Arsenic and Lead in Drinking Water

Presented at ILSI Annual Meeting
La Jolla, CA
January 24, 2017

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
About NSF International

In 1944, NSF was founded as the National Sanitation Foundation at the University of Michigan School of Public Health.

Today, we are NSF International, a 501 (c) 3 non-profit with more than 2600 science professionals in 51 office and lab locations worldwide.
NSF Mission: To protect and improve human health
NSF Water Programs

Additives, Water Contact, Treatment, Performance, Risk Assessment
- Drinking Water System Components – Health Effects
- 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
NSF / WHO PAHO Collaborating Centers

NSF is a WHO/PAHO Collaborating Center since 1996

- Water
  - Home Water Treatment for pathogen reduction
  - Airline Water Safety
  - Water Safety Plans for Utilities
- Food
  - Risk Assessment of Chemicals in Foods
- Indoor Environments
  - Exploring Clean Cookstoves Initiative role
- 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 with drafting of Guidelines)
  - Green House Gases (GHG) Certification
  - Water Sense
The Safe Drinking Water Act (SDWA)

- 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.
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>
<thead>
<tr>
<th>System Service Population</th>
<th>Very Small &lt;=500</th>
<th>Small 501-3,300</th>
<th>Medium 3,301-10,000</th>
<th>Large 10,001-100,000</th>
<th>Very Large &gt;100,000</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Systems</td>
<td>127,896</td>
<td>19,180</td>
<td>5,176</td>
<td>3,861</td>
<td>426</td>
<td>156,539</td>
</tr>
<tr>
<td>% Total Systems</td>
<td>82%</td>
<td>12%</td>
<td>3%</td>
<td>2%</td>
<td>0.3%</td>
<td>100%</td>
</tr>
<tr>
<td>% Total Population</td>
<td>4.5%</td>
<td>7.9%</td>
<td>9.4%</td>
<td>34%</td>
<td>44%</td>
<td>100%</td>
</tr>
</tbody>
</table>
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
<table>
<thead>
<tr>
<th>System Type</th>
<th>Health-Based Violations</th>
<th>Systems in Violation</th>
<th>Population (M) in Violation</th>
<th>Total Systems by Type</th>
<th>Total Population (M) by Type</th>
<th>GPRA-System Basis</th>
<th>GPRA-Population Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CWS</td>
<td>9,906</td>
<td>4,682</td>
<td>22.90</td>
<td>50,808</td>
<td>303.36</td>
<td>91%</td>
<td>92%</td>
</tr>
<tr>
<td>NTNCWS</td>
<td>2,184</td>
<td>1,354</td>
<td>0.40</td>
<td>18,225</td>
<td>6.34</td>
<td>93%</td>
<td>94%</td>
</tr>
<tr>
<td>TNCWS</td>
<td>5,494</td>
<td>4,076</td>
<td>0.55</td>
<td>84,105</td>
<td>12.76</td>
<td>95%</td>
<td>96%</td>
</tr>
<tr>
<td>Total</td>
<td>17,584</td>
<td>10,112</td>
<td>23.85</td>
<td>153,138</td>
<td>322.45</td>
<td>93%</td>
<td>93%</td>
</tr>
</tbody>
</table>

- [https://echo.epa.gov](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

- 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

Modeled global probability of geogenic arsenic contamination in groundwater for reducing and for high-pH/oxidizing aquifer conditions.

Probability of As >10 µg/L
- Poor estimation
- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1

Eawag (www.wrq.eawag.ch)
Arsenic in Bangladesh Drinking Water

Bangladesh - Proportion of Wells with Arsenic Levels (%)

- 22 million persons exposed to >50ug/L As
- 5 million persons exposed to >200ug/L As

33

As
Arsenic
74.922
Arsenic in USA Groundwater
Lead in Drinking Water
The gradual decline in acceptable blood lead levels in children. The 2006 number is the recommend value based on current scientific knowledge.
Blood Lead Levels over Time

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.
† NHANES survey period.
Lead in Drinking Water

- 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

1986 SDWA Lead Ban
1988 Lead Contamination Control Act
1991 Lead Copper Rule
2011 Reduction of Lead Act
2017 Proposed Lead Copper Rule
<table>
<thead>
<tr>
<th>Factor</th>
<th>Distribution Systems</th>
<th>Premise Plumbing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Water</td>
<td>Low impact</td>
<td>Low impact</td>
</tr>
<tr>
<td>Treatment Additives</td>
<td>Coag/Floc, Disinfection, pH adjustment, Corrosion Control, Fluoride</td>
<td>Low impact</td>
</tr>
<tr>
<td>Distribution Materials /</td>
<td>Pumps, valves, meters, paints, coatings, concrete, process media, pipes, gaskets,</td>
<td>Metal or plastic tubing, fittings, solder, valves, faucets, water heaters,</td>
</tr>
<tr>
<td>Equipment</td>
<td>sealing materials, service lines, appurtenances</td>
<td></td>
</tr>
<tr>
<td>Flow Rates</td>
<td>Constant</td>
<td>Intermittent/stagnant</td>
</tr>
<tr>
<td>Temperatures</td>
<td>Cooler</td>
<td>Warmer</td>
</tr>
<tr>
<td>Surface area to volume</td>
<td>0.26 cm²/mL</td>
<td>2.1 cm²/mL</td>
</tr>
<tr>
<td>Water Velocity</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Disinfectant</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>
Lead Service Lines

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

Change in % EBL by area

CDC defines EBLL as 5ug/dl based on the U.S. population of children ages 1-5 years who are in the highest 2.5% of children when tested for lead in their blood.
Distribution Systems are Ecosystems

<table>
<thead>
<tr>
<th>Element</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>76.59</td>
</tr>
<tr>
<td>Ca</td>
<td>10.48</td>
</tr>
<tr>
<td>P</td>
<td>4.61</td>
</tr>
<tr>
<td>Al</td>
<td>3.95</td>
</tr>
<tr>
<td>Mg</td>
<td>1.45</td>
</tr>
<tr>
<td>Si</td>
<td>1.10</td>
</tr>
<tr>
<td>Mn</td>
<td>0.87</td>
</tr>
<tr>
<td>As</td>
<td>0.61</td>
</tr>
<tr>
<td>Zn</td>
<td>0.16</td>
</tr>
<tr>
<td>Cu</td>
<td>0.12</td>
</tr>
<tr>
<td>Pb</td>
<td>0.05</td>
</tr>
</tbody>
</table>
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
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.

City’s water supply was switched back to Lake Huron.

Legionnaires’ cases in Genesee County by month reported

Flint switched its water supply to the Flint River in April 2014.
Analysis of Flint Waters

<table>
<thead>
<tr>
<th></th>
<th>ug Pb/L water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feb-16</td>
<td>70</td>
</tr>
<tr>
<td>Mar-16</td>
<td>60</td>
</tr>
<tr>
<td>Apr-16</td>
<td>50</td>
</tr>
<tr>
<td>May-16</td>
<td>40</td>
</tr>
<tr>
<td>Jun-16</td>
<td>30</td>
</tr>
<tr>
<td>Jul-16</td>
<td>20</td>
</tr>
<tr>
<td>Aug-16</td>
<td>10</td>
</tr>
<tr>
<td>Sep-16</td>
<td>0</td>
</tr>
<tr>
<td>Oct-16</td>
<td>10</td>
</tr>
<tr>
<td>Nov-16</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>ug Pb/L water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (First Draw)</td>
<td>10.6 ppb</td>
</tr>
<tr>
<td>90th Percentile (First Draw)</td>
<td>26.8 ppb</td>
</tr>
<tr>
<td>Maximum (First Draw)</td>
<td>158 ppb</td>
</tr>
<tr>
<td>Maximum (Any sample)</td>
<td>1051 ppb</td>
</tr>
<tr>
<td>Total No. of Samples</td>
<td>271</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>System Service Population</th>
<th>Very Small &lt;=500</th>
<th>Small 501-3,300</th>
<th>Medium 3,301-10,000</th>
<th>Large 10,001-100,000</th>
<th>Very Large &gt;100,000</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Systems</td>
<td>127,896</td>
<td>19,180</td>
<td>5,176</td>
<td>3,861</td>
<td>426</td>
<td>156,539</td>
</tr>
<tr>
<td>% Total Systems</td>
<td>82%</td>
<td>12%</td>
<td>3%</td>
<td>2%</td>
<td>0.3%</td>
<td>100%</td>
</tr>
<tr>
<td>% Total Population</td>
<td>4.5%</td>
<td>7.9%</td>
<td>9.4%</td>
<td>34%</td>
<td>44%</td>
<td>100%</td>
</tr>
</tbody>
</table>
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

- **2006**: 29
- **2008**: 27
- **2010**: 35
- **2012**: 40
- **2014**: 45

**FIGURE 2** Median per capita long-term debt

- **2006**: 71
- **2008**: 69
- **2010**: 97
- **2012**: 114
- **2014**: 113
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