UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGIONAL ADMINISTRATOR
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

REPLY TO THE ATTENTION OF:

MEMORANDUM

DATE: November 4, 2015

SUBJECT: Transmittal of Final Report - High Lead at Three Residences in Flint, Michigan

FROM: Tinka G. Hyde Tinka G. Hyde
Water Division Director

TO: Jim Sygo
Deputy Director
Michigan Department of Environmental Quality

Howard Croft
Director of Flint Public Works

Enclosed please find for your file a final redacted version of a report prepared by EPA Scientist, Miguel Del Toral, regarding lead in drinking water at three residences in Flint, Michigan. The redactions remove personally identifiable and medical information. This report has been finalized and is also being provided to the National Drinking Water Advisory Council (NDWAC) for discussion during their upcoming meeting on November 17-19, 2015. We understand you saw an earlier version of this document; and note that most of the recommendations in that interim report are already being implemented (e.g., the City of Flint has switched back to Detroit water; filters have been provided to residents; and additional corrosion control treatment will be implemented).

The final report contains important new information indicating that physical disturbances of lead service lines can dislodge the protective coating that prevents lead from leaching into drinking water. The final report recommends notifying residents about the potential risks of increased lead levels in drinking water when work is undertaken that may disturb lead service lines.

cc: Natasha L. Henderson, City of Flint Administrator

High Lead Levels in Flint, Michigan

The purpose of this report is to present the findings of activities conducted in response to high lead levels in drinking water reported to the United States Environmental Protection Agency Region 5 Office (EPA) by a resident in the City of Flint, Michigan.

Background Information

Prior to April 30, 2014, the City of Flint purchased water from the City of Detroit. On April 30, 2014, the City of Flint switched from utilizing purchased water from Detroit to a new water source, the Flint River. Subsequent to the change in source water, the City of Flint experienced a number of water quality issues resulting in violations of National Primary Drinking Water Regulations (NPDWR) including acute and non-acute Coliform Maximum Contaminant Level (MCL) violations and Total Trihalomethanes (TTHM) MCL violations (see Appendix A).

Beginning in January 2015, [redacted], a resident of Flint, called the Flint Water Department (FWD) regarding the water quality in her home. In response to the initial and subsequent calls, the FWD visited the [redacted] home on a number of occasions and also collected tap water samples. [redacted] also contacted EPA regarding these same water quality issues and medical issues she believes are associated with the water quality in Flint.

Following initial calls on the general water quality, on February 26, 2015, [redacted] contacted EPA regarding high lead levels found in her drinking water by the City of Flint. The result of the initial lead in water sample collected by the City of Flint on February 18, 2015 from the [redacted] home was 104 µg/L and the level of iron in the water exceeded the capability of the instrument to measure (>3.3 mg/L). On February 26, 2015, upon receiving the lead results from [redacted], the EPA contacted the Michigan Department of Environmental Quality (MDEQ) regarding the high lead result. The MDEQ advised that the City of Flint collect a follow-up sample for lead at the [redacted] home.

On March 3, 2015, the City of Flint collected a follow-up sample for lead at the [redacted] residence and the result of this second sample was 397 µg/L[1]. Subsequent to receiving her second result, EPA spoke to [redacted] via phone on March 19, 2015, and the following information was provided by [redacted]:

- The [redacted] home is a HUD home which was gutted and renovated in 2011. All existing plumbing had been removed and the [redacted] installed plastic plumbing.
- Due to high iron levels in the tap water, the [redacted] installed an iron filter downstream of the service line inlet into the home.
- [redacted] indicated that at this time they are not drinking the water or using it for cooking. She stated that her child's blood lead level (BLL) was originally at [redacted] in 2012 and that a more recent test showed it had increased to [redacted], but she noted that

[1] *Note: A third water sample had been collected on April 2, 2015, but the results had not been provided to the* [redacted] *at the time the interim report was written. The third lead in water sample result was 707 µg/L*

the BLL testing was done well after the child had stopped drinking the water and may have been higher during the time the child was consuming the water.
- Water samples collected by the City of Flint from her home were collected from the kitchen tap after the iron filter was physically removed.
- The Flint Water Department (FWD) informed [redacted] that her service line does not connect to the water main in front of her home as is typically the case for most homes.
- On March 18, 2015, City of Flint personnel went to the [redacted] home to locate the external shut-off valve in conjunction with the planned replacement of the [redacted] service line and were unsuccessful. Eventually it was discovered that the external shut-off valve was located at the corner of [redacted] and Bryant Street, two houses down from the [redacted] home.

As part of EPA's effort to respond to [redacted] concerns regarding her water results, EPA contacted the FWD. The following information was provided to EPA by the FWD:

- [redacted] home is one of the first homes built on the block and the service line runs for approximately 50-60 yards, connecting to the water main on Bryant Street which runs perpendicular to [redacted] (see Appendix A).
- Flint has a large number of lead service lines, so it would not be surprising to find that this is a very long lead line.
- The first sample from the [redacted] home was collected with the iron filter in place, and the second was with the iron filter physically removed. The iron filter was located just after the water meter.
- [redacted] showed FWD a video of her son 10 minutes after taking a bath, and that he had a full body rash in the video.

It was a common practice in the early 1900s to purchase large parcels of land and later subdivide them. Since service lines are typically run from the water main to the nearest location on a property and it is possible that the [redacted] home may have originally been part of a larger parcel of land that encompassed the two homes that now exist adjacent to the [redacted] home and was subsequently divided, leaving the original home connected to the same service connection and water main, while the newer homes were connected to a more recent water main installed along [redacted].

Based on a suspected conflict of interest at the healthcare facility that originally tested her son's BLL, [redacted] took her son to a different healthcare facility to have his blood lead tested again. On April 1, 2015, [redacted] provided EPA with a copy of her child's blood lead testing performed on March 27, 2015, showing a higher BLL ([redacted]) than the original test.

Due to the persistently high lead results, the FWD shut off the water service to the [redacted] home on April 3, 2015. Per agreement between the FWD and [redacted], her home was then connected to her neighbor's home via a garden hose, from one hose bib to another. This was understood to be a temporary measure until the [redacted] service line could be replaced. The [redacted] used this water connection only for bathing, washing dishes and washing clothes.

At the invitation of [redacted], EPA visited the [redacted] home on April 27, 2015, and reviewed the internal plumbing and information provided by [redacted], including water samples and spent filter cartridges. During this visit, EPA observed that the internal pipes, valves and connectors at the [redacted] residence were made of CPVC plastic, approved by NSF for potable drinking water applications, with a few minor metal connectors. A review of the treatment units in the home by EPA found that there was no iron filter in the home as had previously been thought. The only active treatment device in the home was a whole-home sediment filter which utilizes NSF certified Whirlpool WHKF-WHWC cartridge filters for sediment removal and taste/odor. There was also a non-functioning 'Water Resources International Hydro-Quad Commercial Water Processor' which was bypassed (see Appendix A).

At the request of [redacted], Dr. Marc Edwards at Virginia Tech provided sampling instructions to [redacted] for collecting a series of samples from her home. As part of the instructions, on the night of April 27, 2015, the water at the [redacted] residence was turned back on temporarily and the kitchen tap was flushed for 25 minutes at low flow prior to letting the water sit overnight. A series of sequential samples were collected the following morning (April 28, 2015) and sent to Dr. Edwards for analysis.

Dr. Edwards provided [redacted] with the results of the analyses and also shared the results with EPA on May 5, 2015, along with information regarding other chemical parameters tested (see Appendix B). In addition to very high lead levels in all sample results, the analytical data shows a correlation between lead and phosphate as well as lead and aluminum in all samples. On April 24, 2015, EPA had learned that Flint did not have corrosion control treatment in place and also learned that Flint was using ferric chloride as a coagulant. Consequently, as the City of Flint is not utilizing phosphate or alum as treatment chemicals since the source switch, the results indicate that it is likely that the phosphate and aluminum were being released from the scale within the distribution system network. This scale would have formed on the inside of the pipes in Flint during the time when the City was purchasing water from Detroit, as Detroit utilizes orthophosphate for corrosion control and alum as a coagulant in their water filtration process.

Research conducted by EPA on lead content in pipe scales has shown that scales which form on the inside of lead pipes can be released or dislodged into the water and may contain a high percentage of lead (Appendix C). Although the results received from Virginia Tech were indicative of the presence of a lead service line, the FWD indicated that no records existed to confirm whether any portion of the service line connecting to the [redacted] home was made of lead. However, given the high lead levels found, it was presumed that at least a portion of the service line was likely made of lead. In the course of following up on the high lead at the [redacted] home, additional sample results provided to EPA from other residences in Flint also showed high lead levels.

Primarily from a public health standpoint, but also from a research standpoint, it was important to try to find out what the cause of these very high lead levels might be. EPA Region 5, EPA's Office of Research and Development and others have been working together collaboratively to better understand lead release mechanisms from lead service lines in anticipation of upcoming revisions to the Lead and Copper Rule (LCR) and as part of a collaborative effort in EPA Region 5 to study potential options for optimizing phosphate treatment to control lead in water and the need to reduce phosphorus discharges into the environment. Since the [redacted] service line was scheduled for replacement on May 6, 2015 and the presumption was that at least a portion of the service line was lead, EPA visited the [redacted] home on the day of the service line replacement to gather information and service line pipe samples that could provide additional information as to how lead levels could get as high as they did in this case.

The original service line to the [redacted] home was disconnected and two service line pipe segments from this service line were extracted on May 6, 2015. Additional tap water samples were collected also from two homes on Bryant Street that were connected to the same water main as the [redacted] home (Appendix A). The samples were collected from these homes as they had more typical service line lengths as compared with the [redacted] home. During the same visit, patches of asphalt were also noted along the curb on Browning Avenue, indicating that excavation had occurred. These patches, which were in proximity of the [redacted] service line in the parkway (see Appendix C) may be one of the potential factors contributing to the high lead at the [redacted] home, as it has been shown that physical disturbances to pipes can dislodge the scales within those pipes.

The two service line segments that were extracted were subsequently identified as galvanized iron pipe. Analyses conducted by Virginia Tech on the extracted portions of the pipe indicate that the galvanized iron pipe was fairly typical in terms of composition (see Appendix C). The galvanized iron portion ran from inside the [redacted] home to the external shut-off valve at the corner of [redacted] and Bryant Street. The remainder of the [redacted] original service line from the shut-off valve to the water was made of lead.

Although the service line had been disconnected from the [redacted] home, it was not possible to retrieve a segment of the lead portion of the service line as it was beyond the shut-off valve which had been closed and left in place. Following the disconnection of the original service line, a new service line made of copper was installed from the [redacted] home to the water main in front of the home on [redacted]. Subsequent to the replacement of the service line at the [redacted] home, water samples were also collected from the [redacted] home and sent to the EPA Chicago Regional Laboratory for analysis. In all three homes, the sequential samples were collected using standard protocols used in prior sequential sampling efforts to capture water samples reflecting lead levels from the kitchen tap to the water main. Two additional samples were collected from the water heater drain valve at the [redacted] home to determine if lead deposits had accumulated in the water heater, and a final sample was collected from the bathroom tap. The sequential sampling results indicate that the service line replacement eliminated the high lead levels and that no residual lead had accumulated within the plastic plumbing of the [redacted] residence, which was a potential concern and possibility based on prior research. One of the two samples collected from the [redacted] hot water heater had high lead (32 μg/L), likely from lead particulate that had accumulated in the tank, and the sample collected from the bathroom was 5.5 μg/L.

The sequential samples collected from the two homes on Bryant Street had differing results. At the first home (Site 2), a series of 15 sequential one-liter samples were collected and the results are indicative of a service line that does not contain any portion that is made of lead. Consequently the lead results were low overall for samples representative of the service line. The first sample in the sequential sampling series was the highest, which potentially indicates the presence of leaded brass in the faucet or underlying sink fixtures. Some leaded brasses manufactured prior to the 2011 lead-free law have been shown to release high levels of lead in certain water qualities. Leaded-solder was ruled out as the home plumbing consisted of galvanized iron pipe, and it is presumed that if the galvanized iron pipe were contributing the higher lead, the lead levels would be more consistent in all 15 samples.

At the second home (Site 3), a series of 15 sequential one-liter samples were collected from the kitchen tap and the results indicated that there were no significant sources of lead within the home plumbing but that a portion of the service line is likely made of lead, as indicated by the characteristic peaking of lead levels in the liters capturing water from the service line between the property and the water main, where the portions of many service lines in Flint are made of lead.

All three sets of sequential samples were analyzed for lead, copper, iron, phosphorus and cadmium. In contrast to the samples analyzed by Virginia Tech from the [redacted] home prior to the removal of the original service line, no phosphorus was present in the sequential samples at the [redacted] home following the replacement of the service line. In addition, no phosphorus was detected in the sequential samples from the two homes on Bryant Street. These results indicate that the source of high lead, aluminum and phosphorus in the analyses conducted by Virginia Tech was likely dislodged or disintegrated scale from within the [redacted] original service line.

The sequential sampling results from the [redacted] home before and after service line replacement, as well as the results from the two homes on Bryant Street are included in Appendix B.

Although relative contributions cannot be determined, there are a number of factors that could have contributed to the high lead levels found at the [redacted] home as follows:

1) Corrosiveness of water and lack of mitigating (corrosion control) treatment

The corrosiveness of the water and the absence of mitigative treatment to control lead release are well known factors that can contribute to high lead release.

2) Presence of a lead service line

Lead service lines are the largest source of lead, when present, and can contribute up to 75 percent of the total mass of lead released into the water. The portion of the original service line from the water main to the external shut-off valve at the corner of [redacted] and Bryant Street, estimated to be approximately 25 feet in length, was found to be a lead pipe. In addition, studies have also shown that the scales within galvanized iron pipe downstream of lead pipe segments can be 'seeded' with lead from the lead portion of the service line. The [redacted] service line was much longer than most typical service lines which would allow accumulation of a greater total mass of scale within the pipe.

3) Physical disturbances

A recent EPA study indicates that physical disturbances in proximity to lead service lines can cause the dislodging of the protective scales from within the service lines. The photograph in Appendix C shows the scale that was dislodged from inside a lead service line during routine maintenance work in another city due to a physical disturbance of the line. The dislodged scale and sediment contained a very high concentration of lead. At the time of the EPA visit to the [redacted] home, there were two patches of new asphalt visible on [redacted] along the parkway where the [redacted] original service line was located, indicating recent excavation and possible recent physical disturbances to the [redacted] service line (Appendix C). These potential disturbances were along the galvanized iron section of the service line and as noted above, research has shown that the presence of lead pipe upstream can 'seed' the galvanized iron pipe downstream with lead, which results in an accumulation of lead-bearing scales within the galvanized pipe downstream of the lead portion of the service line. It is reasonable to assume that these physical disturbances to the galvanized iron portion of the service line could therefore result in the same dislodging of scale and sediment as studies have shown can happen with lead service lines.

The street disturbances on [redacted] occurred after the [redacted] moved into the home along the portion of the service line made of galvanized iron pipe. There were no visible signs of disturbance on Bryant Street where the lead portion of the [redacted] service line was situated (see Appendix C). It is likely, given the extremely high lead levels found and the co-occurrence of aluminum, phosphorus and lead, that the long segment of galvanized iron pipe was seeded with lead over the entire length of the pipe and the physical disturbances and other factors such as the water chemistry resulted in the release of large amounts of the high-lead bearing scale and sediment into the water. Virginia Tech also found nearly perfect correlations between the lead in water and markers for galvanized pipe scales including zinc.

Recommendations

As indicated by the results from the [redacted] home and previous EPA work, the presence of lead pipes over many years has likely resulted in the accumulation of lead in the scales within non-lead pipes downstream of the lead pipe and physical disturbances to the leaded or non-leaded portions of the service lines have the potential to release large amounts of scale and sediment that could pose an immediate and acute health hazard to the residents. Consequently, even with corrosion control treatment in place in the future, physical disturbances will be capable of dislodging the high lead-bearing scale and sediment from non-lead pipes as well as lead pipes, as was the case in the earlier EPA study.

Obtaining information on the lead reservoirs in the scales within the lead and non-leaded portions of intact service lines is essential for determining the potential risk to residents from lead-bearing scale released as lead lines are replaced as well as the risk that may remain following removal of the lead lines, where the non-leaded portions of service lines are left in place.

As the [redacted] service line was very long compared to the length of most typical service lines, it is important to assess the potential risk posed by the scale reservoirs in more typical lengths of service lines by extracting both the leaded and non-leaded portions of service lines which have not been physically disturbed. The service lines chosen for extraction and analysis should be representative of the materials commonly used downstream of the lead pipe (e.g., galvanized iron, copper, plastic). Extraction/handling procedures should be developed by EPA to ensure that damage to the scales from the excavation, extraction and delivery of the service line segments is minimized. Sequential sampling should also be conducted on a representative group of homes with common plumbing materials (e.g., galvanized iron, copper, plastic) to determine the extent to which the lead from the service line has seeded the interior plumbing in homes.

It is also critically important to develop and incorporate ongoing training and public education on the potential for high lead release from the scales as a result of any future physical disturbances to service lines and mitigative actions that residents can take to lower their exposure risk. The training and educational material should be assessed for clarity, meaningfulness, and accessibility by a group of residents and health experts to ensure the effectiveness of the communications.

At a minimum, immediate training and public education on the potential risks posed by physical disturbances to service lines should be developed by communications experts and provided to residents, community groups, elected officials, health departments, pediatricians and gynecologists, water and non-water utilities (gas, electric, cable, etc.), plumbing organizations and contractors. Residents should be notified of scheduled work by water and non-water utilities and informed of the potential risk of increased lead levels due to these disturbances.

Appendix A – Background Information

National Primary Drinking Water Regulations (NPDWR) Violations – City of Flint

Following the switch to the Flint River, the City of Flint experienced a series of NPDWR violations as follows:
Acute Coliform MCL violation in August 2014
Monthly Coliform MCL violation in August 2014
Monthly Coliform MCL violation in September 2014
Average TTHM MCL violation in December 2014
Average TTHM MCL violation in March 2015
Average TTHM MCL violation in June 2015

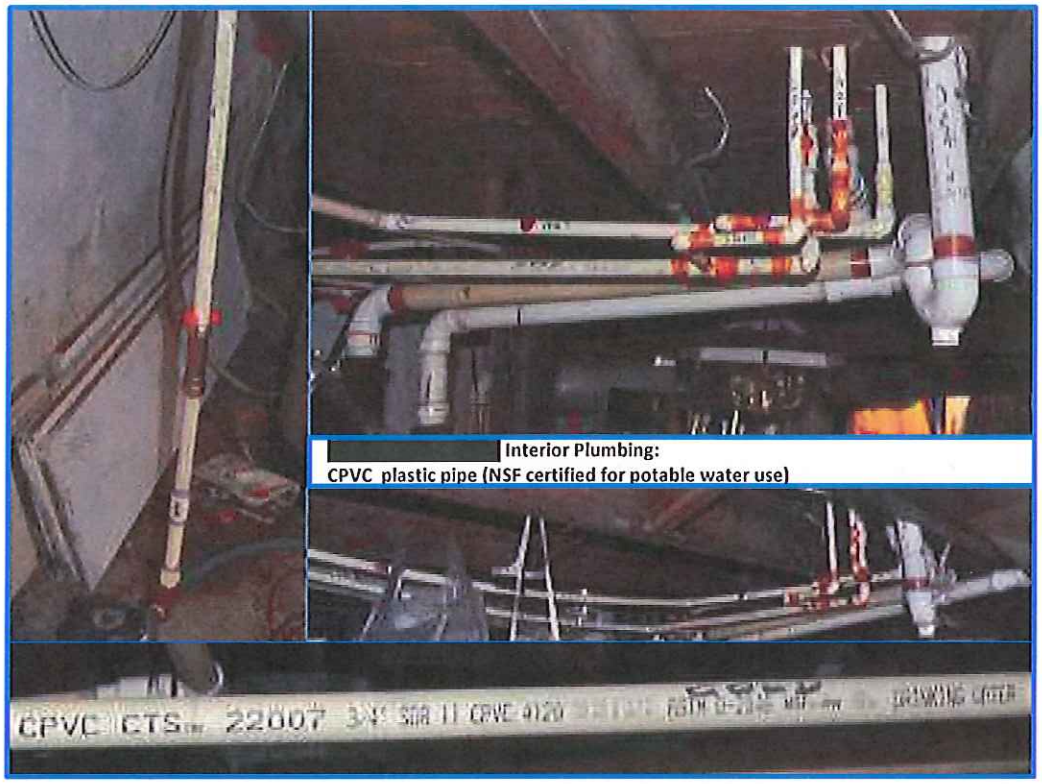
Sampling Sites

The map below shows the three homes that were sampled as provides information on the length of the service lines and the plumbing material. Two portions of the original service line were extracted and analyzed and a third portion was collected from the entry point into the home, but not analyzed.

[map redacted because it shows Personally Identifiable Information]

Internal Plumbing – [redacted]

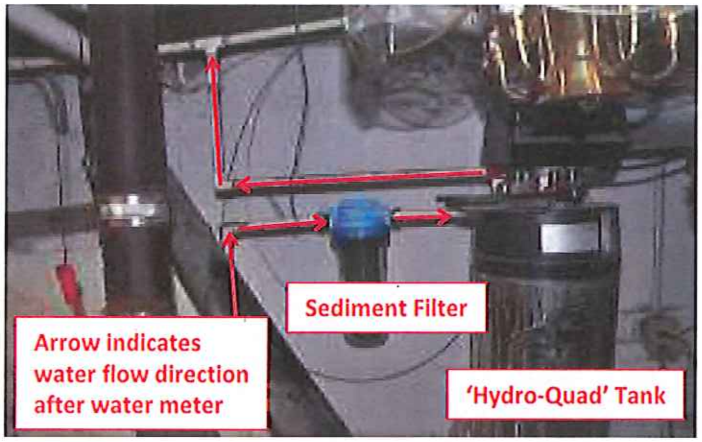
The following pictures were taken at the [redacted] home located at [redacted]. With the exception of a a few minor metallic connectors, all potable water plumbing in the home was found to be CPVC plastic pipe which is NSF-certified for drinking water use.

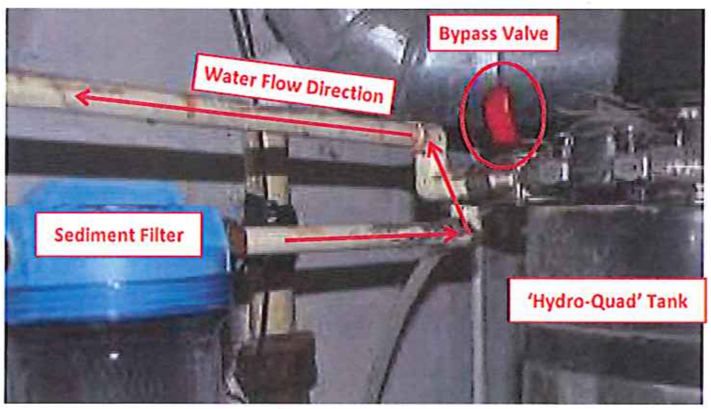


[redacted] **Interior Plumbing:**
CPVC plastic pipe (NSF certified for potable water use)

Treatment Units – [redacted]

The [redacted] home has a whole-home sediment filter, as well a non-functioning 'Hydro-Quad Commercial Water Processor' which is bypassed. There was no iron filter in the home as had been previously reported.





Appendix B – Analytical Results

Lead in water sampling results from the [redacted] residence ([redacted])

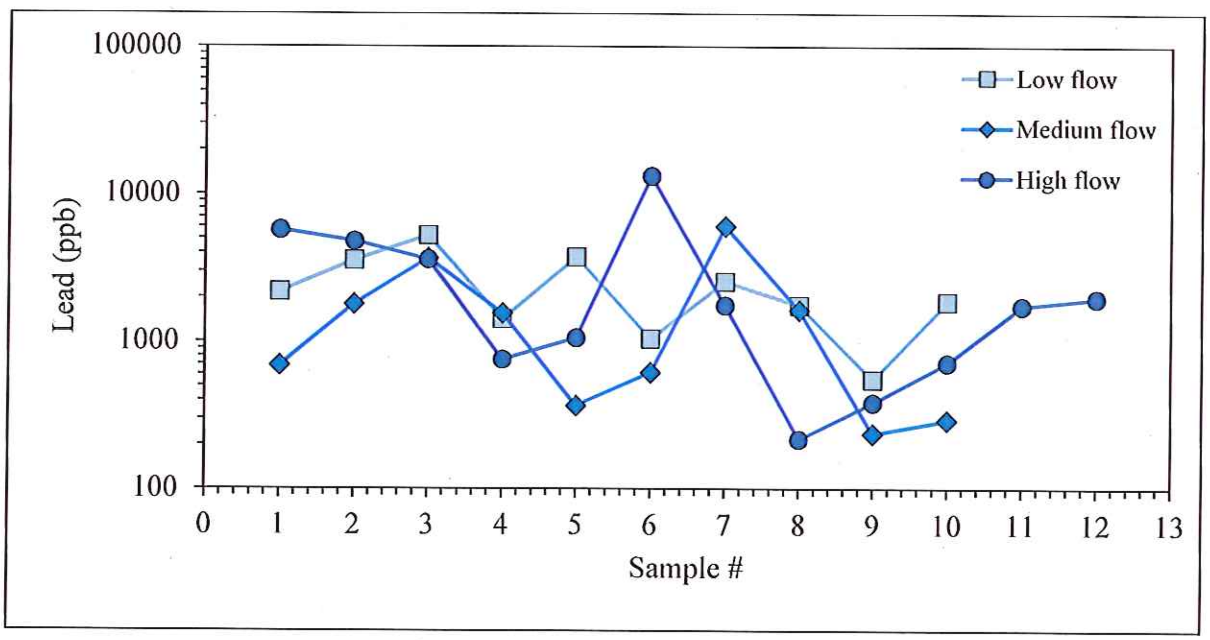
City of Flint Samples

The City of Flint collected water samples from the [redacted] residence and analyzed them for lead. The results for each date are listed below.
February 18, 2015: 104 µg/L
March 3, 2015: 397 µg/L
April 2, 2015: 707 µg/L*

*This sample result had not been provided to the [redacted] at the time the interim report was written.

Virginia Tech Sampling Results (provided courtesy of Virginia Tech)

Samples were collected from the [redacted] home following an extended stagnation period (April 3, 2015 to April 27, 2014) after the water at the [redacted] residence had been shut off. The water was turned back on and three sets of sequential samples were collected on April 28, 2015, at different flow rates (low, medium and high).



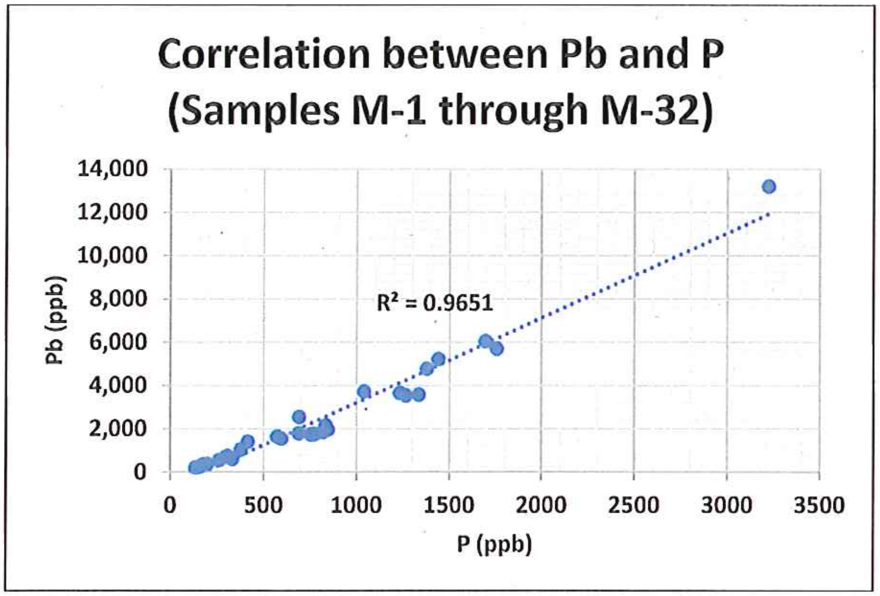
	Low Flow									
	1 L Sample Bottle							125 mL Sample Bottle		
Element (units)	M-1	M-2	M-3	M-4	M-5	M-6	M-7	M-21	M-22	M-23
Ag (ppb)	0	0	0	0	0	0	0	0	0	0
Al (ppb)	2,285	4,199	7,683	1,856	5,623	1,422	3,413	1,865	666	2,015
As (ppb)	3.3	3.9	4	2	3.2	2	2.6	3.6	1.9	3.1
Ba (ppb)	31.3	39.8	27.7	21.2	24.2	20.9	22.8	31.3	21.3	32.6
Ca (ppb)	43,150	43,620	43,580	42,590	43,030	42,030	42,440	40,790	41,050	41,460
Cd (ppb)	2.5	4.2	5.7	1.9	3.9	2	2.5	2.2	1.4	2.4
Cl (ppm)	1,206	1,148	1,272	1,178	1,187	1,214	1,218	1,641	1,076	1,044
Co (ppb)	1.1	1.7	0.9	0.4	0.7	0.4	0.5	0.9	0.3	1
Cr (ppb)	2.1	2.5	2.6	1.3	1.9	1.6	1.5	1.8	1.3	1.7
Cu (ppb)	235	355	294	94	146	101	112	180	82	178
Fe (ppb)	3,598	4,928	3,419	1,446	3,029	2,142	1,780	3,096	1,344	3,241
K (ppb)	3,480	3,508	3,445	3,435	3,430	3,391	3,409	3,256	3,319	3,341
Mg (ppb)	10,310	11,910	17,990	11,290	15,470	10,610	12,720	8,861	9,396	9,098
Mn (ppb)	1,734	2,790	1,093	462	703	429	652	1,382	442	1,509
Mo (ppb)	2.3	2.3	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.8
Na (ppb)	17,790	17,860	17,810	17,620	17,650	17,410	17,610	16,960	17,100	17,280
Ni (ppb)	9.8	16	30.7	8.1	23.2	6.2	15.3	6.6	3.7	6.8
P (ppb)	835	1,267	1,441	416	1,040	379	691	773	261	819
Pb (ppb)	2,171	3,550	5,224	1,412	3,735	1,038	2,542	1,759	552	1,857
S (ppm)	28.5	28.7	28.5	28.4	28.5	28	28	26	27	27.1
Se (ppb)	0.2	0	-0.1	0.1	0.2	0	0.3	0	0	0.2
Si (ppb)	3,212	5,281	12,320	4,474	9,401	3,770	6,231	2,619	2,582	2,775
Sn (ppb)	4.6	4.9	6.1	2.2	4.5	2.3	3	2.3	1.5	2.3
Sr (ppb)	129.4	132.3	128.5	125	127.7	125.3	126.1	126.3	125.5	128
Ti (ppb)	3.4	5.8	8.3	2.1	5.8	1.9	3.1	3	1.4	3.1
U (ppb)	1	1.6	2.6	0.8	1.9	0.7	1.2	0.9	0.4	0.9
V (ppb)	13.9	17.5	23.9	9.8	17.6	8.9	13.8	12.2	6	10.8
Zn (ppb)	1,055	1,848	2,731	777	1,890	839	979	746	513	808

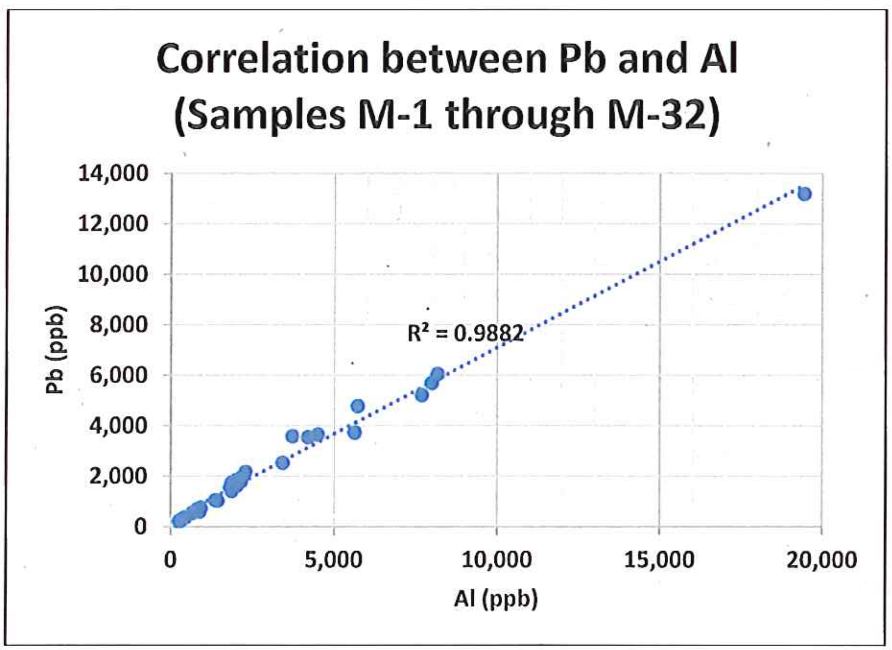
	Medium Flow									
	1 L Sample Bottle							125 mL Sample Bottle		
Element (units)	M-8	M-9	M-10	M-11	M-12	M-13	M-14	M-24	M-25	M-26
Ag (ppb)	0	0	0	0	0	0	0	0	0	0
Al (ppb)	891	2,142	4,493	1,810	431	877	8,159	2,005	286	347
As (ppb)	2.2	2.9	3.9	2.5	2	2.3	4.6	2.7	1.8	2
Ba (ppb)	22	29.1	36.3	28	18.9	22.6	37.1	26.2	18.9	19.4
Ca (ppb)	41,520	41,580	42,080	41,490	41,020	40,850	42,010	40,940	41,110	40,550
Cd (ppb)	1.5	2.4	4	2.1	1	1.5	4.9	2.9	0.9	1
Cl (ppm)	1,329	1,211	1,252	1,225	1,507	1,321	1,324	1,179	1,258	1,318
Co (ppb)	0.4	0.8	1.3	0.7	0.2	0.4	1.4	0.7	0.2	0.2
Cr (ppb)	1.1	1.5	2.2	1.4	1.2	1.1	3.5	2.1	1.1	1.1
Cu (ppb)	104	151	257	144	65	119	267	166	52	59
Fe (ppb)	1,510	2,476	4,254	2,258	912	1,471	4,563	3,450	711	820
K (ppb)	3,363	3,391	3,370	3,352	3,344	3,311	3,360	3,308	3,356	3,311
Mg (ppb)	9,769	9,960	12,360	9,703	9,331	9,513	16,430	10,820	9,237	9,166
Mn (ppb)	498	1,185	1,878	1,052	231	536	1,947	967	167	220
Mo (ppb)	1.8	1.8	1.8	1.9	1.8	1.8	2.2	2	1.7	1.7
Na (ppb)	17,240	17,370	17,370	17,310	17,190	17,010	17,320	17,020	17,140	16,950
Ni (ppb)	4.1	7.7	16.2	6.8	2.7	3.8	33	7.7	2.1	2.4
P (ppb)	321	690	1,233	595	178	332	1,697	573	144	163
Pb (ppb)	688	1,791	3,655	1,549	366	616	6,048	1,631	237	292
S (ppm)	27.6	27.5	27.3	27.3	27.1	26.9	27	26.4	27	26.6
Se (ppb)	0	0	0.2	0.1	0.1	0.2	0.2	0.3	0.1	0
Si (ppb)	2,892	3,591	6,180	3,307	2,445	2,756	11,280	4,184	2,274	2,303
Sn (ppb)	2.2	2.6	4.4	2.5	1.4	1.8	4.9	3	1	1.1
Sr (ppb)	124	128	128	126	124	124	128	126	125	124
Ti (ppb)	1.6	2.9	5.5	2.5	1	1.2	7.7	2.7	0.4	0.6
U (ppb)	0.5	0.9	1.7	0.9	0.4	0.5	2.7	0.9	0.3	0.3
V (ppb)	8.4	11.9	17.5	10.4	8.2	8.4	25.1	9.7	6	7.4
Zn (ppb)	657	933	1,669	836	366	592	1,934	1,304	305	337

	High Flow											
	1 L Sample Bottle						125 mL Sample Bottle					
Element (units)	M-15	M-16	M-17	M-18	M-19	M-20	M-27	M-28	M-29	M-30	M-31	M-32
Ag (ppb)	0	0	0	0	0	0	0	0	0	0	0	0
Al (ppb)	7,984	5,713	3,714.	912	1,354	19,440	1,893	248	455	822	1,859	2,176
As (ppb)	5	4.1	4.3	1.9	2.1	7.4	2.9	2	2.2	2.3	3.2	3.4
Ba (ppb)	40	37	45	21	22	41	32	19	20	22	31	34
Ca (ppb)	42,200	41,870	41,760	41,120	41,110	43,860	41,410	40,730	40,990	40,550	41,000	41,050
Cd (ppb)	5.6	4.1	3.7	1.4	1.9	9.3	2.2	0.9	1.2	1.6	2.1	2.5
Cl (ppm)	1,347	1,261	1,088	1,150	1,138	1,285	891	1,261	1,309	1,215	1,121	1,226
Co (ppb)	1.6	1.4	1.7	0.4	0.4	1.9	0.9	0.2	0.3	0.4	0.9	1
Cr (ppb)	2.8	2.4	2.6	1.3	1.3	4.8	1.7	1.1	1.5	1.5	1.6	1.8
Cu (ppb)	541	24	276	89	105	351	165	52	70	96	167	192
Fe (ppb)	4,926	4,288	5,323	1,509	1,705	6,491	3,074	667	1,215	1,591	3,026	3,349
K (ppb)	3,363	3,350	3,343	3,327	3,305	3,410	3,361	3,320	3,348	3,287	3,333	3,331
Mg (ppb)	15,910	13,430	9,758	9,633	10,240	29,890	9,110	9,158	9,305	9,462	9,051	9,157
Mn (ppb)	2,067	2,058	2,818	498	503	1,975	1,401	149	301	534	1,369	1,638
Mo (ppb)	2	2	2	1.9	1.9	2.2	1.8	1.8	1.8	1.8	1.8	1.8
Na (ppb)	17,340	17,310	17,280	17,110	16,980	17,540	17,370	17,040	17,210	16,840	17,250	17,230
Ni (ppb)	30.6	21.7	11.8	4.6	5.8	80	7.5	3	2.8	3.9	6.3	7.2
P (ppb)	1,758	1,378	1,336	308	378	3,224	771	134	199	299	756	847
Pb (ppb)	5,702	4,781	3,585	755	1,055	13,200	1,752	217	384	715	1,742	1,962
S (ppm)	27.2	26.9	26.8	26.7	26.6	27.1	27	26.6	26.9	26.2	26.8	26.4
Se (ppb)	0.2	0.2	0.2	0	0	0.1	0	0.2	0.1	0.2	0.1	0.1
Si (ppb)	10,530	7,660	3,636	2,830	3,573	26,740	2,680	2,258	2,422	2,687	2,661	2,826
Sn (ppb)	5.6	4.2	3.8	1.8	2	8.9	2.2	1	1.3	1.6	2.2	2.5
Sr (ppb)	129	128	129	125	125	131	128	125	125	125	127	127
Ti (ppb)	8.2	6.1	6.2	1.1	2.2	16.9	3.7	0.5	0.8	1.3	3	3.1
U (ppb)	2.7	2	1.6	0.5	0.6	5.6	0.9	0.3	0.4	0.5	0.9	1
V (ppb)	24.3	19.8	16.3	6.8	8.3	51.3	10.2	6.5	7.8	8	10.9	11.7
Zn (ppb)	2,520	1,622	1,305	593	796	3,652	752	293	395	603	739	856

Correlation between lead, phosphorus and aluminum

The correlation of lead and phosphate, as well as lead and aluminum, indicate that the samples were captured scale and sediment that had formed inside the pipes while the City of Flint was purchasing water from Detroit. The absence of these chemicals in the current treatment provided by Flint indicate that these elements were not in the water passing through the pipes, but came from the scales inside the service line which had disintegrated into the water or were dislodged into the water.

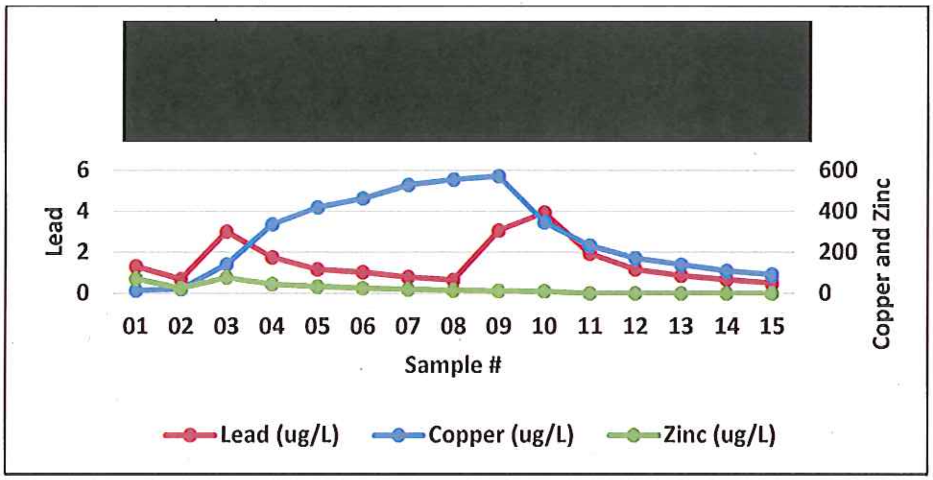




U.S. EPA Region 5 sampling

[redacted] residence (following replacement of service line)

Following the replacement of the [redacted] original service line, a series of 15 sequential samples were collected from the kitchen tap to measure the lead levels and other parameters to ensure that the high lead from the original service line had not contaminated the interior plumbing at the [redacted] home. With the exception of two areas, lead levels were low throughout the [redacted] plumbing following the service line replacement. The two sources of lead that were still detected in the plumbing are likely the water meter (Sample 3) and the new external service shut-off valve (Samples 9-11). Although new brass plumbing components must be lead-free, there can still be some lead that is released from these components.



[redacted]. ([redacted] home)

After Service Line Replacement

Sample #	Site Description	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Cadmium (mg/L)	Iron (mg/L)	Phosphorus (mg/L)
01	Kitchen	13.1	1.3	70.9	U	0.171	U
02	Kitchen	20.1	0.687	23.2	U	0.117	U
03	Kitchen	141	3.01	76.8	U	0.144	U
04	Kitchen	336	1.76	45.4	U	0.151	U
05	Kitchen	419	1.17	32.2	U	0.149	U
06	Kitchen	463	1.03	24.8	U	0.149	U
07	Kitchen	529	0.8	19.6	U	0.146	U
08	Kitchen	554	0.666	14.9	U	0.147	U
09	Kitchen	571	3.07	11.6	U	0.195	U
10	Kitchen	345	3.93	10.3	U	0.282	U
11	Kitchen	233	1.94	0	U	0.283	U

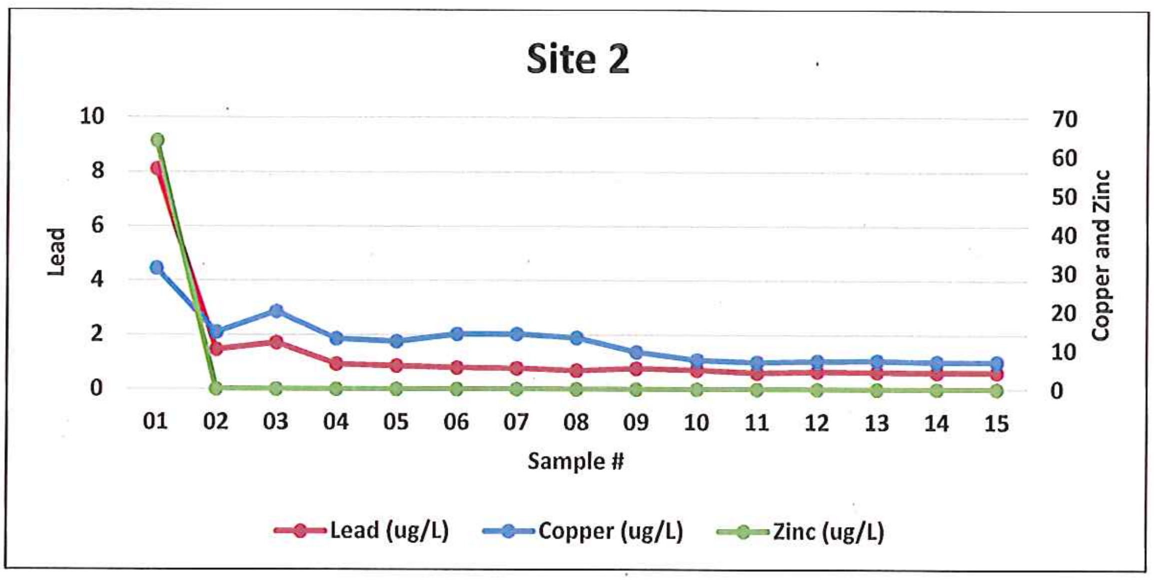
[redacted]. ([redacted] home)

After Service Line Replacement

Sample #	Site Description	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Cadmium (mg/L)	Iron (mg/L)	Phosphorus (mg/L)
12	Kitchen	171	1.17	0	U	0.290	U
13	Kitchen	139	0.864	0	U	0.292	U
14	Kitchen	110	0.67	0	U	0.294	U
15	Kitchen	91.5	0.505	0	U	0.297	U
16	Bathroom	29.7	5.52	71.3	U	0.259	U
17	Water Heater	70.4	31.7	883	U	0.540	0.0877
18	Water Heater	35	9.74	346	U	0.0870	U

<u>Site #2 (Bryant Street)</u>

Based on the results found at this home, it does not appear that any portion of the service line is made of lead, and as a result, the lead levels are low in most samples. The exception is in Sample 1 which reflects water within approximately 15 feet of the kitchen tap and is likely due to brass components in the faucet, underlying valves and fixtures.



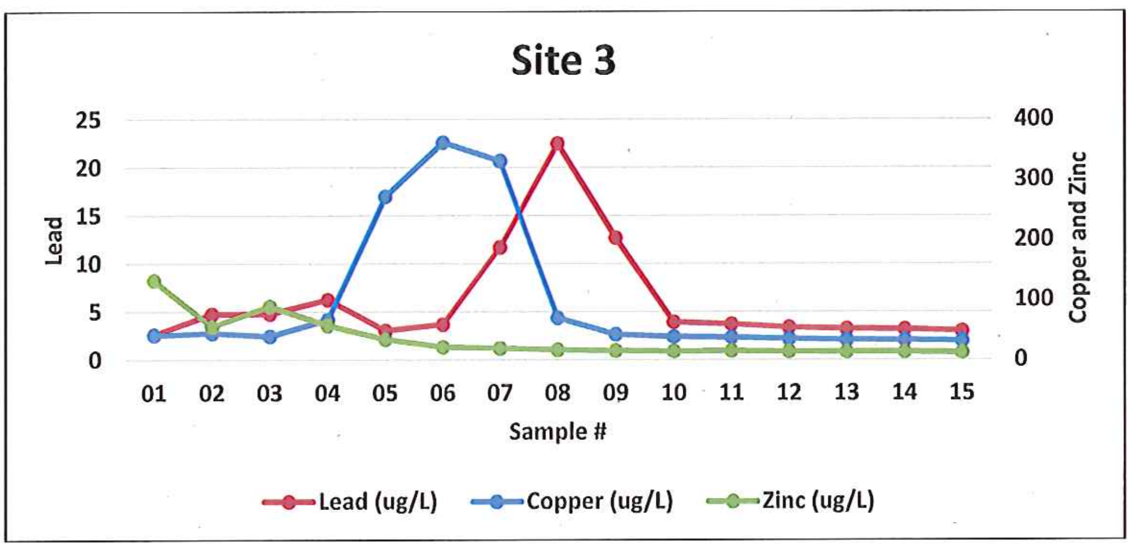
Site 2

(Note: U for Zinc replaced with 0 to show on graph)

Sample #	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Cadmium (mg/L)	Iron (mg/L)	Phosphorus (mg/L)
01	31.1	8.11	64	U	0.0307	U
02	14.7	1.46	U	U	0.0302	U
03	20	1.72	U	U	0.0302	U
04	13	0.933	U	U	0.0301	U
05	12.3	0.862	U	U	0.0311	U
06	14.2	0.795	U	U	0.0298	U
07	14.2	0.769	U	U	0.0311	U
08	13.3	0.691	U	U	0.0317	U
09	9.6	0.774	U	U	0.0319	U
10	7.57	0.715	U	U	0.0313	U
11	7.04	0.611	U	U	0.0301	U
12	7.3	0.655	U	U	0.0336	U
13	7.37	0.644	U	U	0.0308	U
14	7.09	0.631	U	U	0.0313	U
15	7.05	0.621	U	U	0.0300	U

Site #3 (Bryant Street)

Based on the results found at this home, it appears that the portion of the service line from the external service shut-off valve to the water main is made of lead as indicated by the increase in lead levels in samples 7 through 9.



Site 3

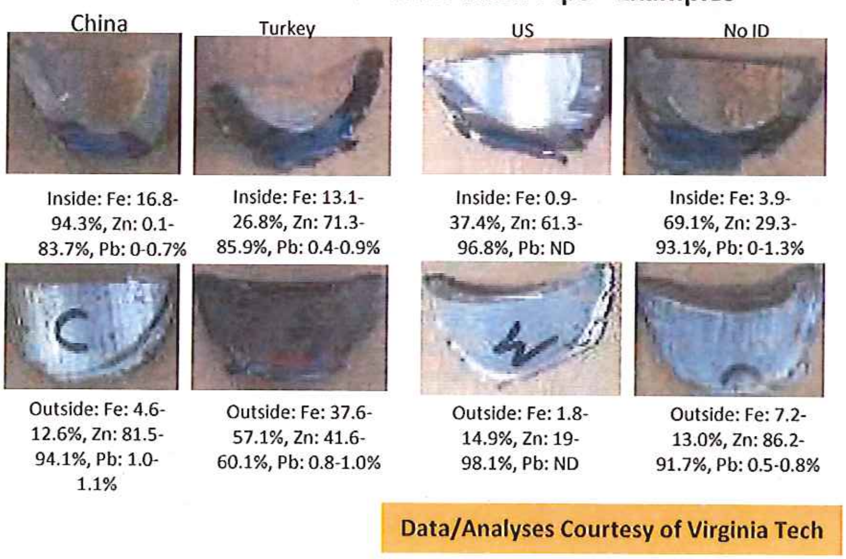
Sample #	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Cadmium (mg/L)	Iron (mg/L)	Phosphorus (mg/L)
01	40.7	2.63	132	U	0.0622	U
02	44.4	4.77	55.3	U	0.249	U
03	39.3	4.79	88.8	U	0.179	U
04	66.8	6.26	57.2	U	0.346	U
05	272	3.07	34.2	U	0.105	U
06	362	3.7	21.4	U	0.0598	U
07	331	11.7	19.5	U	0.0512	U
08	69.9	22.5	16.6	U	0.0399	U
09	42.5	12.7	15.1	U	0.0480	U
10	38.4	3.94	14.4	U	0.0489	U
11	37.5	3.72	14.5	U	0.0492	U
12	34.8	3.39	13.6	U	0.0481	U
13	33.1	3.23	13.1	U	0.0484	U
14	32.8	3.2	13	U	0.0480	U
15	31.4	3	12.3	U	0.0490	U

Analysis of [redacted] original service line pipe (galvanized iron portions)

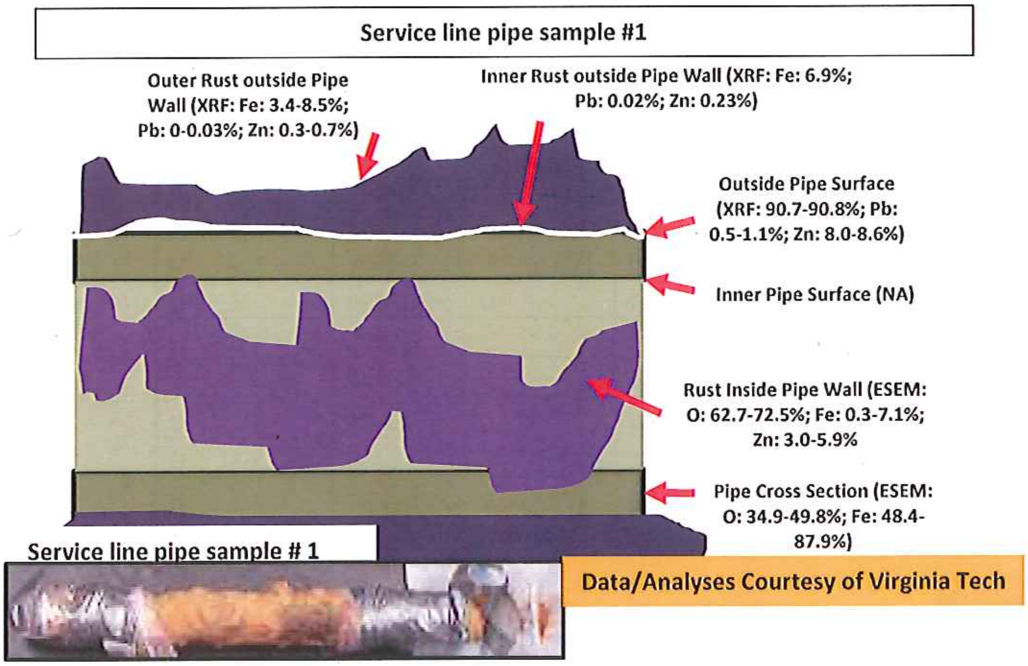
Lead can also be found in galvanized pipe coatings as a contaminant in the zinc that is used to coat the surface of iron pipe in the galvanizing process. As such, two sections of the [redacted] original service line were analyzed for lead content.

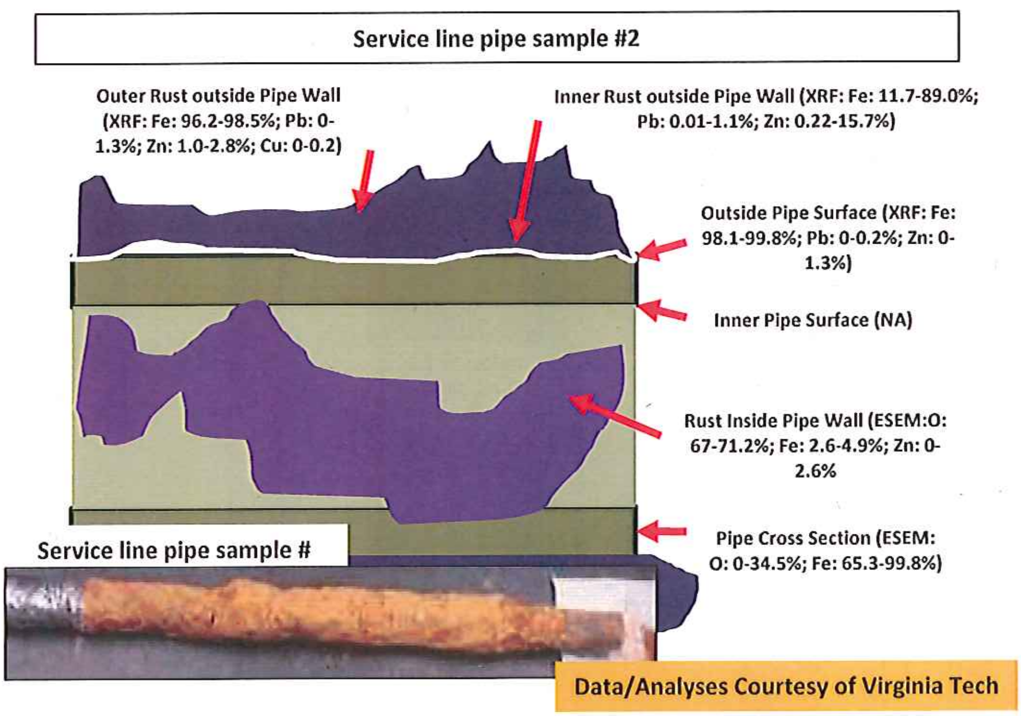
The images and data presented below are for a typical range of galvanized iron pipe.

Lead Content of Galvanized Iron Pipe - Examples



Below are the results of the galvanized pipe analyses conducted by Virginia Tech on the two sections of galvanized iron pipe from the [redacted] original service line. The analyses indicate that the [redacted] original service line was a typical galvanized iron pipe.





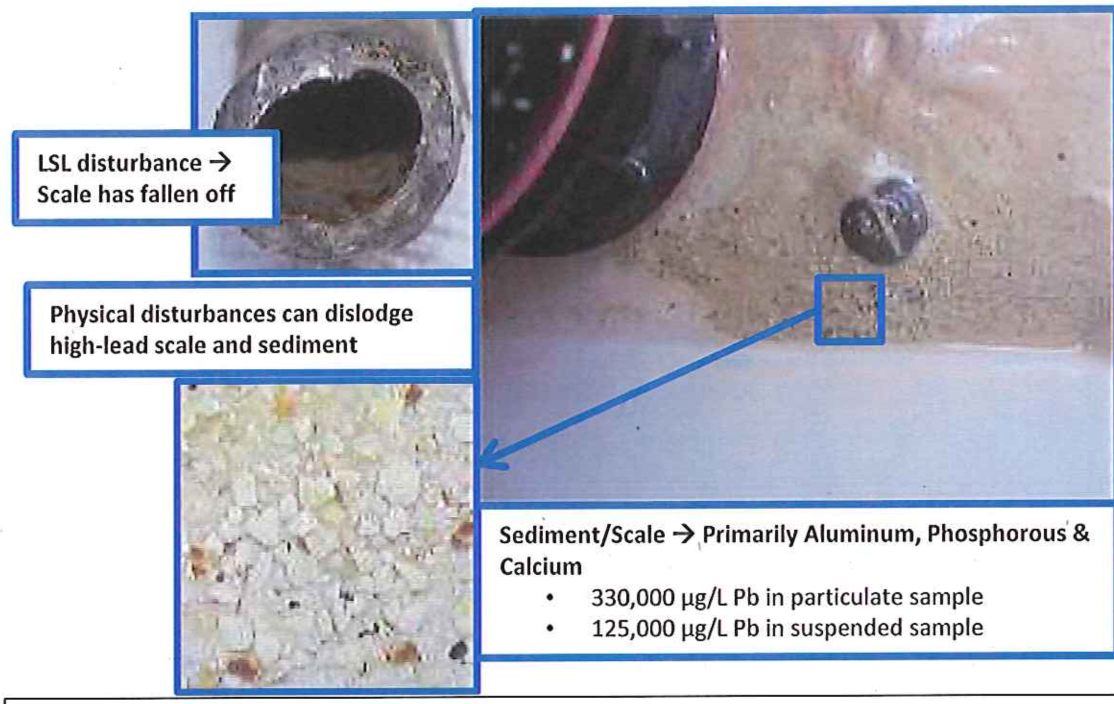
Lead portion of the [redacted] original service line

Lead service lines can contribute up to 75 percent of the total mass release into the water. The portion of the [redacted] original service line from the water main to the external shut-off valve at the corner of [redacted] and Bryant Street is made of lead and is estimated to be approximately 25 feet in length.

Appendix C – Additional Information

Physical disturbance of lead service lines

A recent EPA study indicates that physical disturbances to lead service lines or in proximity to lead service lines can cause the dislodging of the protective scales from within the lines. The photograph below shows the scale that was dislodged from inside a lead service line during routine maintenance work in another city due to a physical disturbance of the line. The dislodged scale and sediment contained a very high concentration of lead.



Lead service line disturbances were found to be a common factor for the majority of sites with high lead levels. It is also possible that low water usage may play a role in sites with the highest lead levels.

Lead service line scale analyses conducted by EPA's Office of Research and Development or obtained from peer-reviewed published literature from cities across the U.S. and in Canada (summarized below) show that scales within lead service lines can contain very high concentrations of lead. The yellow highlighted column in the table below shows the percentage of lead that has been found within different scales inside of lead service lines.

Lead & Element Percentages in Important Corrosion Byproduct Solids							
Mineral Name	Formula	% Pb	%C	%O	%S	% P	%Cl
litharge, massicot	PbO	97.80	0.00	7.20	0.00	0.00	
plattnerite, scrutinyite	PbO_2	86.60	0.00	13.40	0.00	0.00	
Cerussite	$PbCO_3$	77.50	4.50	18.00	0.00	0.00	
Hydrocerussite	$Pb_3(CO_3)_2(OH)_2$	80.10	3.10	16.50	0.00	0.00	0.00
Plumbonacrite	$Pb_{10}(CO_3)_6(OH)_6O$	81.30	2.80	15.70	0.00	0.00	0.00
Anglesite	$PbSO_4$	68.30	0.00	21.10	10.60	0.00	0.00

Lead & Element Percentages in Important Corrosion Byproduct Solids							
Mineral Name	**Formula**	**% Pb**	**%C**	**%O**	**%S**	**% P**	**%Cl**
Leadhillite, Susannite, MacPhersonite	$Pb_4(SO_4)(CO_3)_2(OH)_2$	76.80	2.20	17.80	3.00	0.00	0.00
Hydroxypyromorphite	$Pb_5(PO_4)_3OH$	77.43	0.00	15.55	0.00	6.95	0.00
Chloropyromorphite	$Pb_5(PO_4)_3Cl$	76.38	0.00	14.15	0.00	6.85	2.61
Tertiary Lead Orthophosphate	$Pb_3(PO_4)_2$	76.60	0.00	15.80	0.00	7.60	0.00
Lead(II) orthophosphate	$Pb_9(PO_4)_6$	76.60	0.00	15.80	0.00	7.60	0.00

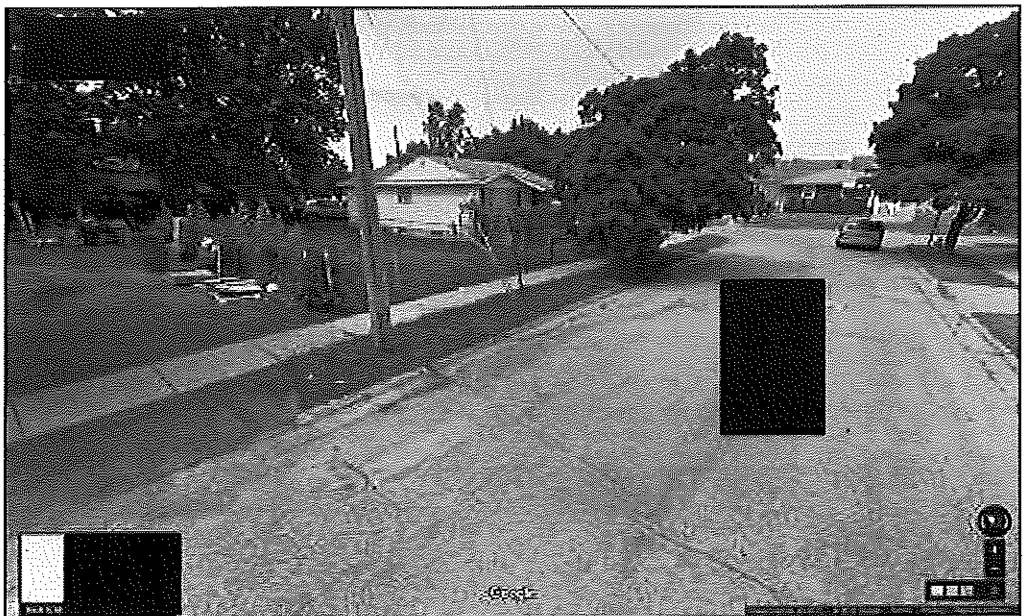
While visiting the [redacted] home, two fresh patches of asphalt were seen along the parkway where the [redacted] original service line was located. The jarring and vibration associated with excavation can dislodge the high lead-bearing scales from within the service line pipes.

Recent patch (#1) of asphalt along curb next to the parkway where the [redacted] service line runs.

Photograph taken by U.S. EPA on April 27, 2015

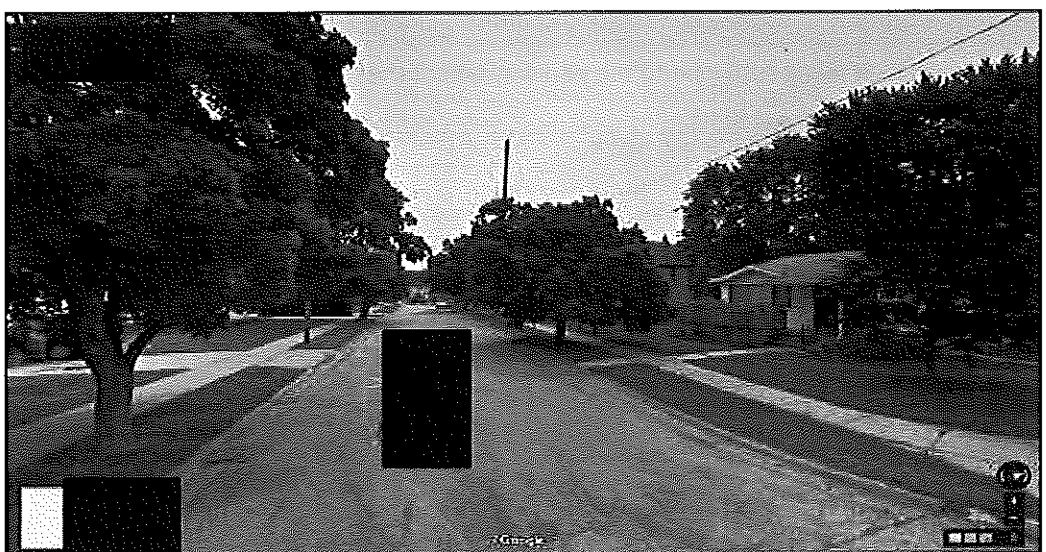
Recent patch (#2) of asphalt along curb next to the parkway where the [redacted] service line runs.

Photograph taken by U.S. EPA on April 27, 2015



July 2011 image [redacted] (view from [redacted] toward Bryant Street).

Google 'Street View' Image 1 captured in July 2011 shows no patches in street along curb next to the parkway where the [redacted] service line runs toward Bryant Street, indicating that the physical disturbances occurred after the date this image was captured (July 2011).



July 2011 image of [redacted] (view from Bryant Street toward [redacted]).

Google 'Street View' Image 2 captured in July 2011 shows no patches in street along curb next to the parkway where the [redacted] service line runs toward Bryant Street, indicating that the physical disturbances occurred after the date this image was captured (July 2011).

Corner of [redacted] and Bryant Street (location of [redacted] original external shut-off valve).

Photograph taken by EPA on April 27, 2015 shows no visible signs of physical disturbances in the vicinity of the lead portion of the [redacted] service line from the external shut-off valve to the water main on Bryant Street.