The Flint MI Water Crisis: Lead, Leaks, Legionella Betrayal

marc edwards
The Distribution System

Source water

Water Treatment Plant

Clean Water

Concrete

Iron with and w/o lining

Pb, Sn, Sb, other soldered joints

Copper, lead, plastic or galvanized service lateral and then home plumbing

To wastewater distribution system and the environment

brass faucet

Hot water heater
Lead and Legionella
Whose responsibility is it?
Physical Drivers that Make Premise Plumbing More Influential

• ≈ 10X more length
• ≈ 10X surface area per unit volume
• 1/4 of the total distribution surface area
• 1/60 of the total volume in premise pipes
• 1/10 of the total volume in toilets and water heaters
Why is Lead in Water Still a Problem in 2016?
Decision by cities to require use of lead service lines…. one of the most serious environmental disasters in US History

Hundreds of years of deaths, deceit and denial.
Lead helps to guard your health

You wouldn’t live today in a house without an adequate plumbing system. For without modern plumbing, sickness might endanger your life. Lead concealed in the walls and under the floors of many modern buildings helps to give the best sanitation.

In some cities today the law specifies that lead pipe alone may be used to bring water from street mains into the building.

Edited From Ad in National Geographic 11/1923
1991 Lead and Copper Rule

Before 1991 Lead MCL was 50 ppb measured in water leaving treatment plant

First rule to:
1) Require Control of a Contaminant to the Tap
2) Share Responsibility between Utility and the Customer
Reasonable Logic

Practical limitations to how effective corrosion control could be

Cost:benefit @ 90%’ile < 15 ppb at WORST CASE HOMES

Educate consumers about avoiding exposure and their responsibility
Success Dependent On

utilities being honest and trustworthy partners with the public

Failure:

Privatization, Cost Pressures, Declining Ethics, Litigation Fears, Lead Makes People Crazy?
<table>
<thead>
<tr>
<th>Reasonable Logic</th>
<th>Current Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical limitations to how effective corrosion control could be</td>
<td>Easier to cheat than work to optimize corrosion control</td>
</tr>
<tr>
<td>Cost:benefit @ 90%’ile of 15 ppb at WORST CASE HOMES</td>
<td>Outdated. Utilities not sampling worst case homes as agreed.</td>
</tr>
<tr>
<td>Educate consumers about avoiding exposure and dangers of water lead</td>
<td>Consumers told water is safe, when it is not. Blame consumers for problems.</td>
</tr>
</tbody>
</table>
# Perspective on Legacy Plumbing Lead Sources

<table>
<thead>
<tr>
<th>Lead-Bearing Plumbing Material</th>
<th>Age of US Homes at Potential Risk</th>
<th>Estimated number of US homes at potential risk</th>
<th>Estimated Mass of Lead per home at potential risk (kg)</th>
<th>Responsibility/ Average Performance Lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brass Plumbing Components</td>
<td>All Pre 1986</td>
<td>All 81 million&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.1&lt;sup&gt;b&lt;/sup&gt; 0.3&lt;sup&gt;b&lt;/sup&gt; 0.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Mostly private ≈ 20-70 years</td>
</tr>
<tr>
<td>Lead pipes, lead service lines, and lead goosenecks (100% lead by weight)</td>
<td>Pre 1986</td>
<td>3.3 - 6.4 million&lt;sup&gt;c&lt;/sup&gt;</td>
<td>19.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>Undeniable Public Responsibility ≈ 100-1000 years</td>
</tr>
<tr>
<td>Lead solder (40% - 50% lead by weight)</td>
<td>Pre 1986</td>
<td>81 million&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Highly variable, but believed very significant&lt;sup&gt;e&lt;/sup&gt;</td>
<td>Mostly private ≈ 20-70 years</td>
</tr>
<tr>
<td>Lead joints in water mains (100% lead by weight)</td>
<td>Pre 1986</td>
<td>All homes served by water mains installed pre 1986</td>
<td>Unknown but believed inconsequential&lt;sup&gt;f&lt;/sup&gt;</td>
<td>NA</td>
</tr>
</tbody>
</table>

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Modified from Triantafyllidou and Edwards (2011)<sup>18</sup>
Even 1 foot of lead pipe, contains enough lead to raise every drop of water used by a family of 4 over 100 years, to over the 15 ppb AL

Lead pipe is the most concentrated lead source in US homes, and it directly affects a product (tap water) that is intended for human consumption
<table>
<thead>
<tr>
<th>Recent Changes</th>
<th>Decreases Pb</th>
<th>Increases Pb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utilities Add Less Chlorine</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Aggressive Water Conservation</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Chloramine Instead of Chlorine</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Reduce Phosphate Doses to “Optimize” Corrosion Control and Save $$</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Created Millions of Disturbed and Partially Replaced LSLs</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>More Exposed Iron Pipe in Mains $\rightarrow$</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>More Fe, Less Cl$_2$ = More Pb</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>More Accumulated Pb Scale, More Pb Particulates from Corrosion Control and Older Pipes</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Higher temperatures?</td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Science Predicts Higher Peak LSL Pb Release in Many Systems Due to These Changes—Little Reason to Hope Things are Improving
Utility Sampling Instructions Have Evolved (Devolved) to Miss Many LSL Pb and Particulate Pb Problems in Water When Present
Generation of Pb Particles

Corrosion or Rusting

Lead Solder, Lead Scale or “Rust” layer

Lead Solder, Lead Pipe or Leaded Brass
Detachment During Flow

Faster water flow in some systems, means more particulate lead

Lead Solder, Lead Scale or “Rust” layer

Pb Plumbing Material
Water Samples of LSL Lead from DC in 2004

2nd Draw Lead (ppb)

WASA profiling and sampling
(< 2 liters/min)

Particulate lead

Typical faucet

Q = Liters/minute
<table>
<thead>
<tr>
<th>Sampling Instructions</th>
<th>Effect vs. Normal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample at low flow</td>
<td>Reduce particulate Pb</td>
</tr>
<tr>
<td>Open tap slowly</td>
<td>Reduce particulate Pb</td>
</tr>
<tr>
<td>Pre-flushing pipes</td>
<td>Reduce LSL and particulate Pb in first draw sample</td>
</tr>
<tr>
<td>Pre-clean aerator</td>
<td>Reduce particulate Pb</td>
</tr>
</tbody>
</table>

*Use of these instructions and “missing” high risk sites has resulted in documented childhood lead poisoning when the utility was officially meeting the LCR and the water was supposedly “safe”*
Day care
Enough lead behind this aerator to poison 5000 kids
(@ CPSC 175 ug Pb acute health risk and 25% bioavailability)
After cleaning aerator water tested “safe” 6 hours later
Example: DC WASA 2005-2008

Consumers instructed to pre-flush pipes 10 minutes the night before LCR sampling to barely meet EPA AL

3 independent entities sampling tap water at this time found very high lead, and a coalition vehemently protested the use of pre-flushing:

EPA RIII/EPA OW allow pre-flushing in DC

CDC (2012) → More lead poisoned kids in DC Homes with LSLs in this time frame
Effect of Bottle Type
Recent Pb Health Data And Human Exposure Considerations
Lead and Adverse Pregnancy Outcomes
Miscarriages/Fetal Death

THE INCREASING USE OF LEAD AS AN ABORTIFACIENT;
A SERIES OF THIRTY CASES OF PLUMBISM.*

By ARTHUR HALL, M.A., M.D. Cantab., F.R.C.P.,
Professor of Pathology, University College, Sheffield; Physician, Sheffield Royal Hospital.

Nov. 13, 1926]

LEAD AS AN ABORTIFACIENT.

Sir,—Some time ago, in country practice, I had a message from a neighbour asking me to see with him a case of acute abdominal disease. The history was this: A robust young woman (married three months) had had pain in the stomach a few days previously, and again on the day before, when she was first seen. On inquiry her doctor was
1900s Lead abortion pill dose exceeded by normal consumption of water in 15% of DC homes with lead pipe in 2003
Fetal Death and Reduced Birth Rates Associated with Exposure to Lead-Contaminated Drinking Water *ES&T* 2013

Trends in DC birth rate (miscarriages) and fetal death rates were consistent with prior work indicating that each 5 ug/dL increase in maternal blood lead doubles miscarriage risk. Fetal death rates correlated to water lead levels and measures of lead pipe occurrence.

ICRP Adult Blood Lead Model
0 → 5 ug/dL in Maternal Blood Lead ≈ 60 ppb water Pb
### Representative Exposures of Concern for Lower Blood Lead Levels

<table>
<thead>
<tr>
<th>Group</th>
<th>Increased BLL of Concern</th>
<th>Water Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula Fed Infants</td>
<td>0 → 1 ug/dL for 50% of those exposed</td>
<td>3.5 ppb</td>
</tr>
<tr>
<td>Formula Fed Infants</td>
<td>0 → 1 ug/L for 10% of those exposed</td>
<td>2 ppb</td>
</tr>
<tr>
<td>Formula Fed Infants</td>
<td>0 → 5 ug/dL for 10% of those exposed</td>
<td>11 ppb</td>
</tr>
</tbody>
</table>

Ryu et al (1983)
Fed leaded milk to infants in US
All dietary Pb intakes accounted for

17 infants

10 fed milk with avg. 10 ppb Pb
7 fed milk with avg. 70 ppb Pb
70 ppb lead in milk raised infants blood lead over lead poisoning threshold in ≈ 30 days, with no sign of leveling off.

8.3 ug/dL increase
What do lead levels look like for a large US city currently meeting the AL, based on thousands of data points, and how does that translate to EBL?
Large City
Consumer Monitoring of Kitchen Taps
1998-2005

90% 10 ppb
99% 70 ppb
99.9% 1717 ppb
≈1% of children in this city predicted to have elevated blood lead (> 10 ug/dL) from tap water consumption alone (> 70 ppb) in a city with 100,000 children that would be 1000 cases of childhood lead poisoning
You do not even have to drink tap water to be exposed.
Water collected @ highest flow from faucet of poisoned child

1.5 liters at 535 ppb lead

Most Pb particles invisible, sink to bottom
Lead remains insoluble during cooking

< 5% particulate lead poured off
One serving of pasta prepared from tapwater in home of lead poisoned child had more lead than eating a dime size paint chip @ 1% lead.
A Revised LCR Needs-Pb

• public education that stops telling consumers with lead services/plumbing that THEIR WATER IS SAFE*

• an attitude at EPA OW and utilities that acknowledges serious water lead health risks, emphasizes important DIRECT links between the LCR and public health, and stops “anything goes” sampling by utilities

• motivated utilities attempting to find high lead in water risks, and the will/means to punish bad actors— or else take LCR sampling completely out of utilities hands

• a plan for complete removal of all lead service lines

*unless it is not safe, in which case we told you so in fine print somewhere
“DC Lead Crisis (2000-2004): High Lead in DC Drinking Water

• est 2000 children not born
  (high miscarriage risks)
• est 200 fetal deaths (>28 weeks pregnancy)
• Hundreds of young children age 1-6 lead poisoned above 10 ug/d, thousands above 5 ug/dL
• Misconduct by government scientists and engineers
• 5 falsified papers/reports and 6 years of lies about health harm
  (CDC, R3 EPA, JAWWA, EHP)
Despite scientific evidence that, at a minimum, hundreds of children suffered elevated blood lead levels in the early 2000s, DC Water chief George Hawkins told HuffPost that it’s not clear to him that anyone had been harmed by the once-toxic water.

“I think the jury is still out.”

http://www.huffingtonpost.com/entry/flint-lead-water-epa_us_569522a8e4b086bc1cd5373c

When might the five kids fighting for their day in court against DC WASA see it? Ans: 2016 15 years after the exposure occurred
April 2014 “Here’s to Flint,” Mayor Dayne Walling said as he raised a glass of water during a small ceremony at Flint’s water plant. “This is an historic step for us,”
“A major concern from a public health standpoint is the absence of corrosion control treatment in the City of Flint”

MEMORANDUM

SUBJECT: High Lead Levels in Flint, Michigan – Interim Report

FROM: Miguel A. Del Toral
Regulations Manager, Ground Water and Drinking Water Branch
...I am really getting tired of the bad actors being defended, the bad actions being ignored, and people trying to do the right thing are constantly being subjected to intense scrutiny as if we were doing something wrong..... I am not happy to find bad things. It is completely stressful because it means children are being damaged and I have to put up with all of the political crap, but where these problems exist I will not ignore them.

I truly, truly hate working here. EPA is a cesspool.

Turns out Miguel and I both independently quit AWWA in 2012-2013 over lead:

misguided policies, third rate science and condoning outright cheating on the LCR.
Corrosive Water: Causes Odors, Colors, Bad Tastes
Corrosive Water: Increases Lead. Effects VISIBLE in lab tests!

Flint

White Particles Are Lead Solids

Lead Solder Sample with Copper pipe

Detroit
Vickie Weiss
Classroom of young scientists
Dear Governor:

I am so mad what happen in Flint, it is bad for kids. They don't have clean water to drink for almost two years. I hope you fix this problem.

Thank you.
Citizen Science Sampling Project: 300 samples across the city
EPA Action Level for Lead Exceeded
Change back to Detroit Water
WATER PICK UP AHEAD
Legionnaires’ expert blames spike in cases on Flint water

By Kristi Tanner and Elisha Anderson, Detroit Free Press 9:33 p.m. EST January 22, 2016

Flint Hospital Reports Finding Legionnaires’ Bacteria In Water

POSTED 1:37 PM, JANUARY 22, 2016, BY CNN Wire

Flint's Legionnaires' Outbreak May Be Tied To Its Contaminated Water

When will Flint catch a break?
1/19/2016 08:35 am ET | Updated 6 days ago

Flint hospital president says he suspected Legionnaires' outbreak stemmed from river

Published January 24, 2016 - Associated Press
EPA Region 5 Administrator Susan Hedman to resign in wake of the Flint water crisis

JAN 21, 2016
Legionella in Flint’s waters
An unfortunate prediction that came true
Game Changer 1:

November 2006 National Research Council Report Identified Premise Plumbing Problems as a High Potential Health Risk and High Priority for Regulation/Research/Action
Game Changer 2: CDC (2008)

Legionella the primary cause of waterborne disease in the U.S., and most of the deaths due to waterborne illness

= Disease of modern plumbing systems
Game Changer 3: Flint (2015-2016)

Demonstrated important role of distribution system operation and management
Legionella bacteria
Lack of corrosion control = Increased *Legionella*

1. More bacteria “food” in river
2. Iron corrosion = more iron entering buildings’ pipes
High levels of corrosion-causing bacteria
Lack of corrosion control = Increased *Legionella*

1. More bacteria “food” in river
2. Iron corrosion = more iron entering buildings’ pipes
3. High iron corrosion removed chlorine disinfectant
NYC Legionnaires’ disease death toll hits double-digits as officials order inspection of all cooling towers, threaten penalties

Major U.S. Legionnaires’ Disease Outbreaks

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>DATE</th>
<th>CASES</th>
<th>DEATHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WASHINGTON, DC</td>
<td>1965</td>
<td>81</td>
<td>14</td>
</tr>
<tr>
<td>PHILADELPHIA, PA</td>
<td>1976</td>
<td>221</td>
<td>34</td>
</tr>
<tr>
<td>BURLINGTON, VA</td>
<td>1980</td>
<td>85</td>
<td>16</td>
</tr>
<tr>
<td>CHICAGO, IL</td>
<td>2012</td>
<td>114</td>
<td>3</td>
</tr>
<tr>
<td>BRONX, NY</td>
<td>2015</td>
<td>124</td>
<td>12</td>
</tr>
<tr>
<td>GENESEE COUNTY</td>
<td>2014/15</td>
<td>87</td>
<td>9</td>
</tr>
</tbody>
</table>
"That just added to the disaster we were already facing," Gov. Snyder says of Legionella spike in Flint area.

"We remain diligent in our efforts to proactively and appropriately address the potential for future cases"
Grateful acknowledgement

• National Science Foundation, RAPID Grant #1556258

• **Citizens of Flint**

• WaterYouFightingFor? (Melissa Mays and LeeAnne Walters)

• **Hurley Medical Center (Mona Hanna-Attisha and others)**

• US EPA Region 5 (Miguel Del Toral)

• ACLU of Michigan (Curt Guyette, Kate Levy)

• Sen. Jim Ananich, Congressman Dan Kildee (and their extraordinary staff)

• 800+ donors supporting our

• Michigan State Health Department // Genesee County Health Department

• Democracy Defense League (Nayyirah Shariff, Claire McClinton, Dr. Laura Sullivan)

• Northeast-Midwest Institute (Elin Betanzo)

• Concerned Pastors for Social Action (Pastors Alfred Harris, Allen Overton)

• Parents for Non-toxic Alternatives (Dr. Yanna Lambrinidou)

• City of Flint (Mayor Karen Weaver, Dayne Walling, Howard Croft, Mike Glasgow)

• Members of the media

• Virginia Tech (staff and students)
Marc Edwards received his bachelor’s degree in Bio-Physics from SUNY Buffalo and an MS/PhD in Environmental Engineering from the University of Washington. In 2004, Time Magazine dubbed Dr. Edwards “The Plumbing Professor” and listed him amongst the 4 most important “Innovators” in water from around the world. The White House awarded him a Presidential Faculty Fellowship in 1996 and he was named a MacArthur Fellow in 2008.

He has received 7 outstanding research publication awards from peer reviewed journals, the Huber Research Prize from the American Society of Civil Engineers (2003), and the National Association of Corrosion Engineers Technical Achievement Award (2008). Volunteer (unfunded) research by Edwards and colleagues on health effects from lead in drinking water documented numerous cases of fetal death and childhood lead poisoning associated with lead in tap water nationwide, including those associated with the 2000-2004 Washington D.C. “Lead Crisis.” That effort culminated in a Congressional Investigation of CDC, an Outstanding Paper Award in ES&T, a Praxis Award in Professional Ethics from Villanova University and the IEEE Barus Award for Defending the Public Interest.