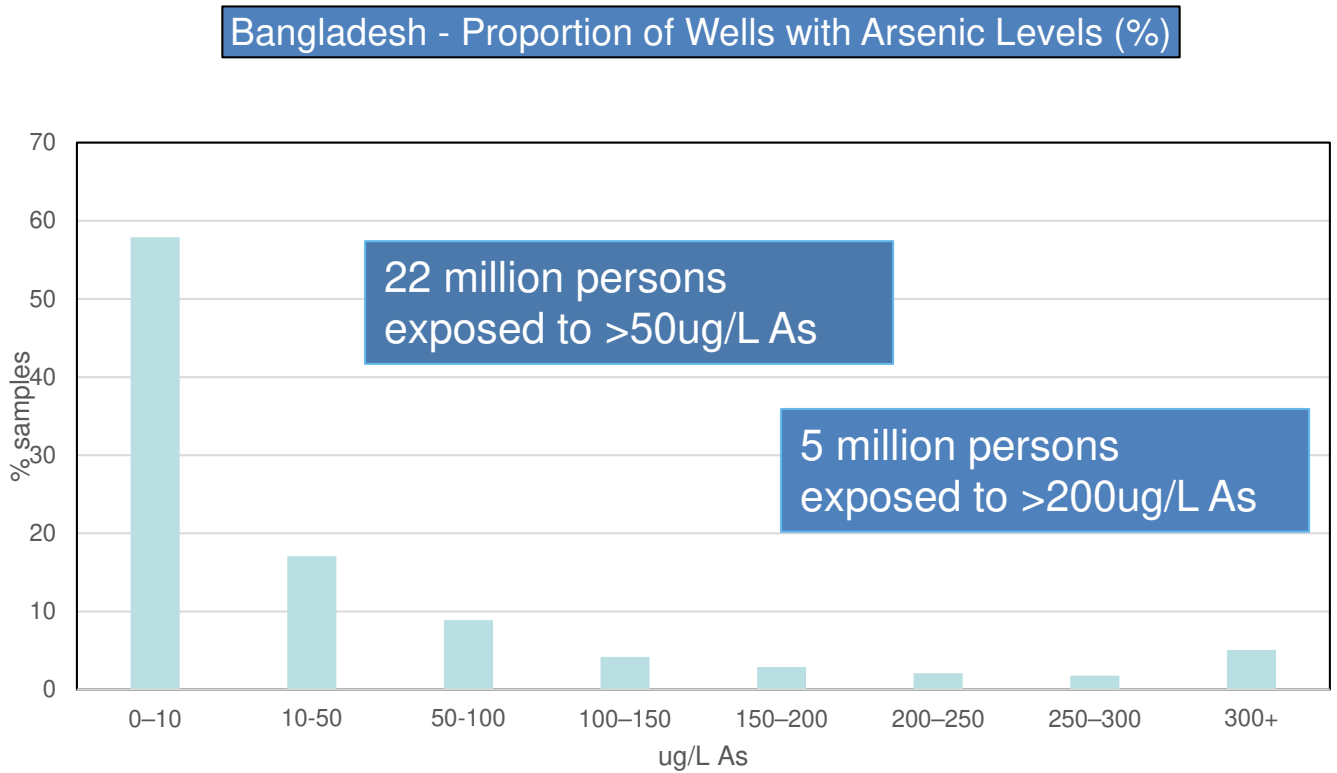
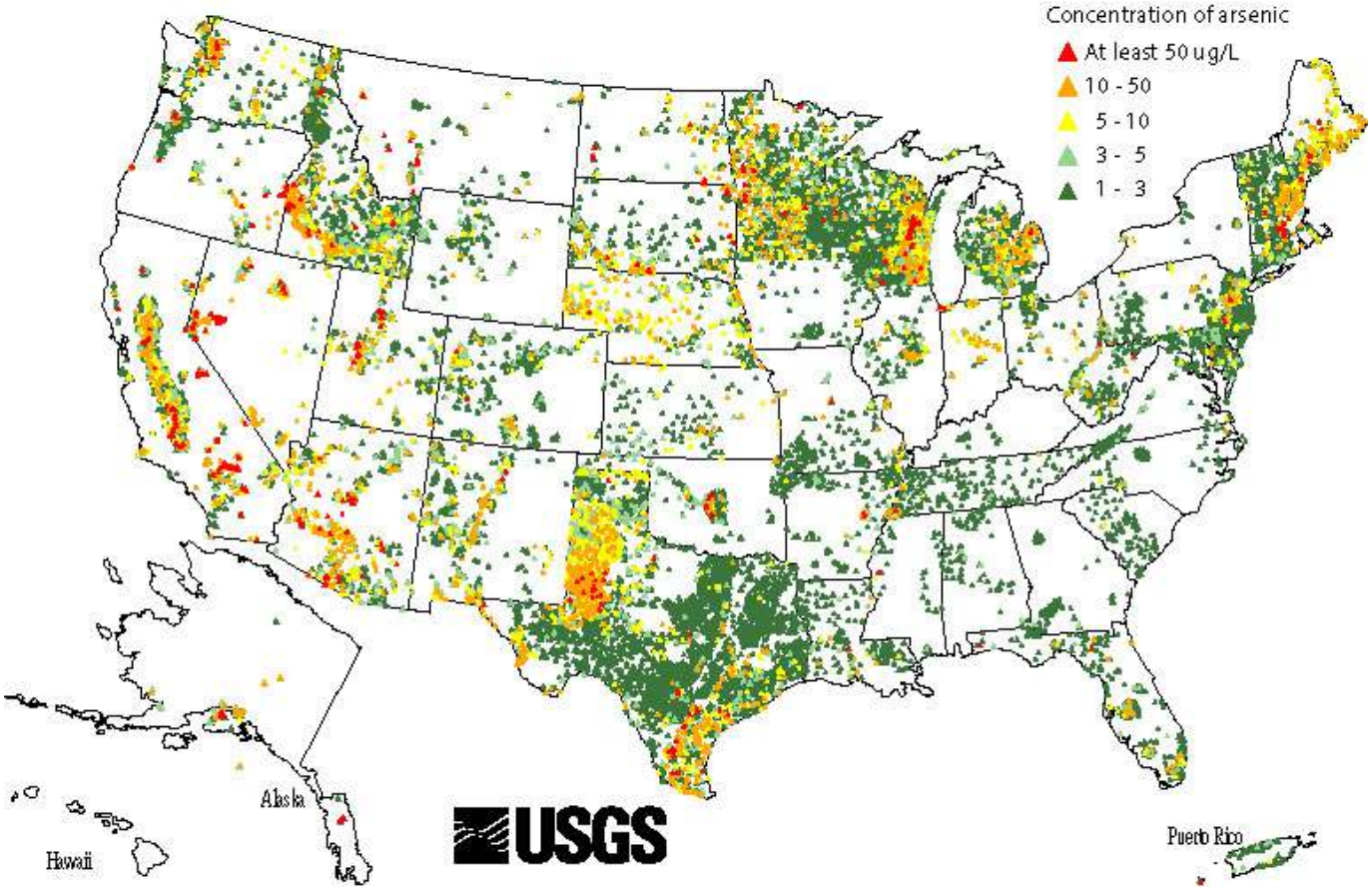


Arsenic in USA Groundwater



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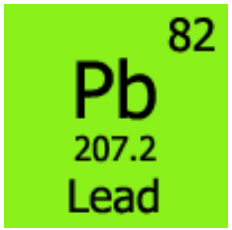
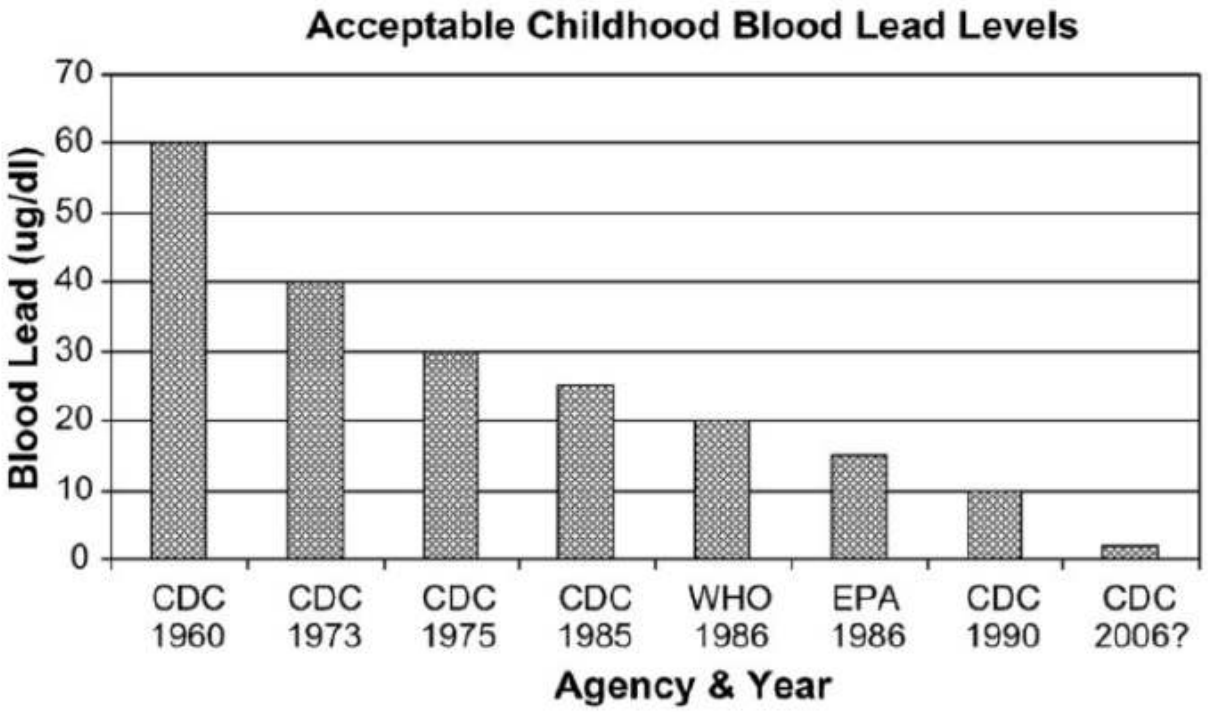
Lead in Drinking Water



Public Health Agencies' Positions on BLL vs Time

82
Pb
207.2
Lead

Fig. 1



The gradual decline in acceptable blood lead levels in children. The 2006 number is the recommend value based on current scientific knowledge.

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Blood Lead Levels over Time

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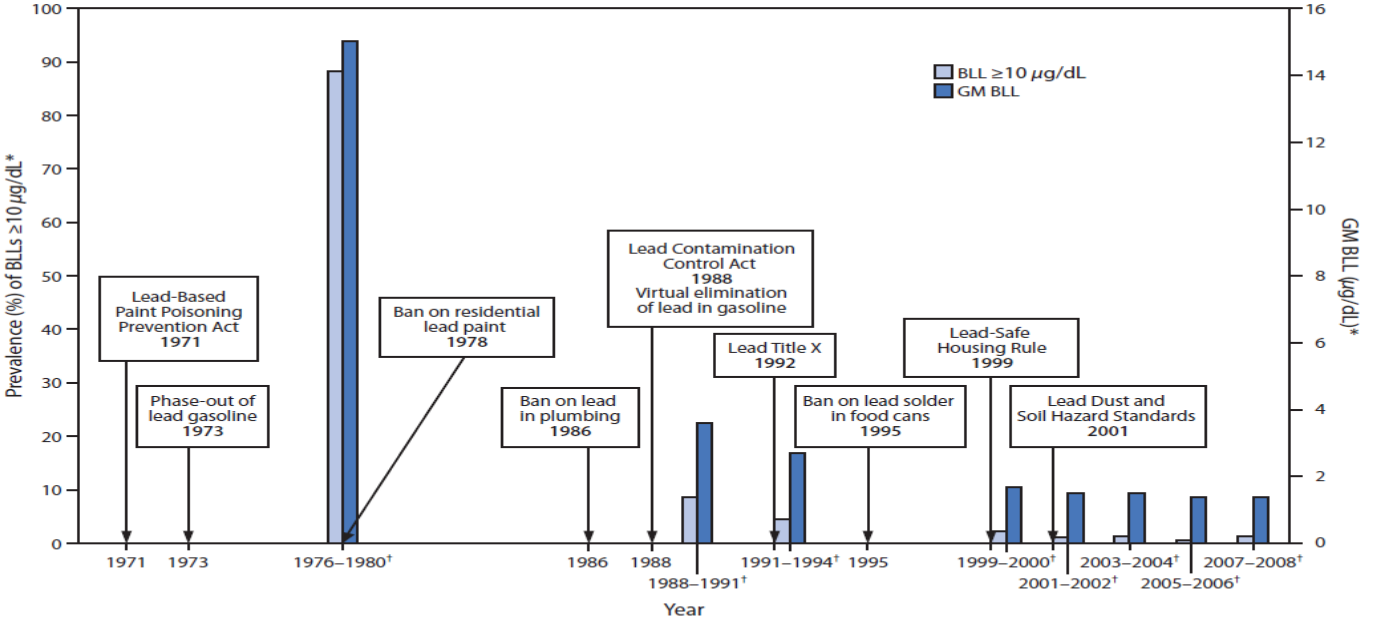
207.2
Lead

FIGURE. Timeline of lead poisoning prevention policies and blood lead levels in children aged 1–5 years, by year — National Health and Nutrition Examination Survey, United States, 1971–2008



Abbreviations: BLL = blood lead level; GM = geometric mean; NHANES = National Health and Nutrition Examination Survey.

Sources: Mahaffey KR, Annest JL, Roberts J, Murphy MS. National estimates of blood lead levels: United States (1976–1980). N Engl J Med 1982;307:573–9. Jones R, Homa D, Meyer P, et al. Trends in blood lead levels and blood lead testing among U.S. children aged 1 to 5 years: 1998–2004. Pediatrics 2009;123:e376-85. National Health and Nutrition Examination Survey, 2000–2008. Available at http://www.cdc.gov/nchs/nhanes.htm. Accessed July 17, 2012.

* National estimates for GM BLLs and prevalence of BLLs ≥10 µg/dL, by NHANES survey period and sample size of children aged 1–5 years: 1976–1980: N = 2,372; 1988–1991: N = 2,232; 1991–1994: N = 2,392; 1999–2000: N = 723; 2001–2002: N = 898; 2003–2004: N = 911; 2005–2006: N = 968; 2007–2008: N = 817.

† NHANES survey period.

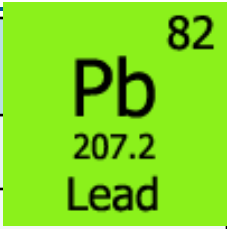
Lead in Drinking Water

82
Pb
207.2
Lead

- High industrial usage, but declining
- Toxicity = neurological development impairment, high blood pressure
- US EPA MCL TT = 15ppb, MCLG = 0ppb
- Lead Copper Rule monitoring (90th percentile < 15ppb)
- Majority of lead sources in drinking water from premise plumbing materials
- Consumer Confidence Reports tracking and reporting
- Corrosion Control Treatment Technique – pH adjustment, phosphates, silicates
- POU and POE treatment technologies
- Lead Service Line replacements
- Soluble vs Particulate Lead

Factors Influencing Lead in Water

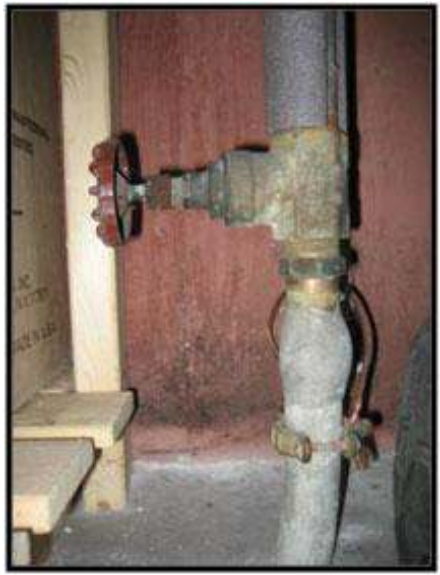
Factor	Distribution Systems	Premise Plumbing
Source Water	Low impact	Low impact
Treatment Additives	Coag/Floc, Disinfection, pH adjustment, Corrosion Control, Fluoride	Low impact
Distribution Materials / Equipment	Pumps, valves, meters, paints, coatings, concrete, process media, pipes, gaskets, sealing materials, service lines, appurtenances	Metal or plastic tubing, fittings, solder, valves, faucets, water heaters,
Flow Rates	Constant	Intermittent/stagnant
Temperatures	Cooler	Warmer
Surface area to volume	0.26 cm^2/mL	2.1 cm^2/mL
Water Velocity	Low	High
Disinfectant	High	Low



Lead Service Lines

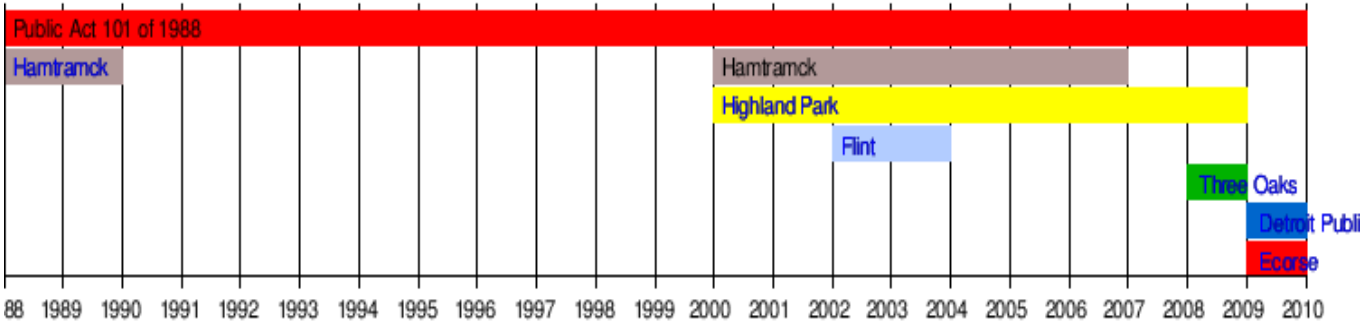
82
Pb
207.2
Lead

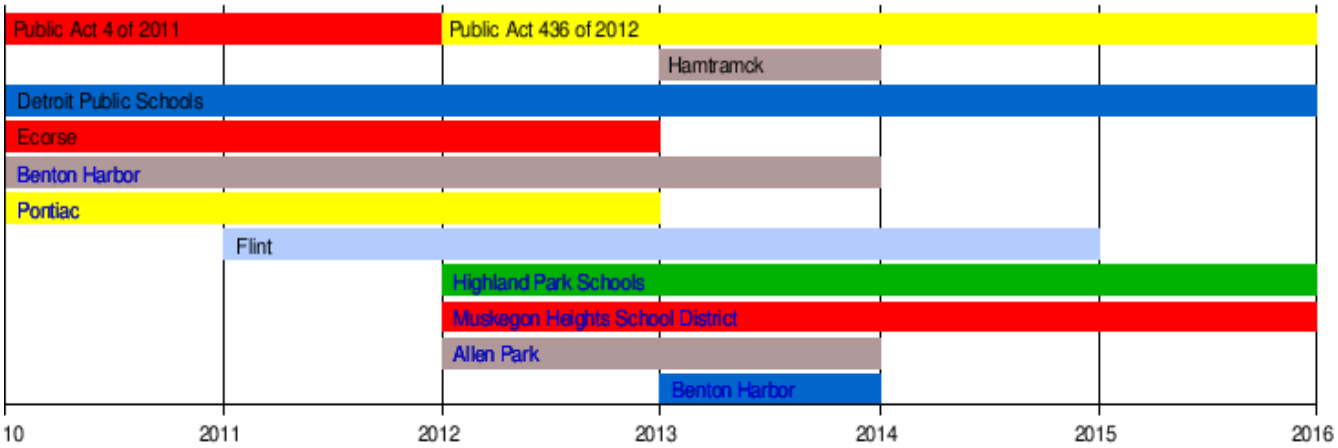
- More than **1 million** lead service lines in the country
- Flint has highlighted the problem of “where are they?”
- Many utilities have ongoing replacement programs.
- Building owners reluctant to replace service lines on their property.
- Partial replacement does not usually solve problem.



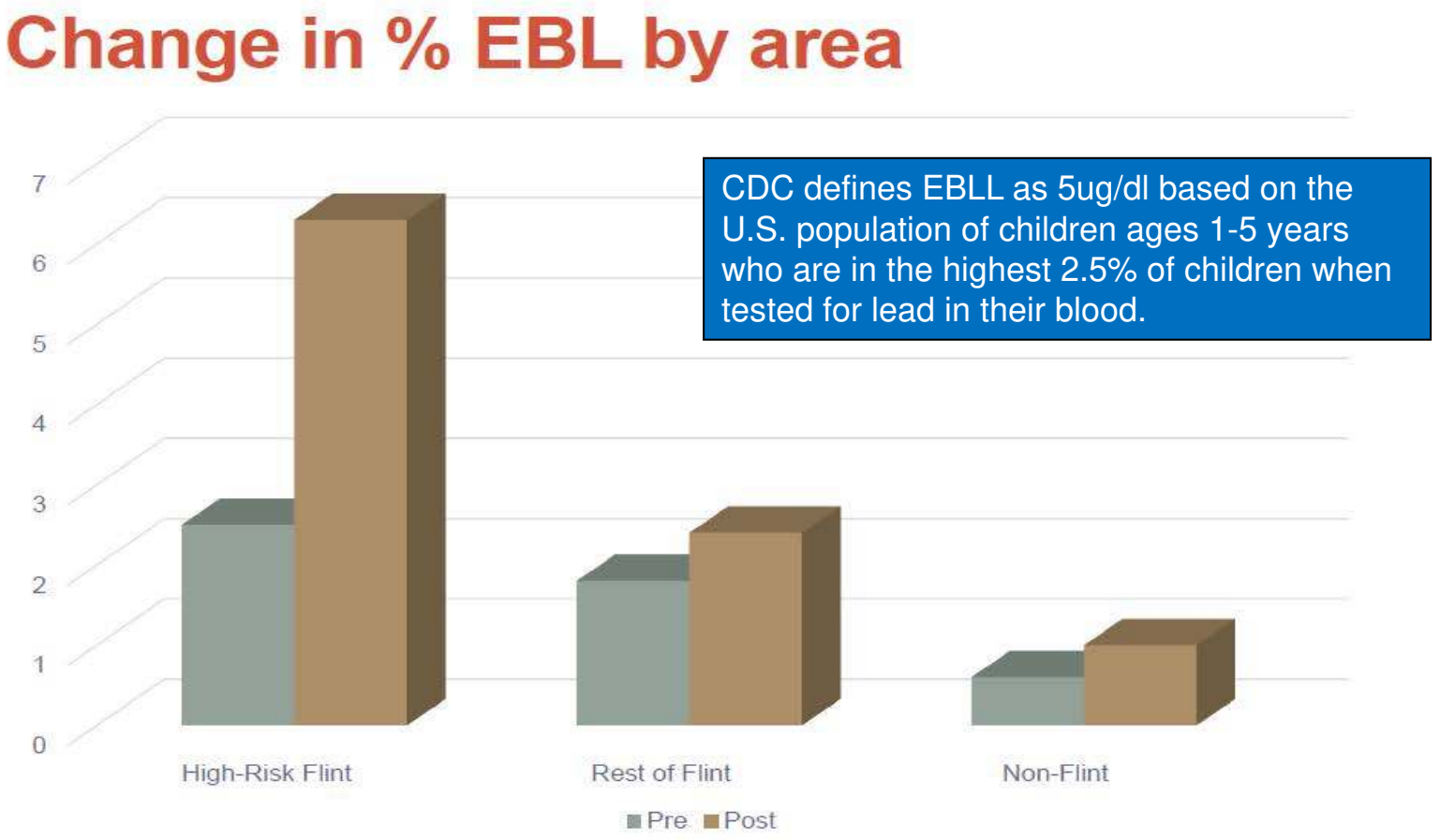
Case Study: Flint

Historical: Michigan Cities w Emergency Financial Managers





Flint: Elevated Blood Lead Levels Detected in Flint by Dr. Mona Hanna-Attisha



Distribution Systems are Ecosystems

Element	%
Fe	76.59
Ca	10.48
P	4.61
Al	3.95
Mg	1.45
Si	1.10
Mn	0.87
As	0.61
Zn	0.16
Cu	0.12
Pb	0.05

Flint Water Crisis - Timeline

- **2011**
  - EFM installed and financial decision made to switch water supply
- **2013**
  - Flint informs Detroit they will build own regional water system by 2016
- **2014**
  - Flint begins using Flint River and shuttered Treatment Plant
  - Immediate complaints of color, taste, odor / rashes, etc
  - 3 boil water advisories due to coliform bacteria detections
  - GM engine plant stops using Flint water because it rusts parts
- **2015**
  - Very high DBPs in water. Detroit offers to reconnect Flint.
  - State pledges $2M for fixes and Flint promises to spend $2.3M for fixes
  - Flint declares water has improved and it meets all regulatory requirements
  - Hurley Medical Center finds high blood lead levels in children
  - Flint urged to stop using Flint River water. State insists water is safe.

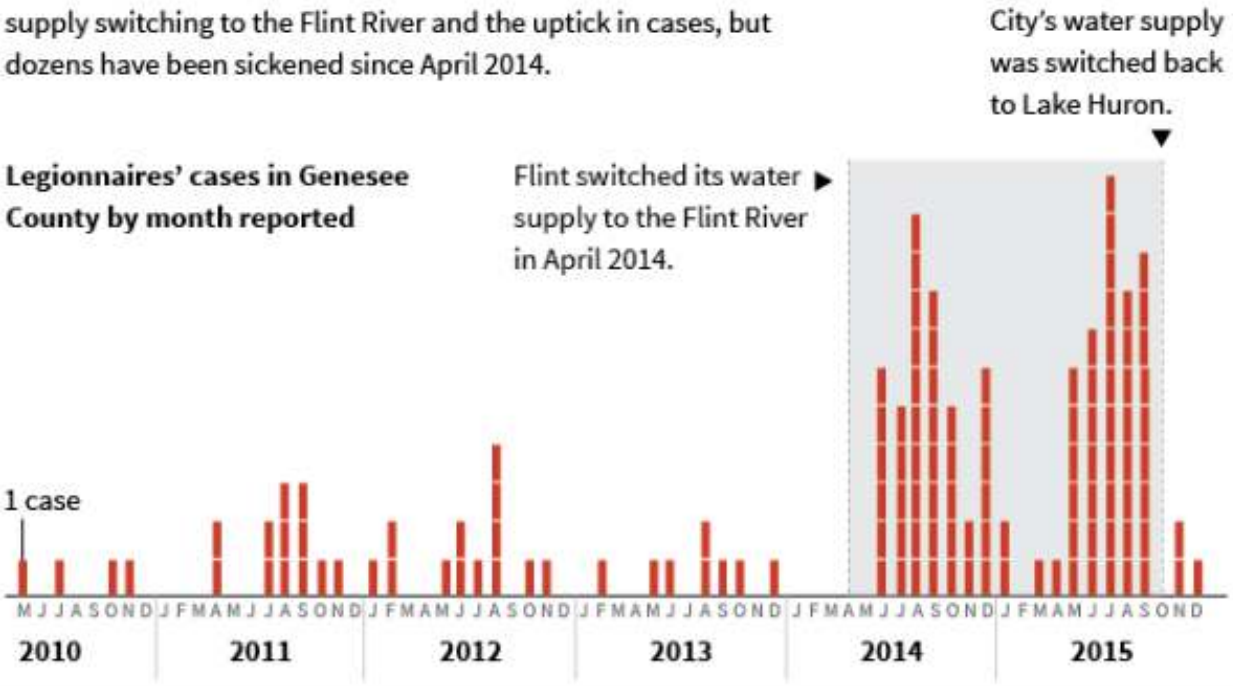
Flint Water Crisis - Timeline

- **2015**
  - Gov. Snyder pledges to take action in response to high blood lead levels.
  - Gov. pledges $1M for filters, bottled water and testing of Flint public schools
  - MI legislature and Governor approve $9.4M in aid and $6M for return to Detroit water.
  - Voters elect new Mayor. MI DEQ Director resigns
- **2016**
  - Governor declares State of Emergency and activates National Guard
  - Federal aid provided and EPA takes over sampling
  - Obama signs emergency declaration – activates FEMA and HHS
  - Lead service line replacement program funded and begins
  - WRDA bill passes and provides $170M to Flint for all types of upgrades/remediation
  - State pushes for end of bottled water distribution unless OK'd by physician
- **2017**
  - Average Pb levels in drinking water Dec 2016 = 8 ppb

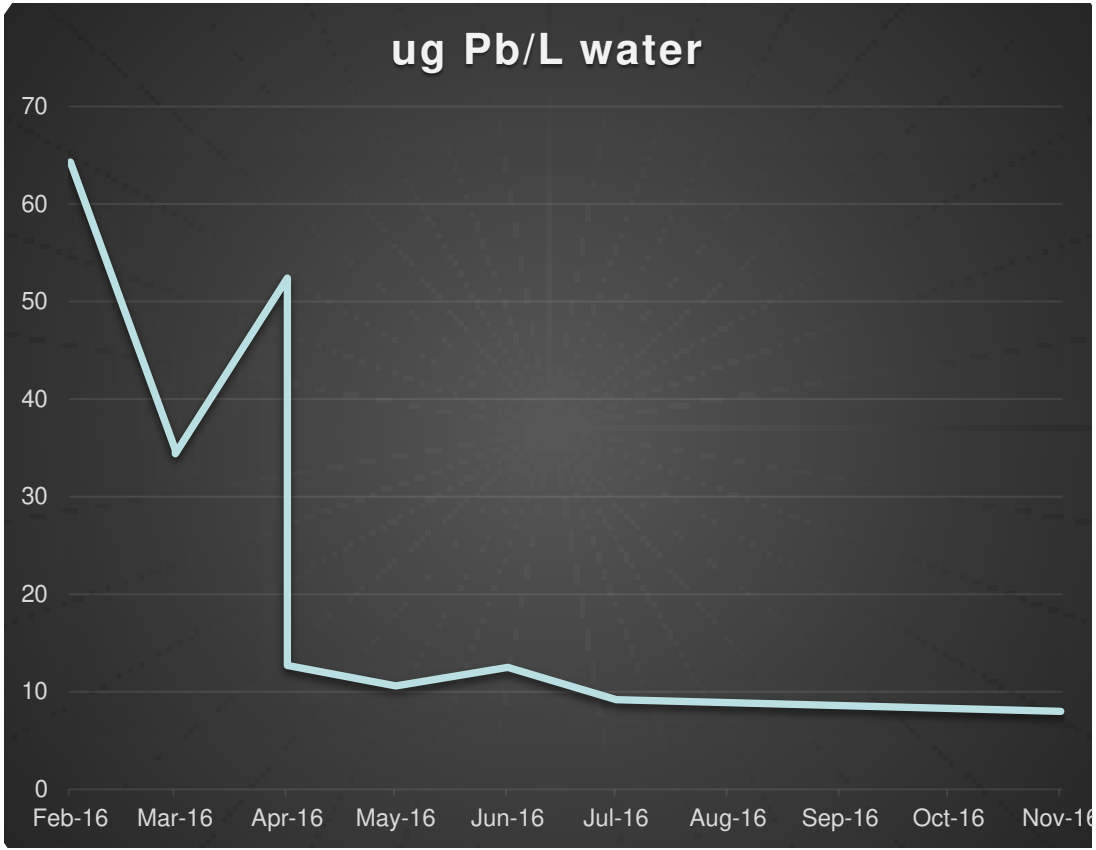
Flint Water Crisis – 2016 Timeline

Legionnaires' Cases Rose Sharply In Flint After Water Switch

No official link has yet been detected between the city's water supply switching to the Flint River and the uptick in cases, but dozens have been sickened since April 2014.



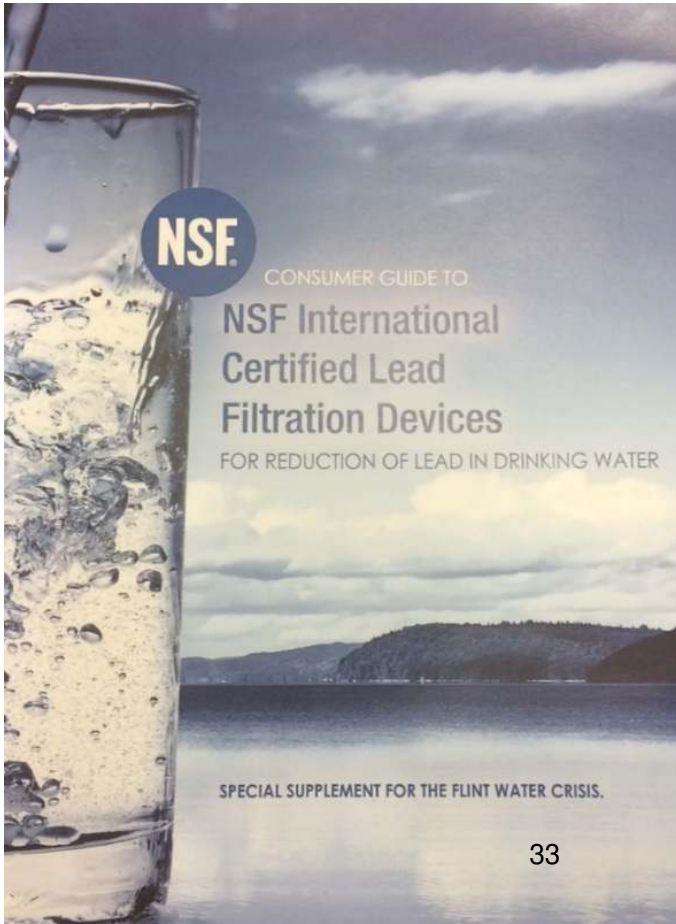
Analysis of Flint Waters



Average (First Draw)	10.6 ppb
90th Percentile (First Draw)	26.8 ppb
Maximum (First Draw)	158 ppb
Maximum (Any sample)	1051 ppb
Total No. of Samples	271

NSF Certified Filters Specified for Flint Residents

- Influent waters exceeded 150ppb ratings
- Particulate lead responsible for high numbers
- Filters performed to 1 ppb or less
- Filters certified to NSF Std 42/53
- Flint residents advised to keep using filters



Water Infrastructure Report Card

- American Society of Civil Engineers' "Report Card" = D+
- Water Main Breaks and Leaks are health issues too
- $1000B/25 yrs needed – Lead Service Lines, CSOs, Wastewater, Storm Water

2012 AWWA report "Buried No Longer: Confronting America's Water Infrastructure Challenge."

Table 2. U.S. drinking water system summary (USEPA, 2012)

System Service Population	Very Small <=500	Small 501–3,300	Medium 3,301–10,000	Large 10,001–100,000	Very Large >100,000	Total
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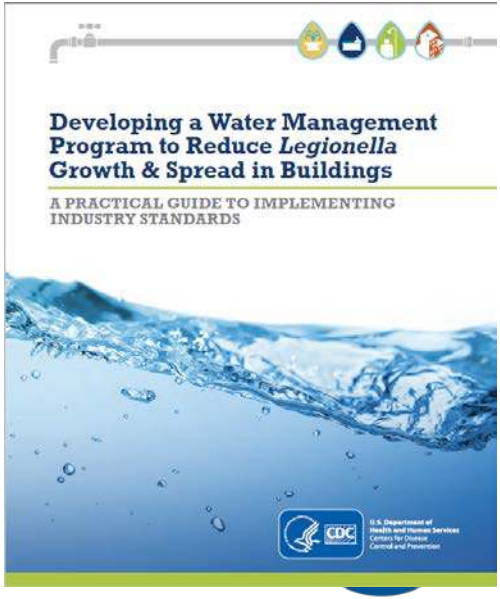
% Total Population	4.5%	7.9%	9.4%	34%	44%	100%

Water Utility Issues

- Costs of regulatory compliance
- Cost transfer (grants to loans (SRF))
- O&M costs increasing rapidly
- Rising rates / affordability
- Water age / turnover / chlorine residual / biofilm
- Legacy materials in the distribution system
- Lead service lines, brass fittings, solder in homes

Other Drinking Water Issues in the News

- Declining population centers / Environmental justice issues
- Water conservation / cost of drinking water / affordability of water
- PFOS/PFOA (Perfluorinated Compounds)
- Agricultural Nutrient runoff - Harmful Algal Blooms – Cyanotoxins
- Emerging contaminants including trace pharmaceuticals
- Fracking/Drilling impacts on aquifers
- Legionella in Premise Plumbing and in Cooling Towers



Trends in Costs of Municipal Water

FIGURE 1 Median per capita operating expenses

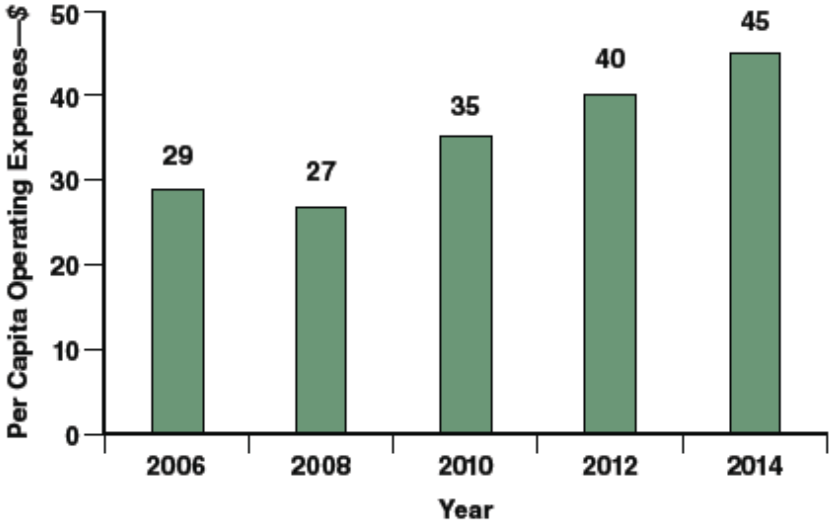
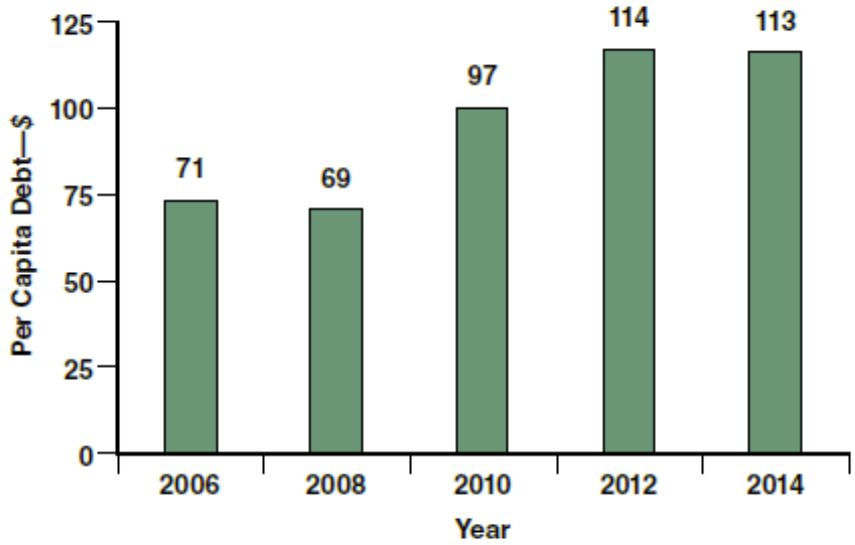
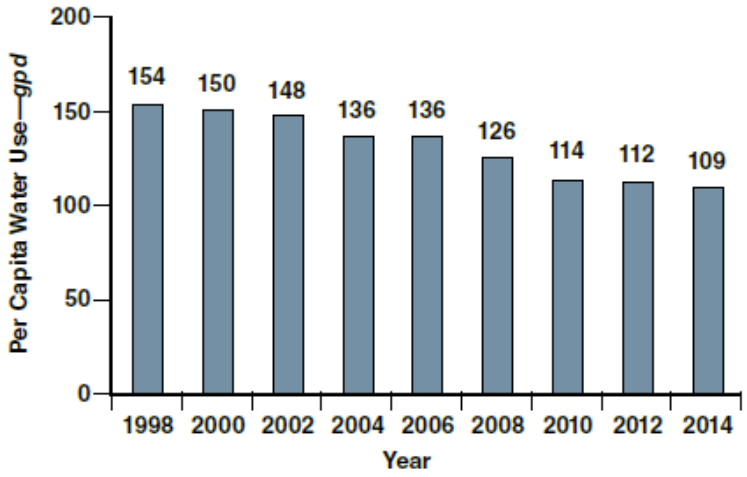


FIGURE 2 Median per capita long-term debt



Trends in Use and Costs of Municipal Water

FIGURE 3 Water use per capita



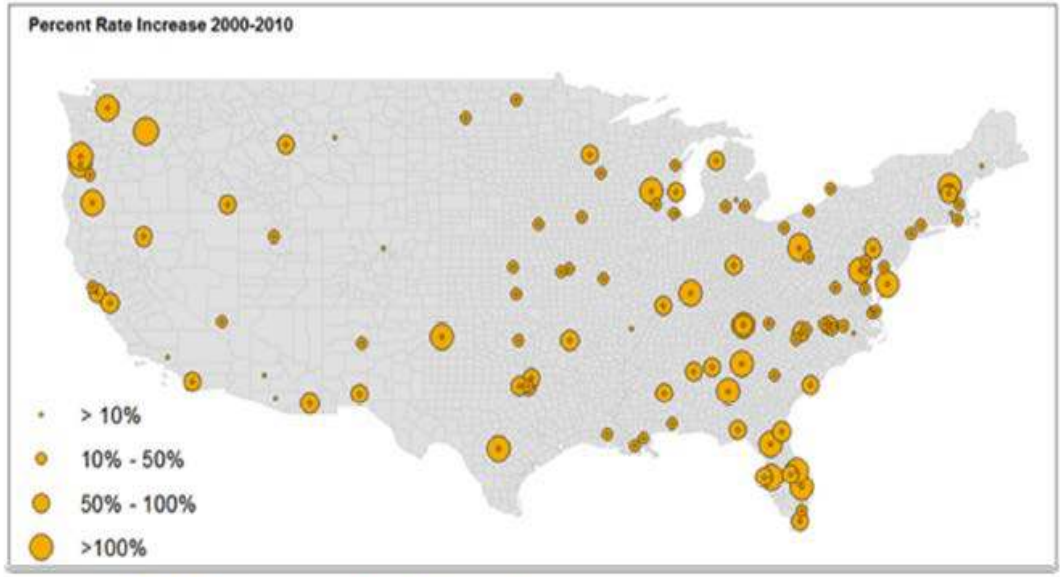


Figure 1: Water Rate Increases from 2000 - 2010

Bianca Rahill-Marier, Upmanu Lall. “America’s Water: An exploratory analysis of Municipal Water Survey Data”

Key Take Aways

- Arsenic is a natural contaminant in groundwater that will persist
- Lead is a man made contaminant problem that will eventually be reduced
- Infrastructure problems will continue to persist
- Cost of drinking water will increase as will opportunities to cut corners
- Public trust and confidence issues – New LCR
- Smaller utilities are at higher risk
- Expect more “self protection” in the way of POU/POE
- Flint can happen anywhere!

Committed to Environmental & Public Health

Contact: Stan Hazan, Sr. Director Science & Regulatory Affairs hazan@nsf.org 1-734-769-5105 www.nsf.org