CORROSION CONTROL MEASURES TO PREVENT LEAD IN DRINKING WATER

Colter Andersen

Workshop Objectives

Attendees will gain a greater understanding of:

- Factors that lead to corrosion in water systems
- Requirements of the Lead and Copper Rule
- Water Quality Parameter Monitoring and Adjustment
- Conflicting compliance objectives
- Methods to predict and prevent corrosion

The Flint Water Disaster

- We will begin by first considering the Flint Michigan Lead contamination event.
- It is a story of corrosion, lead contamination, and the erosion of public trust

Flint, Michigan Disaster

Date: **2014 - 2016**

Problem: **High levels of lead discovered in drinking water in homes, schools, and public venues**

Cause: **Interior corrosion of service lines containing lead & lead-based solder caused by a *change in water source***

Outcomes: **Massive public outcry; increased blood lead levels in children, resignations; legal problems, loss of public trust**

Why review the Flint disaster?

1. Understand and analyze the series of events which led up to the crisis
2. Learn the factors that led to the decisions to make critical changes in water production
3. Understand the scientific reasons for the corrosion problem
4. Identify lessons we can apply in the future

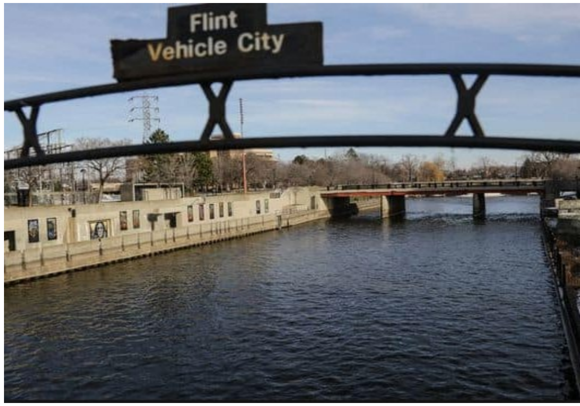
Flint, Michigan

- Just 70 miles from Detroit (“Motor City”)
- USA’s “Automobile Manufacturing Powerhouse”
- General Motors founded in Flint in 1908
- All Chevy’s and Buicks were manufactured in Flint (including the first Corvette prototype in 1953
- Origin of the United Auto Workers Union
- Home to 80,000 auto workers in the 1970’s
- Population of 200,000 in the 1970’s

The Auto Giant's Exit Brings Flint to its Knees

- Massive downsizing of GM beginning in 1980's
- From 80,000 to around 5,000 auto workers
- Population declines from 200,000 to below 100,000
- In 2010, 41% of residents below poverty line
- In 2011, City deficit of $25 Million
- Flint became known for high crime rate as one of the most dangerous cities in the US
- Becomes known as the epicenter of the "Rust Belt" as once strong manufacturing cities became desolate

Flint River



- Prior to 1967, source was the Flint River
- In 1967 until 2014, Flint switched to using Lake Huron Water from Detroit Water & Sewerage Department
- In 1970's Flint river was severely degraded from nutrients, oils, toxins, low DO, bacterial problems
- 2001, the state ordered cleanup of 134 industrial and agribusiness sites within the Flint River watershed
- Flint river water is considered to be 19 times more corrosive than Lake Huron water

Cuyahoga River (Water History)

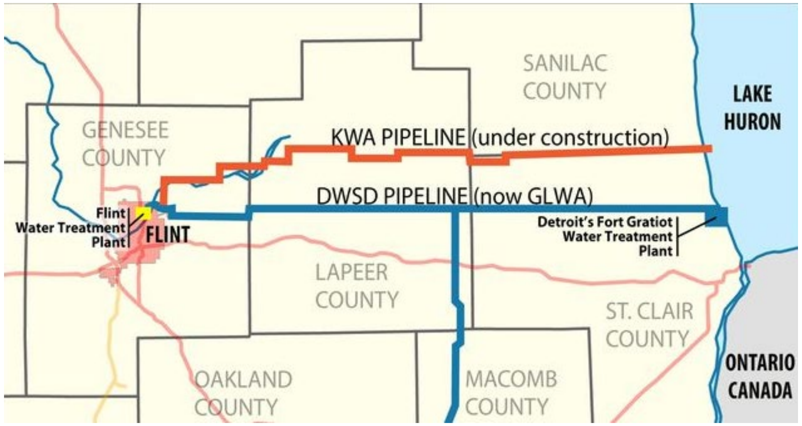
The Cuyahoga River (in Cleveland Ohio, another NE industrial giant) became a major factor toward the passage of the **Clean Water Act** (1972), when it caught on fire.

Follow the 'lack-of' money

- As decent-paying jobs left Flint, so did the businesses that had been supported by a well-paid blue-collar workforce.
- Since 2000, Flint has been forced to declare a state of financial emergency two times, the most recent in 2011.
- The decision to switch from Detroit Water was projected to save $200 million over the following 25-year period

Flint Switches Water Sources

- 2012: New Pipeline project is launched to purchase Huron Water from Karegnodi Water Authority (KWA) instead of from Detroit Water and Sewerage Department (DWSD).
- **Flint River Water** it is decided, will be used in the interim (until the pipeline is completed)



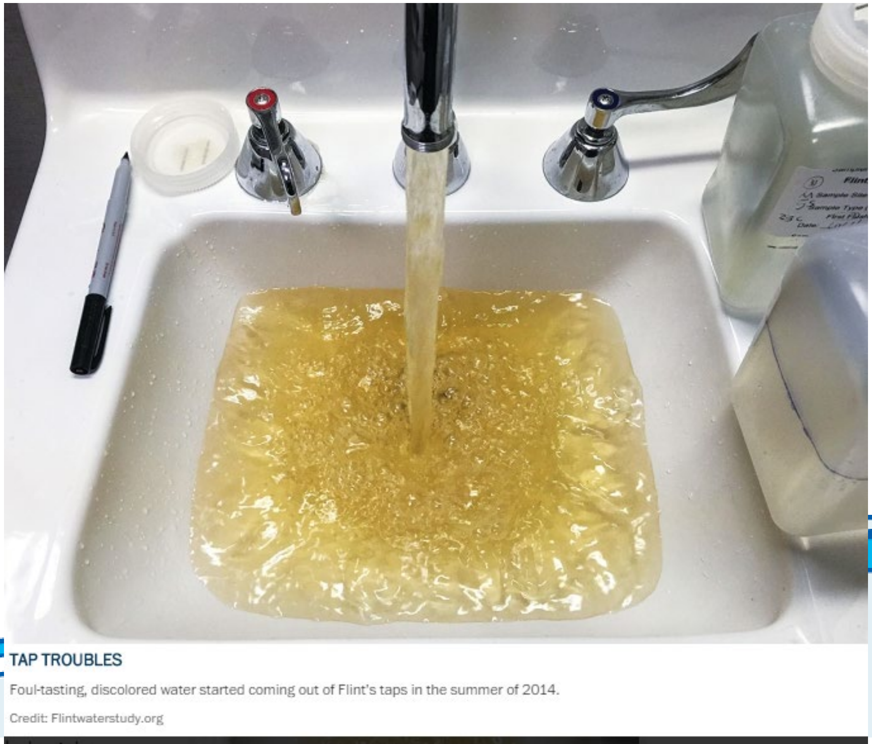
Pipeline Construction to Huron Water (KWA pipeline)

Real problem not identified - but a pattern emerges

- September 5, 2014 - Flint issues boil water advisory after a positive test for total coliform bacteria.
- City officials tell residents they will flush the pipes and add more chlorine to the water.
- After four days, residents are told they can safely resume drinking water from the tap.

Customer complaints

- Customer reports of odd colors from the tap — greens and browns — and offensive smells and tastes.
- Soon there were reports of rashes and clumps of hair falling out.
- Parts from a General Motors engine plant here were corroding, so the company stopped using Flint's water.



Corrosion spotted first by GM

- October 2014 - The General Motors plant in Flint stops using the city's water due to concerns about high levels of chlorine corroding engine parts.
- The company strikes a deal with a neighboring township to purchase water from Lake Huron in lieu of using water from the Flint River. The switch is anticipated to cost the city $400,000
- Note that, at this point, it appeared that chlorine was expected as the cause of GM's corrosion problems

Flushing

Photo credit: Erin Brockovich of actual Flint flushing

- November 2, 2014 City increases hydrant flushing to address red water concerns
- December 16, 2014 City receives official violation notice from the Michigan DEQ for violations of the Safe Drinking Water Act for total trihalomethanes

Chlorine increased

- To mitigate the bacteria problems chlorine levels were increased
- January 2, 2015 - The city warns residents the water contains byproducts of disinfectants that may cause health issues including an increased risk for cancer over time.
- The letter is sent after the state finds that the level of disinfecting chemicals in the water exceeds the threshold set by the Safe Drinking Water Act.
- The water is deemed safe for the general population, but the elderly and parents of young children are cautioned to consult with their doctors.

A helping hand was extended

- January 12, 2015 - The DWSD offers to reconnect the city with Lake Huron water, waiving a $4 million fee to restore service.

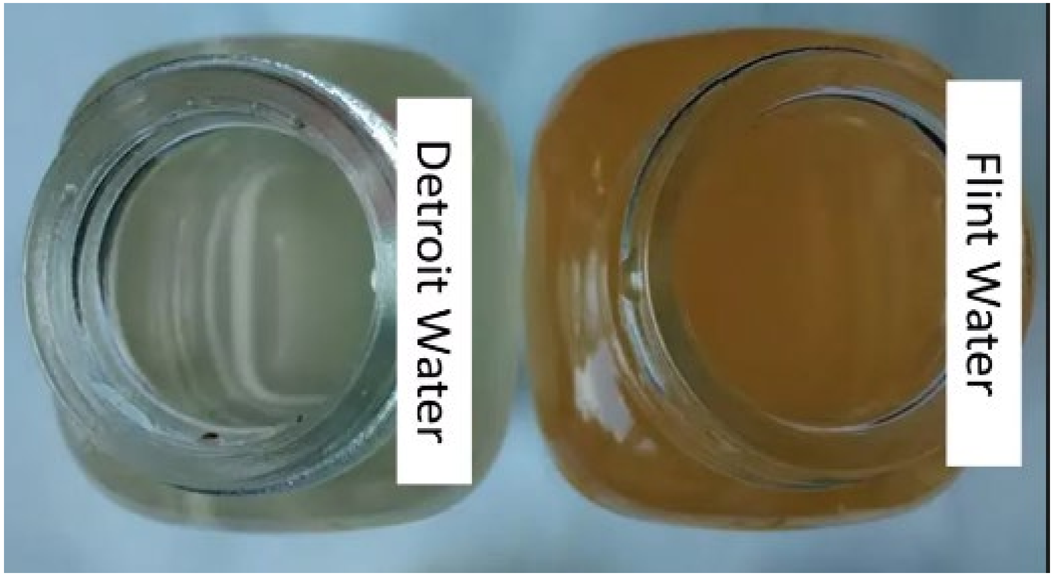
- City officials decline, citing concerns water rates could go up more than $12 million each year, even with the reconnection fee waiver.

Public outcry

January 21, 2015 - Residents tote jugs of discolored water to a community forum. The Detroit Free Press reports children are developing rashes and suffering from mysterious illnesses.

Reddish-Brown Water

Rapid iron corrosion in Flint River water was eating up the chlorine disinfectant, and causing much more iron release than in Detroit water



Lead Found in Flint Drinking Water

- February 26, 2015 - The Environmental Protection Agency detects dangerous levels of lead in the water at the home of Flint resident Lee-Anne Walters.
- A mother of four, she had first contacted the EPA with concerns about dark sediment in her tap water possibly making her children sick.
- Testing revealed that her water had 104 parts per billion (ppb) of lead, nearly 7 times greater than the 15 ppb AL
- March 18, 2015 - Walters follows up with the EPA after another test indicates the lead level in her water is 397 ppb.

Attempts to end use of Flint River

- March 23, 2015 - Flint City Council members vote 7-1 to stop using river water and to reconnect with Detroit.
- However, state-appointed emergency manager, Jerry Ambrose overrules the vote calling it "incomprehensible" because costs would skyrocket and "water from Detroit is no safer than water from Flint."
- June 5, 2015 - A group of clergy and activists file a lawsuit against the city, claiming that the river water is a health risk. The city attorney fires back in July that the lawsuit is baseless. The case is dismissed in September.

No corrosion control

- June 24, 2015 - An EPA manager issues a memo, "High Lead Levels in Flint," warning the city is not providing corrosion control treatment to mitigate the presence of lead in drinking water.
- August 17, 2015 - The MDEQ orders Flint to optimize corrosion control treatment in the water supply after state testing from the first six months of 2015 reveals elevated lead levels.
- September 9, 2015 - The EPA announces it will assist Flint in developing a corrosion control treatment

Virginia Tech Study

- August 23, 2015 - Virginia Tech Professor Marc Edwards notifies the MDEQ his team will be conducting a water quality study.
- September 8, 2015 - The Virginia Tech team issues a preliminary report indicating 40% of Flint homes have elevated lead levels.
- September 11, 2015 - Virginia Tech concludes Flint water is more corrosive than Detroit water and recommends the state declare that the water is not safe for drinking or cooking; the river water was corroding old pipes and lead is leaching into the water

Elevated blood lead levels

- September 24, 2015 - A research team led by Dr. Mona Hanna-Attisha, a pediatrician from the Hurley Medical Center, releases a study revealing the number of children with elevated lead levels in their blood nearly doubled after the city switched its water source.
- In neighborhoods with the most severe contamination problems, testing showed lead levels tripled.

Lead in school drinking water

- October 2, 2015 - The Michigan Department of Health and Human Services (MDHHS) reviews the data from the Hurley Medical Center and verifies the findings. The state begins testing drinking water in schools and distributing free water filters.
- October 8, 2015 - The MDEQ announces three Flint schools tested positive for dangerous lead levels in the water.
- Governor Snyder says the city will discontinue using Flint River water.

Flint River finally abandoned

- October 15, 2015 - Governor Snyder signs a spending bill appropriating $9.35 million to help Flint reconnect with Detroit for water and provide health services for residents.
- October 16, 2015 - The city switches back to Detroit water. Residents are cautioned that it will take weeks for the system to be properly flushed out and there may be lingering issues.
- The EPA establishes a Flint Safe Drinking Water Task Force.

Next came the lawsuits, charges, and finger-pointing

Fallout begins

- November 13, 2015 - Residents file a federal class action lawsuit claiming 14 state and city officials, including Governor Snyder, knowingly exposed Flint residents to toxic water.
- December 14, 2015 - Flint declares a state of emergency.
- December 29, 2015 - MDEQ Director Dan Wyant resigns after the Flint Water Advisory Task Force concludes the crisis resulted from a failure of state regulators.

Testimony and charges

- March 17, 2016 - Governor Snyder testifies before the House Committee on Oversight and Government Reform.
- March 31, 2016 - Lawyers, including some with the NAACP, file a class action lawsuit against Lockwood, Andrews & Newnam, PC, the state of Michigan, Governor Snyder and others. Plaintiffs seek damages for those affected by the water crisis.
- April 20, 2016 - Criminal charges are filed against government employees Mike Glasgow, Stephen Busch and Mike Prysby.

More suits and actions

- April 25, 2016 - Five hundred and fourteen residents and former residents of Flint file a class action lawsuit against the EPA. The plaintiffs allege negligence and demand more than $220 million in damages
- May 4, 2016 - Mike Glasgow reaches a deal with prosecutors contingent on his cooperating as a witness in the investigation.
- May 9, 2016 - Fired city administrator Natasha Henderson files a federal lawsuit against the city of Flint and Mayor Karen Weaver.

Charges and related suits

- June 22, 2016 - The Michigan Attorney General Bill Schuette files civil lawsuits against two companies for their alleged role in the Flint water crisis. Including Veolia North America, charged with negligence, fraud, and public nuisance.
- July 29, 2016 - Six current and former state workers are charged as the criminal investigation continues.
- December 20, 2016 - Four officials -- two of Flint's former emergency managers, who reported directly to the governor, and two water plant officials -- are charged with felonies of false pretenses and conspiracy.

The Flint water system - with operators like us

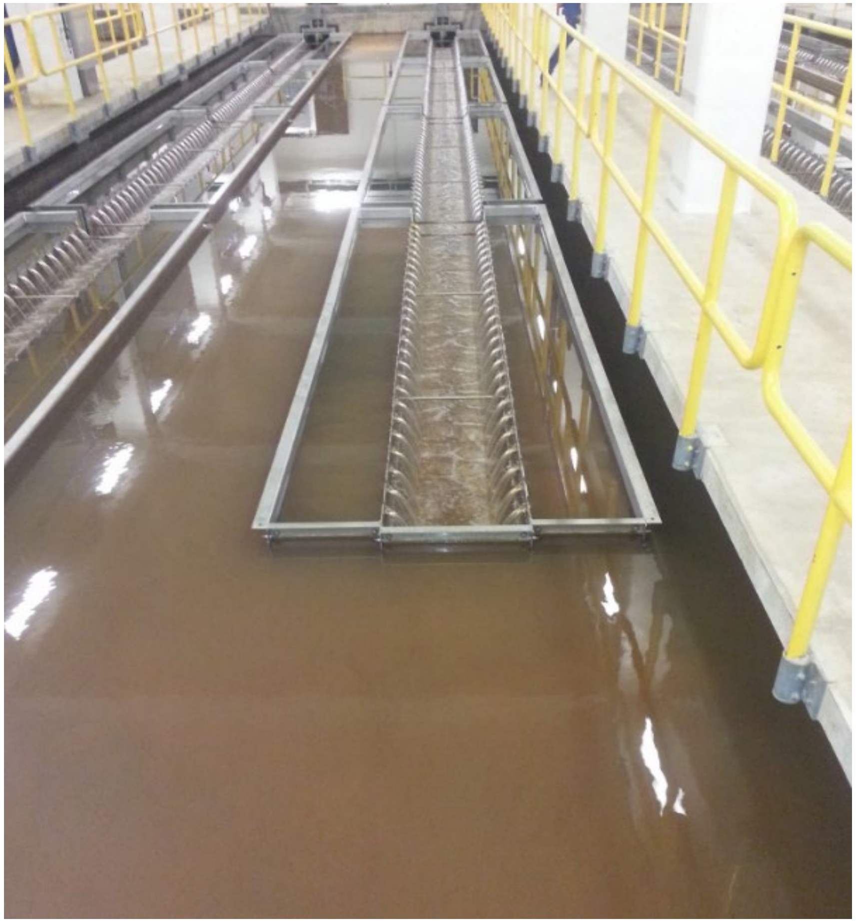
Inside the Flint Treatment Plant

Flint River Intake Structure

Flint Ozone Generator

The Flint treatment train included ozone as a first step to decrease organics, mineral precipitates and DBP's.

Flint Clarifier after Ferric Chloride coagulation



The decision to use the coagulant Ferric Chloride contributed to the corrosion of lead.

We will revisit this topic in more detail later.

Flint slaked Lime softening

Water softening can increase the likelihood of corrosion by removing alkalinity.

The slaked lime mixer at the Flint WTP has also been suspected as the incubator for legionella bacteria which led to multiple victims and fatalities from Legionnaires Disease.

Clarification after lime treatment

The addition of the lime raises the pH of the treated water. This caused hardness causing constituents to precipitate out of solution.

Sand Filtration with Granular Activated Carbon

Granular activated carbon was added to the filter media to reduce TOC (total organic carbon) content and hence reduce Total Trihalomethanes.

Chlorination

Final disinfection accomplished using gas chlorine from ton cylinders.

Gas chlorine also lowers the pH of water.

Fluoridation

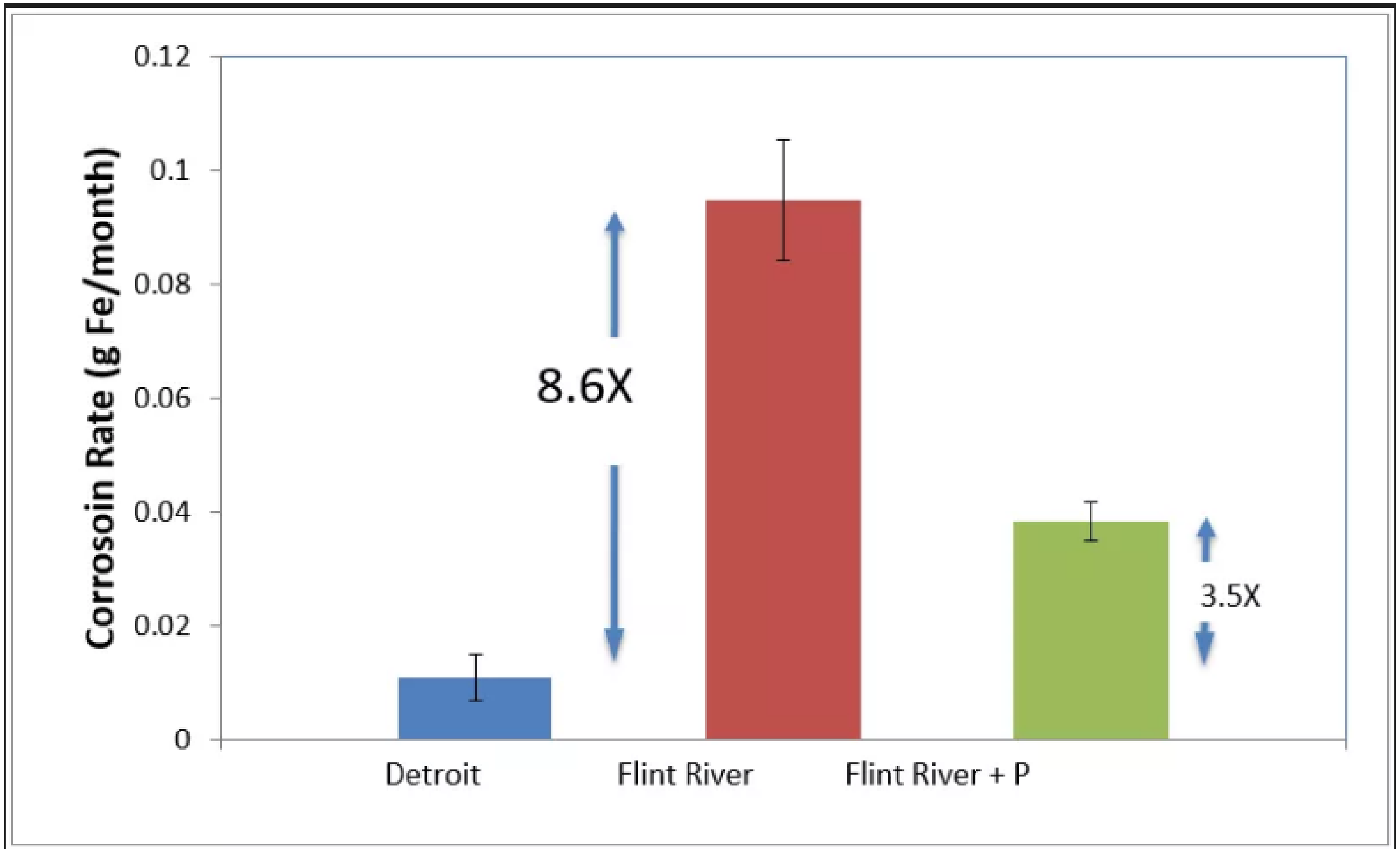
Finished water levels of fluoride (around 1 ppm) did not likely contribute to the corrosiveness of the water – however the undiluted fluoride chemical is a corrosive agent.

Nails exposed to Flint and Detroit water for 1 month

State Agency Notifies EPA: Flint Did Not Implement Corrosion Controls

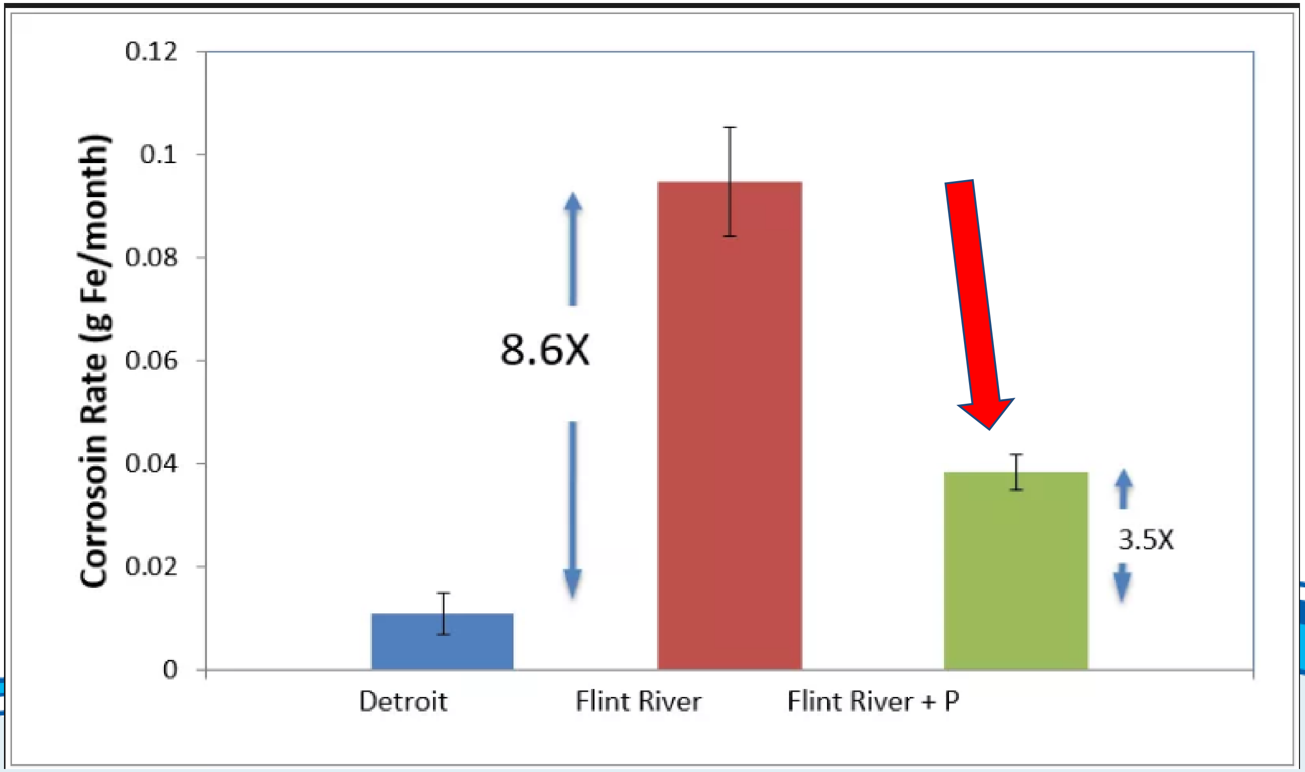
The EPA [says it had been notified](https://) by the MDEQ on or about April 24, 2015 "that the City did not have corrosion control treatment in place at the Flint Water Treatment Plant."

Head to head comparison of iron corrosion in Flint River vs. Detroit Water.



Cost of corrosion with orthophosphate

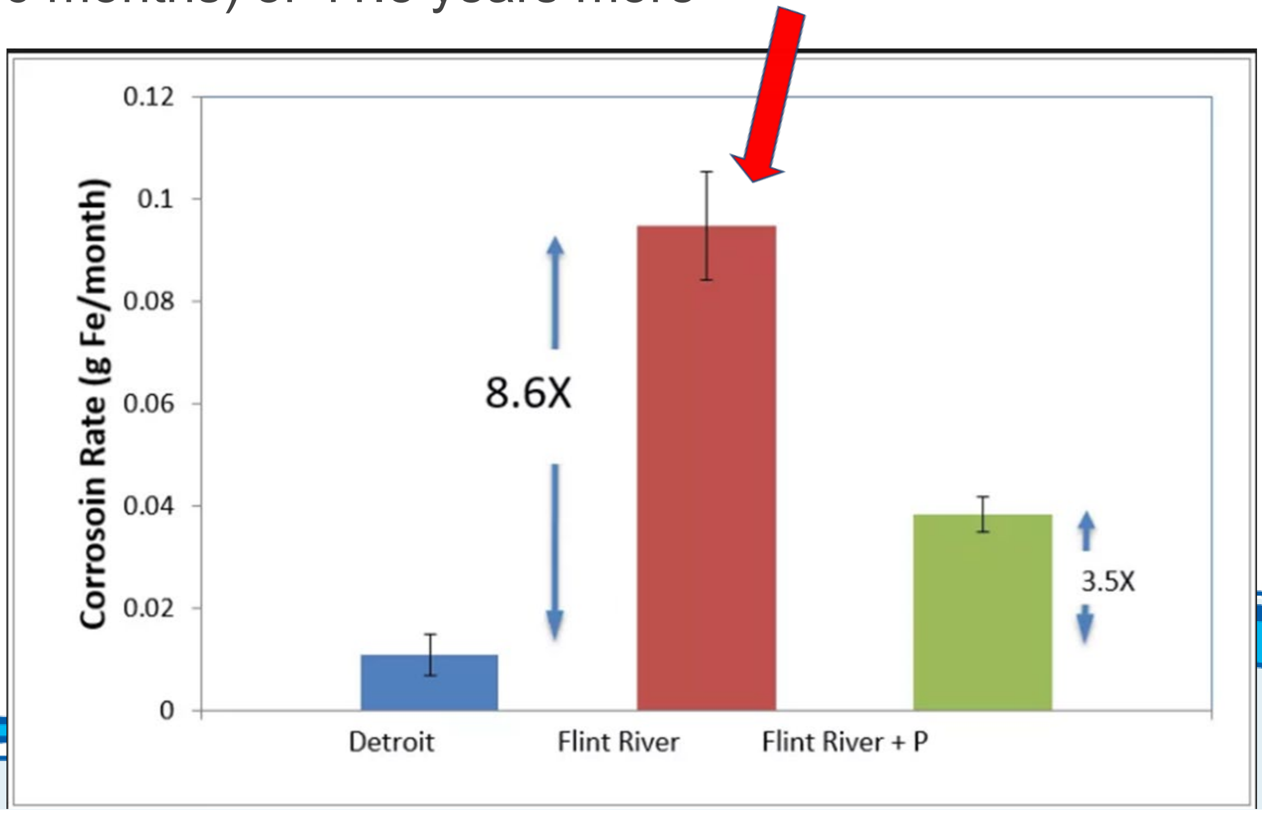
Had an orthophosphate corrosion inhibitor been added to Flint River water, in the last 16 months the city pipes would essentially have aged about 56 months (56 months = 3.5 faster corrosion X 16 months) more than if Detroit water was used.



Cost of corrosion without orthophosphate

- Unfortunately, the Flint River water was added to the pipe system than using Detroit water. without any phosphate inhibitor. In tests, this condition was 8.6 times more corrosive than Detroit water

- Assuming this rate applies to the actual city pipe system, the 16 months on Flint River water aged the pipes about 138 months (138 = 8.6 X 16 months) or 11.5 years more



Corrosion Control

Lead pipe - Steel Pipe - and Lead Pipe Coated with Orthophosphate

Regulations Misinterpreted

- The Lead and Copper Rule says that after a switch, the provider must conduct a monitoring period to accumulate data from real world sampling tests.
- Flint was required to conduct two 6 month periods in succession which they did. This is where the DEQ dropped the ball.
- In utilities serving more than 50,000 people, an anti-corrosion program is supposed to be put in place from day one throughout the monitoring period. The DEQ interpreted the rule incorrectly and never forced Flint to do this

Microbially Induced Corrosion (MIC)

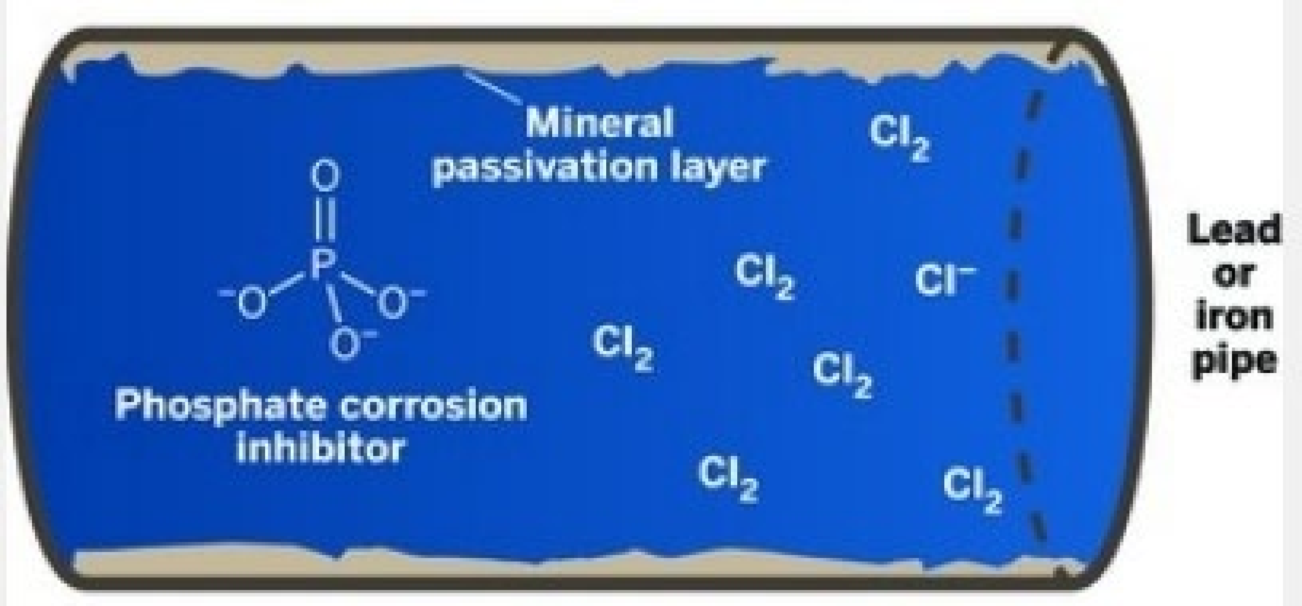
- Bacteria that can further accelerate metal pipe corrosion.
- Biological Activity Reaction Test (BART) kits to look for specific MIC bacteria including: heterotrophic aerobic bacteria (HAB), acid producing bacteria (APB), iron reducing bacteria (IRB), sulfate reducing bacteria (SRB), and slime forming bacteria (SLYM)
- These bacterial groups were all found in the Flint River source water

Actual Flint results with BART test kit

Heterotrophic Bacteria | Acid Producing Bacteria | Iron Reducing Bacteria | Sulfate Reducing Bacteria | Slime Forming Bacteria

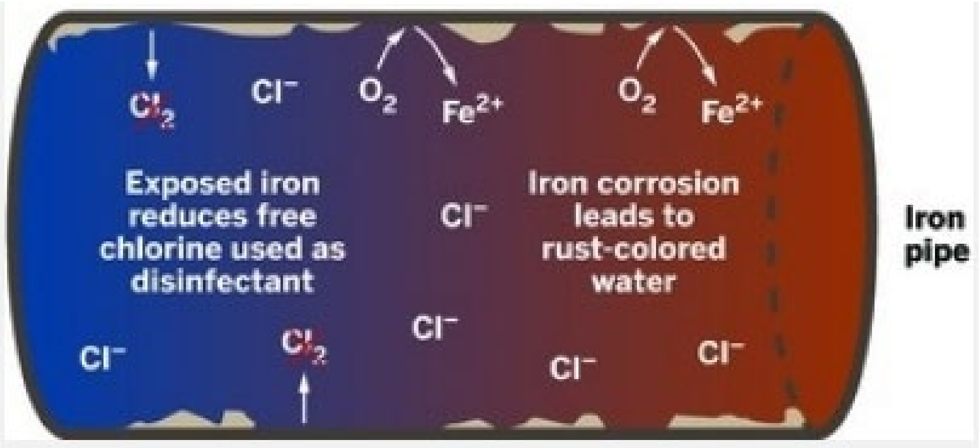
Detroit Water

- When Flint used Detroit water the system benefited from a phosphate corrosion inhibitor which deposited a protective mineral layer on the pipe interior



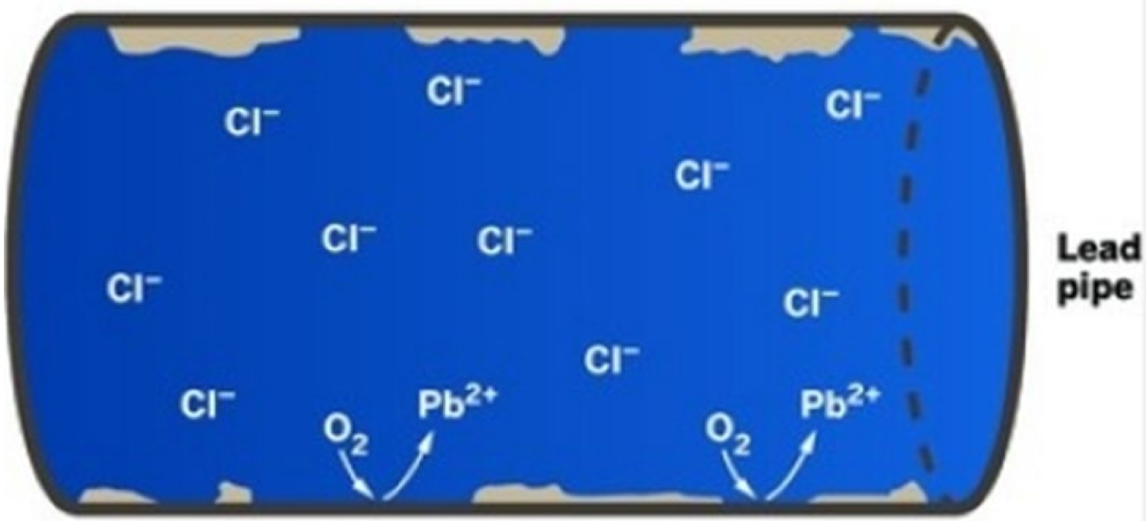
Treated Flint River Water

- Flint River water treatment did not include provisions for corrosion control.
- The corrosiveness increased due to high chloride levels and the deposited phosphate layer dissolved away.
- As iron pipes corroded, Chlorine residuals were used up and rust-colored water was produced.



Lead Service Lines

- Flints lead problem was the result of corrosion of lead service lines, and those lines which included lead-based solder.



Oxidants such as dissolved O_2 corrode pipes and leach soluble metal.

Replacement of Lead Service Lines

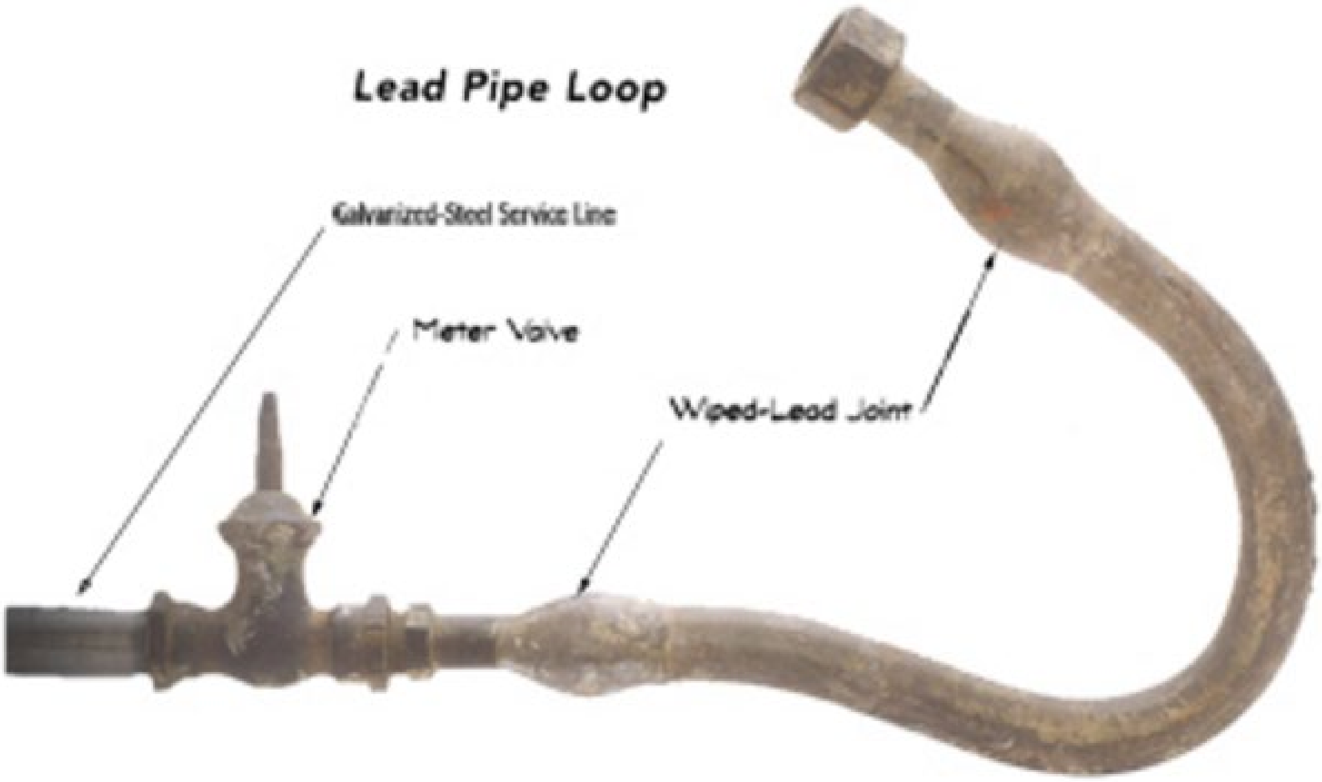
- It is estimated it would take 128 full time workers 1 full year to replace Flint's lead service lines

Lessons Learned

- The Flint story will continue to be a part of water history – just like Walkerton and Millwaukee. Water operators will continue to study these events in order to ensure safe water for their customers.
- In the next sections we will discuss corrosion control measures, water quality parameters, and LCR compliance issues
- Where applicable we will link our study back to the Flint story

Part 2: Lead and Copper Rule Compliance

Lead & Copper Rule Review



Lead and Copper Rule (LCR) Background

- LCR, June 7, 1991
- Lead (Pb) Action Level (AL): 0.015 mg/L (15ppb)
- Copper (Cu) Action level: 1.3mg/L (1300 ug/L)
- An AL exceedance is not a violation, but can trigger other requirements.
- Applies to all Community Water Systems (CWSs) and Nontransient Noncommunity water systems (NTNCWs)

The Lead and Copper Rule for Drinking Water followed other previous laws banning or regulating lead in paint, gasoline, and industrial uses. Lead was also addressed in the Clean Water Act

Lead and Copper Sample Collection Method

- First Draw
- 6-hour standing time
- One-liter Volume
- System or residents can collect
- Samples are taken from kitchen/bathroom cold water taps, typically used for consumption.

Number of samples based on population.

Exhibit II-2: Minimum Number of Lead and Copper Tap Samples for Systems on Standard Monitoring	
System Size	**No. of Samples**
> 100,000	100
10,001 - 100,000	60
3,301 - 10,000	40
501 - 3,300	20
101 – 500	10
≤ 100	5
If fewer than five tap sites are used for human consumption, the Revisions clarify that you must collect more than one sample from the same location on different days to obtain the minimum number of required samples. Alternatively, your State may allow you to collect one sample per available sample tap.	

<table>
<tr><th colspan="2">Exhibit II-7: Tiering Classification</th></tr>
<tr><th>If you are a CWS</th><th>If you are an NTNCWS</th></tr>
<tr><td>Tier 1 sampling sites are single family structures:
• with copper pipes with lead solder installed after 1982 (but before the effective date of your State's lead ban) or contain lead pipes; and/or
• that are served by a lead service line.
Note: When multiple-family residences (MFRs) comprise at least 20% of the structures served by a water system, the system may count them as Tier 1 sites.</td><td>Tier 1 sampling sites consist of buildings:
• with copper pipes with lead solder installed after 1982 (but before the effective date of your State's lead ban) or contain lead pipes; and/or
• that are served by a lead service line.</td></tr>
<tr><td>Tier 2 sampling sites consist of buildings, including MFRs:
• with copper pipes with lead solder installed after 1982 (but before effective date of your State's lead ban) or contain lead pipes; and/or
• that are served by a lead service line.</td><td>Tier 2 sampling sites consist of buildings with copper pipes with lead solder installed before 1983.</td></tr>
<tr><td>Tier 3 sampling sites are single family structures with copper pipes having lead solder installed before 1983.</td><td>Tier 3: Not applicable.</td></tr>
<tr><td colspan="2">Representative Sample: If a CWS or NTNCWS cannot collect enough samples from tiered sites, it must collect them from sites where the plumbing is similar to that used at other sites served by the water system.</td></tr>
</table>

Water Quality Factors Affecting Release of Lead and Copper (EPA Technical Recommendations 2.3)

- Alkalnity
- pH
- Dissolved Inorganic Carbon
- Corrosion inhibitors
- Hardness (calcium and magnesium)
- Buffer intensity
- Dissolved Oxygen
- Ammonia, chloride, and sulfate
- Oxidation Reduction Potential
- Natural Organic Matter
- Iron, aluminum, and magnesium

Consumer Confidence Reports

- Must Include:
  Educational statement about lead in drinking water – irrespective of systems lead levels

Test Results						
Contaminant	Violation (Y/N)	Sample Date	Highest Level Detected	Unit Measurement	MCL	Possible Source of Contamination
Microbiological Contaminants						
Total Coliform Bacteria	N	Monthly	0	*CFU/* 100mL	Presence of coliform bacteria in 5% of monthly samples	Naturally present in the environment, sewage leaks, runoff from livestock areas
Fecal (*E. coli*)	N	Monthly	0	*CFU/* 100mL		
Inorganic Contaminants						
Nitrate +Nitrite (as Nitrogen)	N	8/14/14	0.98	ppm	10	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Lead and Copper						
Lead[1]	N	9/24/13	0.0029	ppb	Allowed amount 15ppb	Corrosion of household plumbing systems, erosion of natural deposits
Copper	N	9/24/13	0.17	ppb	Allowed amount 1.3 ppm	Corrosion of household plumbing systems; erosion of natural deposits; leaching from wood preservatives

Lead Consumer Notice

- Within 30 days of learning the results, all systems must provide individual Pb tap results to people who receive water from sites that were sampled
- *This applies regardless of whether the results exceeded the Lead action level*

Consumer Notice of Tap Water Result

Dear Consumer,

Granville Exempted Village School District is served by the Village of Granville, a public water system (PWS) responsible for providing drinking water that meets state and federal standards. A drinking water sample for lead was collected at this location and the result is:

Amount of Lead in water:

Location of sample	Collection date	Sample Tap	Result, ug/L	Sample Type
Granville High School, 248 New Burg St	3/30/2016	Drinking Fountain	18.8	First Draw
Granville High School, 248 New Burg St	3/30/2016	Drinking Fountain	540.0	First Draw
Granville High School, 248 New Burg St	3/30/2016	Drinking Fountain	14.1	First Draw
Granville Middle School, 210 New Burg St	3/30/2016	Drinking Fountain	51.6	First Draw
Granville Middle School, 210 New Burg St	3/30/2016	Drinking Fountain	42.9	First Draw
Granville Middle School, 210 New Burg St	3/30/2016	Drinking Fountain	32.1	First Draw
Granville Elementary School, 310 N. Granger St	3/30/2016	Drinking Fountain	123.0	First Draw
Granville Elementary School, 310 N. Granger St	3/30/2016	Kitchen Sink	<5.0	First Draw
Granville Elementary School, 310 N. Granger St	3/30/2016	Kitchen Sink	<5.0	First Draw

Action Level for Lead: 15 micrograms per liter (ug/L)

What Is Being Done?

The locations that produced levels that exceed the action level have been placed out of service and will remain out of service until we remedy the cause of elevated levels. After remedy has been instituted, additional water testing will occur. GEVSD is providing educational materials to parents and employees.

Health Effects of Exposure to Lead

Children

- Behavior and learning problems
- Lower IQ and hyperactivity
- Slowed growth
- Hearing problems
- Anemia

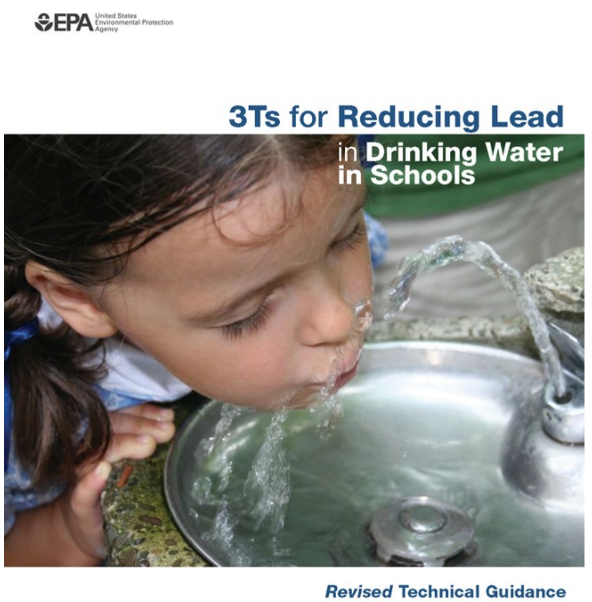
Pregnant Women

- Reduced growth of the fetus
- Premature birth

Lead is neurotoxic and can disrupt children's development, leading to behavioral problems and decreased intelligence.

Children affected by Lead in Flint Drinking Water

- The percentage of affected kids went from 2.4% to 4.9% as a result of the Flint lead corrosion crisis
- *In areas with the highest lead concentrations in the water, about 10% of the children had elevated blood levels of the element*



Compliance is based on the 90th percentile

- An easy way to visualize the 90th percentile is to imagine a system that collects ten LCR samples
- If you arrange the sample results from least to greatest, the 90th percentile would be the second to largest (or the 9th) value.
- **Example**: *Fictitious Lead results from 10 samples*

1 ug | 2 ug | 4 ug | 6 ug | 6 ug | 7 ug | 9 ug | 13 ug| 14 ug |22 ug

* The 90th percentile results from Flint were 25 *ug* for Lead

Optimized Water Quality Parameters

- Systems installing CCT must conduct 2 consecutive 6 months of follow-up tap and WQP monitoring
- Monitoring is conducted every 2 weeks
- *If system continues to exceed the Pb action level after corrosion control treatment is in place; the system must replace Lead Service Lines (LSL).*
- *At least 7% of Lead Service Lines must be replaced annually; State can require accelerated schedule.*

Exhibit I-1: Corrosion Control Treatment Steps

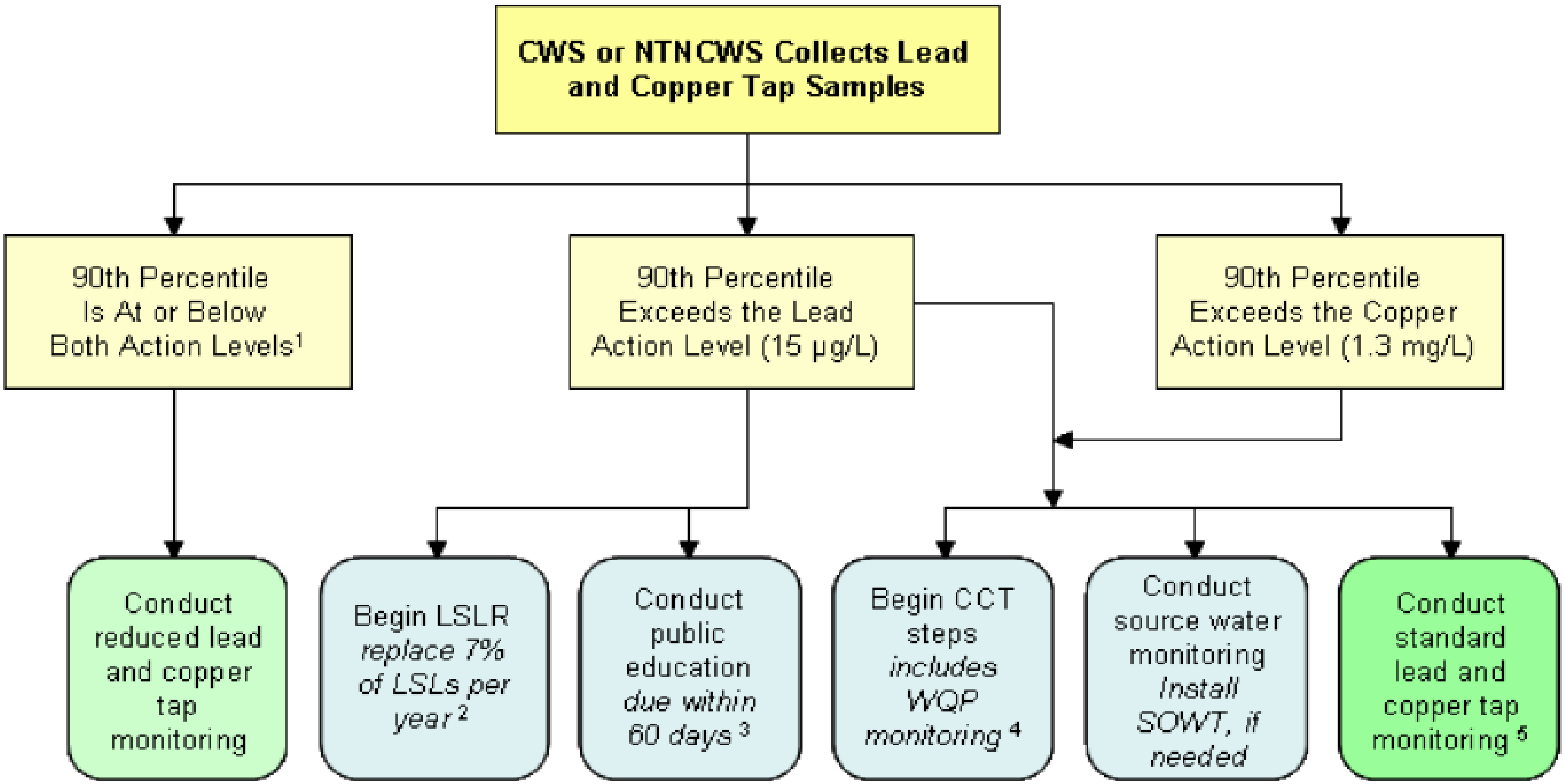
Requirement	Timetable for Completing Corrosion Control Treatment for Systems Serving:	
	50,000 or fewer people [1]	More than 50,000
Step 1: System recommends type of treatment to be installed	6 months [2]	N/A (Part of corrosion control study)
Step 2: State decides whether study is required	12 months [2]	N/A (System must conduct study)
Step 3: System completes study	18 months after State decision to conduct study	July 1, 1994
Step 4: State determines type of treatment to be installed	1. **If study is required:** 6 months after study is completed 2. **If no study is required:** Serves $\leq$ 3,300: 24 months; Serves 3,301 - 50,000: 18 months [2]	January 1, 1995
Step 5: System installs treatment	24 months after State decision regarding type of treatment to be installed	January 1, 1997
Step 6: System conducts follow-up monitoring	12 months after treatment installation (2 consecutive 6-month periods)	January 1, 1998
Step 7: State designates OWQPs [3]	6 months after follow-up monitoring	July 1, 1998
Step 8: System conducts continued monitoring	The schedule based on whether an action level is exceeded and/or compliance with OWQP ranges or minimums	

[1]A system whose population exceeds 50,000 after July 1, 1994, must follow the schedule for medium-size systems, beginning with the requirement to complete a corrosion control study.

[2] Indicates the number of months *after the end of the monitoring period during which* the lead and/or copper action level was exceeded. Prior to the Short-Term Revisions, this was expressed as number of months after exceeding an action level.

[3]The State is not required to designate OWQPs for systems serving 50,000 or fewer people that no longer exceed both action levels after installing treatment. However, some States have opted to do so.

Exhibit I-4. Follow up Actions Resulting from Lead and Copper Tap Monitoring



[1] Includes systems serving ≤ 50,000 people and (b)(3) systems; (b)(2) systems also must conduct WQP monitoring.
[2] Required if lead action level is exceeded after treatment.
[3] Counted from the end of the monitoring period with the lead ALE.
[4] Includes non-(b)(3) systems serving more than 50,000 people, irrespective of their 90th percentile levels.
[5] Systems that meet their OWQPs and do not exceed the lead action level can qualify for reduced lead and copper tap monitoring.

California Water Systems Regulations – Lead Service Line Identification & Replacement

- By **July 1, 2018**, a public water system shall compile an **inventory of known lead user service lines in use** in its distribution system and identify areas that may have lead user service lines in use in its distribution system.

- After completing the inventory required pursuant to subdivision (a), a public water system shall provide a **timeline for replacement of known lead user service lines** in use in its distribution system to the board.

California Water Systems Regulations – Lead Service Line Identification & Replacement (2)

By **July 1, 2020**, a public water system with areas that may have lead user service lines in use in its distribution system shall do either of the following:

(A) **Determine the existence or absence of lead user service lines** in use in its distribution system and provide that information to the board.

(B) **Provide a timeline to the board for replacement** of user service lines whose content cannot be determined.

Optimized Water Quality Parameter Compliance Examples

- **We will review excerpts from:**
- EPA Guidance Document EPA 815-R-99-019
- **How to Determine Compliance with Optimal Water Quality Parameters as Revised by the Lead and Copper Rule Minor Revisions**

Optimized Water Quality Parameters Considered In Corrosion Control Strategies

Exhibit II-9: Sample Handling Requirements for Lead, Copper, and Water Quality Parameters

Contaminant or Parameters	Preservative	Container[1]	Maximum Holding Time[2]
Lead	Conc. HNO_3 to pH <2[3]	P or G	6 months
Copper	Conc. HNO_3 to pH <2[3]	P or G	6 months
pH	None	P or G	Test Immediately[4]
Conductivity	Cool, 4°C	P or G	28 days
Calcium	Conc. HNO_3 to pH <2[5]	P or G	6 months
Alkalinity	Cool, 4°C	P or G	14 days
Orthophosphate	Cool, 4°C	P or G	48 days
Silica	Cool, 4°C	P only	28 days
Temperature	None	P or G	Test Immediately[4]

The following Compliance examples are for a system conducting monitoring for Water Quality Parameters

Compliance Period: January - June 2001

System description: The system has 1 entry point and 1 distribution tap site. It monitors biweekly at its entry point and every six months at its tap site. The systems treatment is pH & alkalinity adjustment, using lime and sodium bicarbonate.

State Action: The state designates the following OWQPs:

pH = 7.5 at entry point

= 7.2 at tap site

Alkalinity (mg/L as Ca CO3) = 40 at entry point

= 35 at tap site.

Entry Point Monitoring pH Results: This example shows how to determine compliance for pH

- Note that the system sampled more frequently than biweekly following an excursion. Each value below the OWQP pH minimum of 7.5 is shown in bold.

Entry Point pH Results for the 6-month Monitoring Period of January - June 2001					
State-specified pH minimum = 7.5					
Collection Date	Result = Daily value	Collection Date	Result = Daily value	Collection Date	Result = Daily value
Jan. 3	8.1	March 3	7.6	April 28	7.8
Jan. 17	8.2	March 13	7.8	May 8	7.8
Jan. 31	7.8	March 27	7.0	May 22	7.8
Feb. 14	7.8	March 29	7.9	June 5	8.2
Feb. 28	7.2	April 10	7.6	June 19	7.8

Compliance Calculation Procedure

1. Count the first day the sample is below the pH minimum value. Use the date the sample was collected and not the date the sample results were received.

2. Stop counting when a sample result from the same location and for the same parameter is at or above the minimum (in this example a sample taken from the entry point and measured for pH).

Do not count the day the sample is at or above the pH minimum value in the calculation

3. Repeat this procedure for each pH reading that falls below the pH minimum value (or 7.5 in this example).

The following table below shows the number of days where the pH level was less than 7.5.

Number of Days that the System Had Excursions		
Collection Date of Sample That Began the Excursion	Number of Days with Excursions	
Feb. 28	Feb. 28 - March 2	3 days
March 27	March 27 - 28	2 days
Total Number of Days with Excursions	5 days	

Example of Water Quality Parameter monitoring results for a system which as a minimum Alkalinity of 40 mg/L . *Calculate the number of days the system had excursions.*

Entry Point Alkalinity Results For January - June 2001					
State-Specified Alkalinity minimum = 40 mg/L as $CaCO_3$					
Collection Date	Result = Daily Value	Collection Date	Result = Daily Value	Collection Date	Result = Daily Value
Jan. 3	45	March 13	50	May 8	45
Jan. 17	42	March 27	35	May 22	32
Jan. 31	45	March 29	45	May 23	33
Feb. 14	41	April 10	32	May 25	45
Feb. 28	35	April 11	45	June 5	40
March 3	55	April 24	43	June 19	42

The following table below shows the number of days where the alkalinity concentration was less than State-specified minimum of 40 mg/L as $CaCO_3$.

Number of Days that the System Had Excursions		
Collection Date of the Sample That Began the Excursion	Number of Days with Excursions	
Feb. 28	Feb. 28 - March 2	3 days
March 27	March 27 & 28	2 days
April 10	April 10	1 day
May 22	May 22 - May 24	3 days
Total Number of Days with Excursions	9 days	

Overall Compliance

Example System 1 Overall Compliance with WQPs for January - June 2001 (*T* indicates an excursion)				
Day w/ excursion	Entry Point		Tap	
	pH	alkalinity	pH	alkalinity
Feb. 28, 2001	*T*	*T*		
Mar. 1, 2001	*T*	*T*		
Mar. 2, 2001	*T*	*T*		
Mar. 27, 2001	*T*	*T*		
Mar. 28, 2001	*T*	*T*		
Apr.10, 2001		*T*		
May 22, 2001		*T*	*T*	*T*
May 23, 2001		*T*	*T*	*T*
May 24, 2001		*T*	*T*	*T*
May 25, 2001			*T*	*T*
Total Number of days w/ excursions = 10 days				

Example:

Calculating overall compliance with Optimal Water Quality Parameters over a 6 Month Period.

Note that excursions for both pH and Alkalinity have been combined.

Part 3: Corrosion Control

Basic Water Quality Considerations for Corrosion 1

Langelier Index

- The Langelier Saturation index (LSI) is an equilibrium model and provides an indicator of the degree of saturation of water with respect to calcium carbonate
- Water with a Langelier saturation index of 1.0 is one pH unit above saturation. Reducing the pH by 1 unit will bring the water into equilibrium.
- This occurs because the portion of total alkalinity decreases as the pH decreases, according to the equilibria describing the dissociation of carbonic acid:

$$H_2CO_3 \rightleftarrows HCO_3^- + H^+$$

$$HCO_3^- \rightleftarrows CO_3^{2-} + H^+$$

Interpreting the Langelier Index

$$LSI = pH - pH_s$$

- pH is the measured water pH
- pHs is the pH at saturation in calcite or calcium carbonate

❑ **If LSI is negative**: No potential to scale, the water will dissolve CaCO3

❑ **If LSI is positive**: Scale can form and CaCO3 precipitation may occur

❑ *If LSI is close to zero*: Borderline scale potential. Water quality or changes in temperature, or evaporation could change the index.

Basic Water Quality Considerations for Corrosion 2

- Alkalnity
- pH
- Dissolved Inorganic Carbon
- Corrosion inhibitors
- Hardness (calcium and magnesium)
- Buffer intensity
- Dissolved Oxygen
- Ammonia, chloride, and sulfate
- Oxidation Reduction Potential
- Natural Organic Matter
- Iron, aluminum, and magnesium

pH & Alkalinity

- The pH of water is a measure of its acidity, otherwise known as its hydrogen ion concentration (H+ or H3O+).
- Alkalinity is the capacity of water to neutralize acid. It is primarily the sum of carbonate, bicarbonate, and hydroxide anions in the water as shown in Equation 1 (Stumm and Morgan, 1981).
- Alkalinity = 2CO32- + HCO3- + OH- – H+ Equation 1
- DIC is an estimate of the total amount of inorganic carbon

Notes on pH Measurement

- **The water's pH influences many other corrosion-related parameters (i.e., buffer capacity, alkalinity, ORP) and has a large influence on corrosion inhibitor effectiveness**.
- It is best to measure pH in the field at the time of sample collection using a calibrated instrument.
- The pH of highly purified waters and the pH of waters that are not in equilibrium with the atmosphere are subject to changes as dissolved gases are either absorbed or desorbed.
- To minimize these impacts, EPA recommends filling sampling containers completely and keeping them sealed prior to analysis (USEPA, 1982).

D.I.C.

- D.I.C. is an estimate of the total amount of inorganic carbon
- DIC = CO2 + H2CO3 + CO32- + HCO3- Equation 2
- Alkalinity and DIC are closely related. Most alkalinity comes from **bicarbonate** and **carbonate** ions in the water.
- *Although water operators are more familiar with alkalinity, DIC is the parameter more closely related to corrosion because it directly measures the available carbonate species in the water that can react with lead and copper to form passivating scales*.

Available Corrosion Control Treatment Methods

- **Alkalinity and pH adjustment** – effectively used by many systems for corrosion control. This shifts the water from corrosive to slightly scale-forming.
- **Phosphate-based corrosion inhibitors** have been widely used to control lead and copper – these methods cause a scale layer to be formed on the pipe interior
- **Silicate-based corrosion inhibitors** – not as widely used but works the same way as phosphate inhibitors, depositing a scale layer on the pipe interior
- **Calcium hardness adjustment** - research has shown that calcium carbonate films only rarely form on lead and copper pipe and are not considered an effective form of corrosion control

Pipe Scales

Pipe scales can be complex and can include two types of compounds:

(1) **passivating films** that form when pipe material and water react directly with each other

(2) **deposited scale material** that forms when substances in the water (e.g., iron, manganese, aluminum, calcium) precipitate out and build up on the pipe surface.

Scales can have layers and are influenced by treatment history. The structure and compounds in the existing corrosion scale can influence the effectiveness of CCT.

Treatment chemicals commonly used

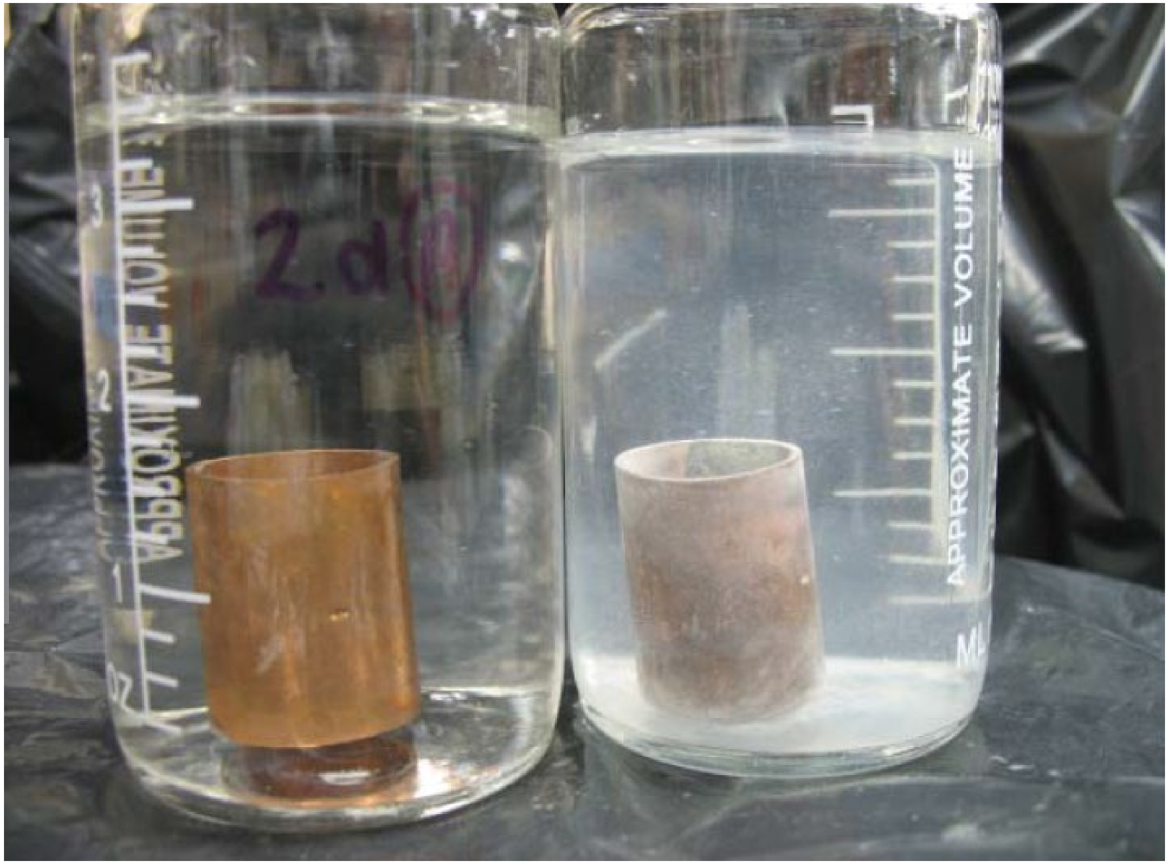
Chemical	Use	Composition	Alkalinity Change	DIC Change	Notes
Baking Soda, $NaHCO_3$, (sodium bicarbonate)	Increases alkalinity with moderate increase in pH.	95% purity. Dry storage with solution feed.	0.60 mg/L as $CaCO_3$ alkalinity per mg/L as $NaHCO_3$	0.14 mg/L as C per mg/L as $NaHCO_3$	Good alkalinity adjustment chemical but expensive.
Carbon Dioxide, CO_2	Lowers pH. Converts hydroxide to bicarbonate and carbonate species.	Pressurized gas storage. Fed either through eduction or directly.	None	0.27 mg/L as C per mg/L as CO_2	Can be used to enhance NaOH or lime feed systems.
Caustic Soda, NaOH (sodium hydroxide) Or KOH (potassium hydroxide)[1]	Raises pH. Converts excess carbon dioxide to carbonate alkalinity species.	93% purity liquid bulk, but generally shipped and stored, at < 50% purity to prevent freezing. KOH has a higher freezing point and may be stored at higher concentrations.	1.55 mg/L as $CaCO_3$ alkalinity per mg/L as NaOH	None	pH control is difficult when applied to poorly buffered water. Is a hazardous chemical, requires safe handling and containment areas
Hydrated Lime, $Ca(OH)_2$ (calcium hydroxide)[2]	Raises pH. Increases alkalinity and calcium content (i.e., hardness).	95 to 98% purity as $Ca(OH)_2$. 74% active ingredient as CaO. Dry storage with slurry feed.	1.21 mg/L as $CaCO_3$ alkalinity per mg/L as $Ca(OH)_2$	None	pH control is difficult when applied to poorly buffered water. Slurry feed can cause excess turbidity. O&M is intensive.

Treatment chemicals for corrosion continued

Soda Ash, Na_2CO_3 (sodium carbonate) Or Potash, KCO_3 (potassium carbonate)	Increases alkalinity with moderate increase in pH.	95% purity. Dry storage with solution feed.	0.90 mg/L as $CaCO_3$ alkalinity per mg/L as Na_2HCO_3	0.11 mg/L as C per mg/L as Na_2CO_3	More pH increase caused compared with $NaHCO_3$, but less costly. Has increased buffer capacity over hydroxides.
Sodium Silicates Na_2SiO_3	Moderate increases in alkalinity and pH	Available in liquid form mainly in 1:3.2 or 1:2 ratios of Na_2O:SiO_2	Depends on formulation	None	More expensive than other options but easier to handle than lime and other solid feed options. Has additional benefits in sequestering or passivating metals.

Corrosion in Flint Pipes

CSMR ratios above 0.58 associated with corrosion



In this photo,lead solder coupons have been placed in waters with different CSMR ratios:

Left: CSMR = **0.2**

Right: CSMR = **13.0**

After 3 days the corrosion of lead is observable in the form of a white precipitate.

Questions?

Final Steps:

- Questions-