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My Private Lead Service Line Replacement

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3 Key Takeaways:

1. A homeowner's decision to replace their lead service line can be confounded by factors including their understanding of the science, their perceptions of their lead exposure risks, and the cost of the work.
2. First draw and 5-minute flush samples may not capture the peak lead concentration, further confounding a customer's replacement decision.
3. In my case, lead service line replacement significantly lowered lead concentrations after stagnation based on sequential sampling.

The science around lead service line (LSL) replacement and drinking water quality is important to water professionals, but they are also topics of concern, and often confusion, for private homeowners may have to weigh the documented risks of lead exposure in the context of their own lives (e.g. what is the age of the house? Are there pregnant women or children at home?) against potentially expensive, even cost prohibitive replacement options.

My unique position as both an environmental engineer, professor, and a homeowner with an LSL made me well aware of the documented risks of lead in the literature, but even with my informed perspective, I found the decision to replace was not so straightforward given the information from my local utility's free lead sampling program, weighing the replacement costs, and the other impacts the replacement might have on my property. So together with a colleague, one of my undergraduate students, and my husband (who is also an engineer by training and willing to go along with my experiment) we decided to capture a homeowner's decision-making process based on our scientific backgrounds and engineering judgement. Our experience may be helpful in communicating the potential benefits of a full lead service line replacement to homeowners who must start the process of replacing a private LSL.

LEAD AND MY HOME

Lead in drinking water originating from LSLs and other premise plumbing is a serious public health concern, particularly for its effects on the cognitive development of children. LSLs are the largest source of lead in drinking water when they are present in public systems. Most countries have banned the use of new lead pipes in drinking water distribution systems, but there are legacy lead pipes in many drinking water systems throughout the industrialized world including the US. Because lead is a toxic metal and harmful to humans, particularly pregnant women and children, at very low exposure levels, the maximum contaminant level goal set by the United States Environmental Protection Agency (USEPA) for lead in drinking water is zero.

USEPA sets action levels for lead and copper sampled at the consumer's tap after 6 hours stagnation, and if lead concentrations exceed 15 ppb or copper concentrations exceed 1.3 ppm in more than 10% of customer taps sampled, the system must take additional actions to control corrosion, e.g., additional water quality parameter monitoring, source water monitoring/treatment, corrosion control, and public education (USEPA, 1991). One action that a utility might take is to fully replace or partially replace lead service lines within their distribution network.

Replacing LSLs can be confounded by ownership differences across the length of pipe depending on local ordinances, right-of-ways, and property history. It is common for LSLs to have a portion under ownership of the water provider, often from the curb to the water meter, with the rest of the pipeline belonging to the homeowner. A full LSL replacement replaces the entire line, both public and private sections, from the utility-owned water main to the private residence. Full replacement is considered the best option since it completely removes any lead pipe that could contact the potable supply (assuming the household plumbing is lead free). However, replacing a service line is costly and requires homeowner consent and cooperation. In many cases, public water utilities pay to replace the public system's portion of the water distribution system while the homeowners choose to replace the private service line to their homes (i.e., full LSL replacement), or they may decide they cannot or won't, keeping some lead pipe in their plumbing network (i.e., partial LSL replacement).

My home is a 1920's American Foursquare (four bedroom, 1.5 bath – see Figure 1) located just outside of Providence, Rhode Island. The home had a partial lead line at the time I bought it in the Summer of 2017, and in my case, the utility owned public main under the street had also been recently replaced. The length of the LSL from the curb stop to the basement is approximately 40 ft. Taking the age of the home into consideration, interior plumbing appears to be a mixture of copper and possibly brass. It is likely that lead solder was used in some areas of the interior plumbing system, although this was not thoroughly examined or confirmed because of some of the premise plumbing is not immediately accessible.

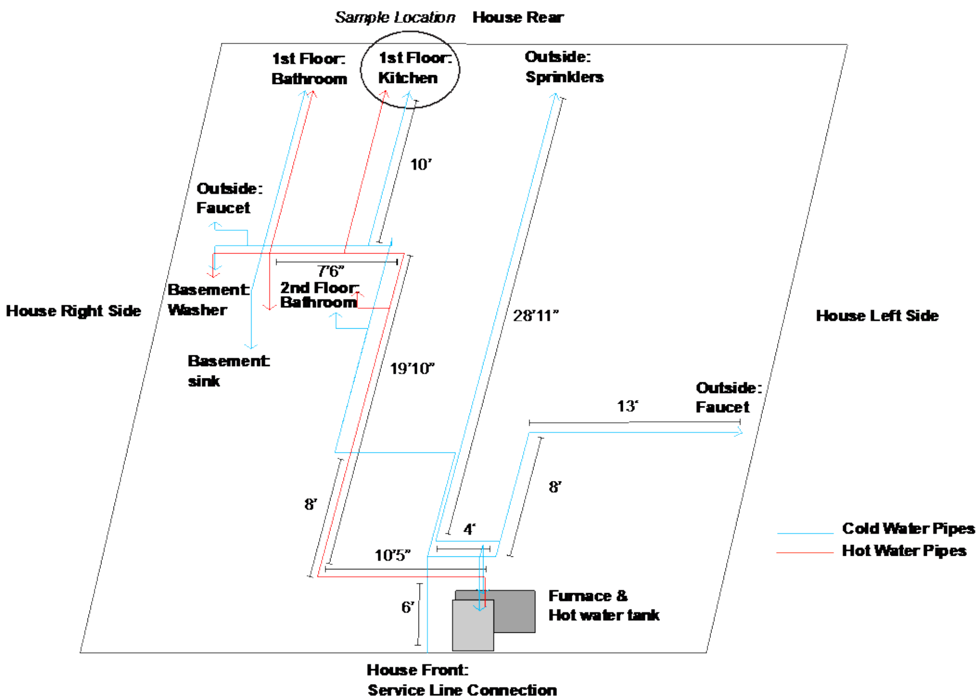

Figure 1: Home plumbing schematic

Our drinking water is provided by Providence Water (PW), which draws water from the Situate Reservoir in Rhode Island. The reservoir has low pH, alkalinity, and turbidity, and it has seasonal turnovers as typical for water bodies in the northeastern US. Raw water is treated conventionally with aeration, coagulation-flocculation, sedimentation, filtration, and disinfection. Additionally, the water receives fluoride as well as lime addition, and the pH is adjusted for corrosion control through the distribution system. A small portion of the PW system also receives orthophosphates as a pilot program for improved corrosion control.

PW has tracked recent elevated levels of lead in some homes and buildings within their distribution network that violate USEPA's Lead and Copper Rule. In 2018, PW's 90th percentile level was 22 ppb, which is above the lead action limit of 15 ppb. PW has responded by investing 45 million dollars to replace LSLs, and it has made changes to its treatment process to improve corrosion control including maintaining a high pH (~10) in the distribution system and piloting orthophosphate as a corrosion inhibitor.

PW is also increased rehabilitating water mains, improved flushing programs, and expanding public education about lead in drinking water. Besides mailing informational pamphlets, PW also provides a “lead service location map” on their website (www.provwater.com) where homeowners can identify if they currently have a utility-owned public lead service line. PW also offers lead testing kits free of charge to its customers; for those testing PW water in their homes, free kits are picked up and dropped off at their Providence office. If a homeowner has a privately owned lead service line, PW has incentivized replacement of the old line with a 0% interest 10-year loan program – this decreases the upfront expense of the replacement cost, roughly $3,500, as noted in flyers mailed to homeowner customers of PW in the spring of 2020.

APPROACHING THE DECISION AS A SCIENTIST AND HOMEOWNER

Even though I am well informed about the risks of lead exposure from LSLs from my professional experience, I found my questions as a homeowner, specifically the options and their costs, delayed my decision to replace the line. Together with my husband, we tried to assess the various ways we could be exposed to lead in our home. Typically, we only drank water from the refrigerator equipped with a filter (NSF 53 certified to remove lead), and we are both healthy adults. However, I was pregnant and that put me in the at-risk category, since lead bioaccumulates and can be transferred from the mother’s bones to the fetus, possibly affecting fetus brain development.

As parents-to-be, we were interested in minimizing exposure from the potential sources of lead in our home, such as lead-based paint, solder in plumbing, and fixtures. Lead solder from premise plumbing can contribute lead to water, and given the age of the house, we likely had this throughout our system. There is also lead paint inside and outside of the house, but a lead paint inspector encapsulated any chipping lead paint throughout, so we considered the risk of lead exposure via paint to be low after these minor fixes were made.

Our second consideration was the cost to replace our LSL, i.e., could we afford it with other expenses? Should we get a loan? At the time of the replacement, Providence water was offering a 0% 3-year loan at the time to replace the private side of the LSL. The utility now offers a 10-year 0% interest loan. How does the cost of replacement compare to purchasing filters and only drinking filtered water? We estimated based on the cost of a typical (Brita) filter, average household water consumption, and the life of a filter that after 20 years the cumulative cost of the filter would be greater than the LSL replacement, assuming the LSL replacement is $5,000.

When we asked a realtor about whether or not this investment would increase the value of our home, he thought that it might, but it certainly would not decrease the value. Therefore, if we just considered the costs of the replacement, replacing the LSL would makes sense if we planned on being in our home for a long time (20 years) but using a Brita type filter if we planned on only living there for a few years. Of course, committing to using a filter for drinking water would require that we remember to keep up with filter replacements in order to effectively remove the lead from the water.

Our other considerations were mostly cosmetic concerns, but they are valid issues to keep in mind as they will likely be important to most homeowners. The sidewalk in front of the house by the curbstop would be excavated and would need to be replaced at our expense by a contractor. Our lawn would need to be excavated (much to my husband's disappointment), and we were told that excavation could increase up to our porch if the line could not be pulled out of the soil from a distance. If they needed to excavate under the porch then it would require further work by a contractor to fix at our expense. The sprinkler system would also need repairs after the replacement as the excavation would likely go through the sprinkler line.

As an engineer, I suspected that the greatest risk of exposure to lead was likely the service line to the home. Even though our home's premise plumbing likely has lead solder, I assumed that the 40 ft long LSL was the largest potential source of lead based on surface area exposure if water lay stagnant during periods of no use. The LSL also takes the most time to flush given its distance from the tap. Additionally, if water quality from the utility were to change and lead were inadvertently released from the LSL as a result of changing water conditions at the treatment plant, we would be at a greater risk. I decided that collecting some data on my current lead concentrations after periods of stagnation would increase my confidence in my hypothesis that the LSL posed a risk to lead exposure in our home. Additionally, Providence, RI, has prior violations of the LCR and so further collection of data from a typical older home in the area before and after a LSL replacement would make an interesting case study.

Many water utilities offer various forms of lead testing for their customers, some free and some at a cost. I followed the directions on the home test kit that I picked up for free from PW, then sampled from my kitchen sink after an 8-hour stagnation in two 0.5 L sample bottles. This scenario is inherently conservative since it mimics typical overnight minimal water use conditions and increases the opportunity for higher lead levels at the location where someone living in the home may consume water following the stagnation. No other water was running at the time of the sample collection. I collected a first draw sample and a 5-minute flush sample, which represented the water quality after approximately 17 L of water were flushed from the plumbing. The next day I returned the samples to PW and waited for the analysis.

The first sample collected from the first draw of 0.5 L of water from the faucet after stagnation contained 4.5 ppb of lead while the the sample collected after 5 minutes of flushing contained 3.1 ppb of lead. Both results were less than the lead action level, and if I didn't have some background on the science of lead, I might have thought that although I have a LSL, there was little risk from these low lead levels.

What if the results from my lead test were compared to sequential sampling of lead after stagnation – would I feel more confident making the decision to replace my LSL? I was able to determine how many liters of water to collect in order to draw water that has been stagnated in the service line based on measuring temperature changes in the water prior to the sampling effort. The hot water tank in my basement is directly next to the service line entrance to the basement. When I turn on the hot water after things have sat overnight, it takes approximately 4L of water running through the pipes before it becomes increasingly warmer, indicating water originating from the hot water tank had reached the tap (see Figure 2). Based on this information, I determined that 15 sequential samples from the kitchen faucet (two 250 mL and thirteen 1 L samples) were required to analyze for lead. I assumed samples prior to 4 L originated from the house plumbing and samples after 4 L originated from the lead service line outside the house.

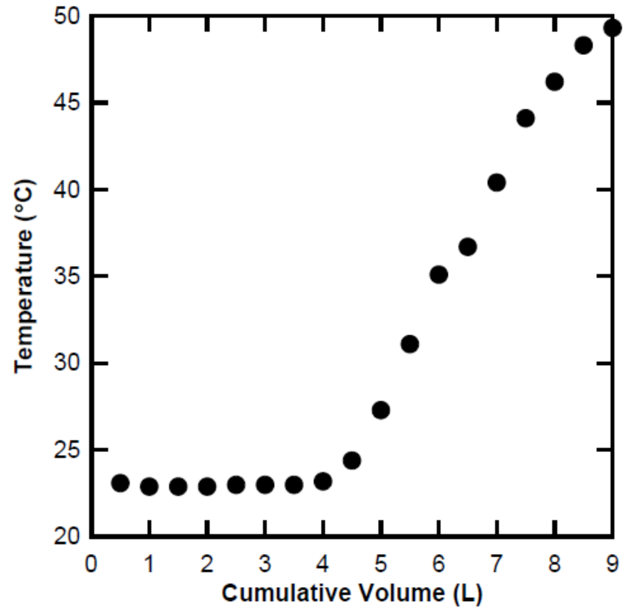

Figure 2: Preliminary Water Temperature Sampling

After an 8 hour stagnation period, sequential samples were collected and each were analyzed for temperature, conductivity, pH, and free chlorine by myself, with assistance by my colleague Joseph Goodwill (Assistant Professor of Civil and Environmental Engineering at the University of Rhode Island), and my undergraduate student, Ashley Bosse. It was a hot day in August when the samples were drawn and we noted a temperature change after 4 L of water were sampled, presumably when cooler water was withdrawn from the service line in the ground. Conductivity was within the expected range for treated surface water and it didn't change significantly with cumulative volume. Free chlorine increased with increasing cumulative volume collected, which is expected since chlorine residual decays as water ages. Finally, pH was also consistent with cumulative sampled volume; PW maintains a high pH (around 10) in the distribution system as part of its lead corrosion control strategy.

The samples were analyzed for lead, copper, and iron using ICP-MS. Average copper and iron concentrations were 1.68 ppb (standard deviation of 0.68 ppb) and 53.8 ppb (standard deviation of 2.5 ppb), respectively. The copper concentration was well below the action level of 1.3 ppm. In general, there was no significant change in copper or iron concentrations between sequential samples.

Lead concentrations averaged 11.8 ppb (standard deviation of 7.2 ppb) and a slug of higher lead concentrations were withdrawn from the faucet between 3.5 L and 7.5 L with a maximum concentration of approximately 30 ppb measured at the cumulative withdrawal volume of 5.5 L – note, this is twice the lead action level of 15 ppb. Based on when the water changed temperature, the spike in lead levels measured between these cumulative collected volumes is consistent with our previous estimate of water originating from pipes from outside the house after 4 L were drawn. After 7.5 L of water were drawn, the lead concentration decreased to approximately 9 ppb.

Based on the results of sequential sampling, I felt more confident in spending money to replace my lead service line. The data supported that the lead was coming from the service line, so replacing this service line should minimize the risk of exposure after stagnation periods and in the event there was an inadvertent change in finished water quality from the utility, like lower pH, that could easily result in more pipe corrosion and lead release.

THE REPLACEMENT

In August of 2018, a local contractor, in collaboration with PW and the city, replaced my LSL. Work was carried out over a course of one day following standard service line replacement protocols. After water service was shut off at the curb stop, the LSL was disconnected in the basement at the water meter, and two concrete pads of the sidewalk were excavated. An attempt was made to remove the LSL by pulling it out from the excavated sidewalk area; unfortunately, this didn't work, so approximately 20 ft the front lawn had to be excavated.

The LSL was 3/8 inches in diameter and replaced by a 1-inch type k copper pipe. Following replacement and reconnection, the excavation of the front lawn was backfilled. Water was flushed through all household plumbing by the contractor in accordance with replacement guidelines as follows. Outdoor spigots were opened completely and flushed for 15 minutes. Indoor fixtures (with aerators removed) were flushed with cold water beginning on the first floor and ending on the second floor for 30 minutes each.

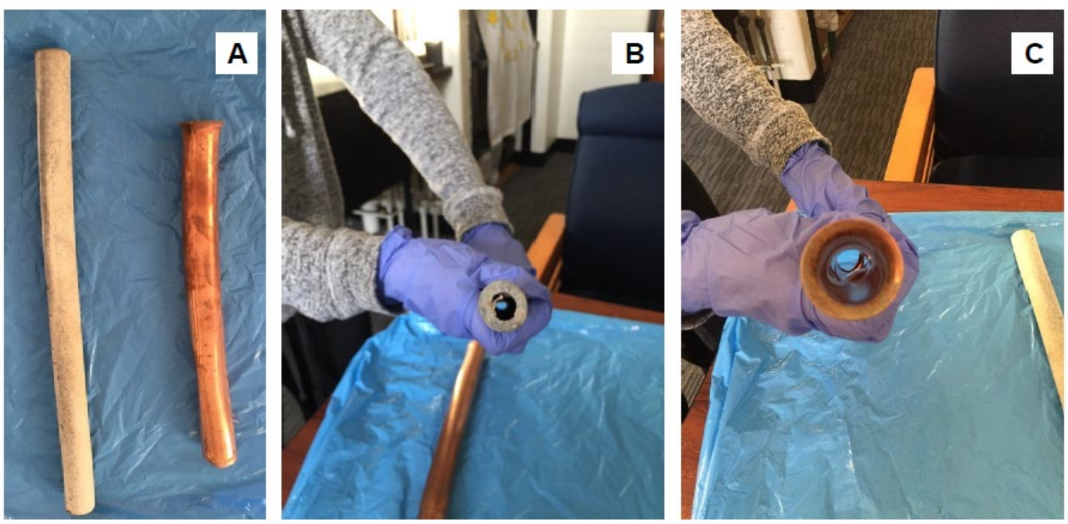

Figure 3: A comparison of old and new service lines (A); old lead line (B) and the new copper line (C)

Several months after the replacement, I collected more sequential samples after an 8-hour stagnation period from my kitchen sink tap as a comparison with pre-replacement water quality using the same sampling methods. No significant differences in temperature, pH, specific conductivity, or free chlorine before and after the replacement of the service line were found. Average iron and copper concentrations increased slightly after the replacement, as shown in

Figure 4. The average iron concentration was 60.2 ppb (standard deviation of 4.9 ppb) and the average copper concentration was 2.59 ppb (standard deviation of 1.67 ppb).

The most notable difference in metals concentrations were the lead concentrations before and after service line replacement (Figure 4). After replacement, the average lead concentration was 1.8 ppb (standard deviation of 0.3 ppb), which was over 6.5 times smaller than the pre-replacement average of 11.8 ppb, and well below the action level. Concentrations of lead also did not significantly change with sequential samples. With these results in hand, I felt good with the decision to replace my LSL.

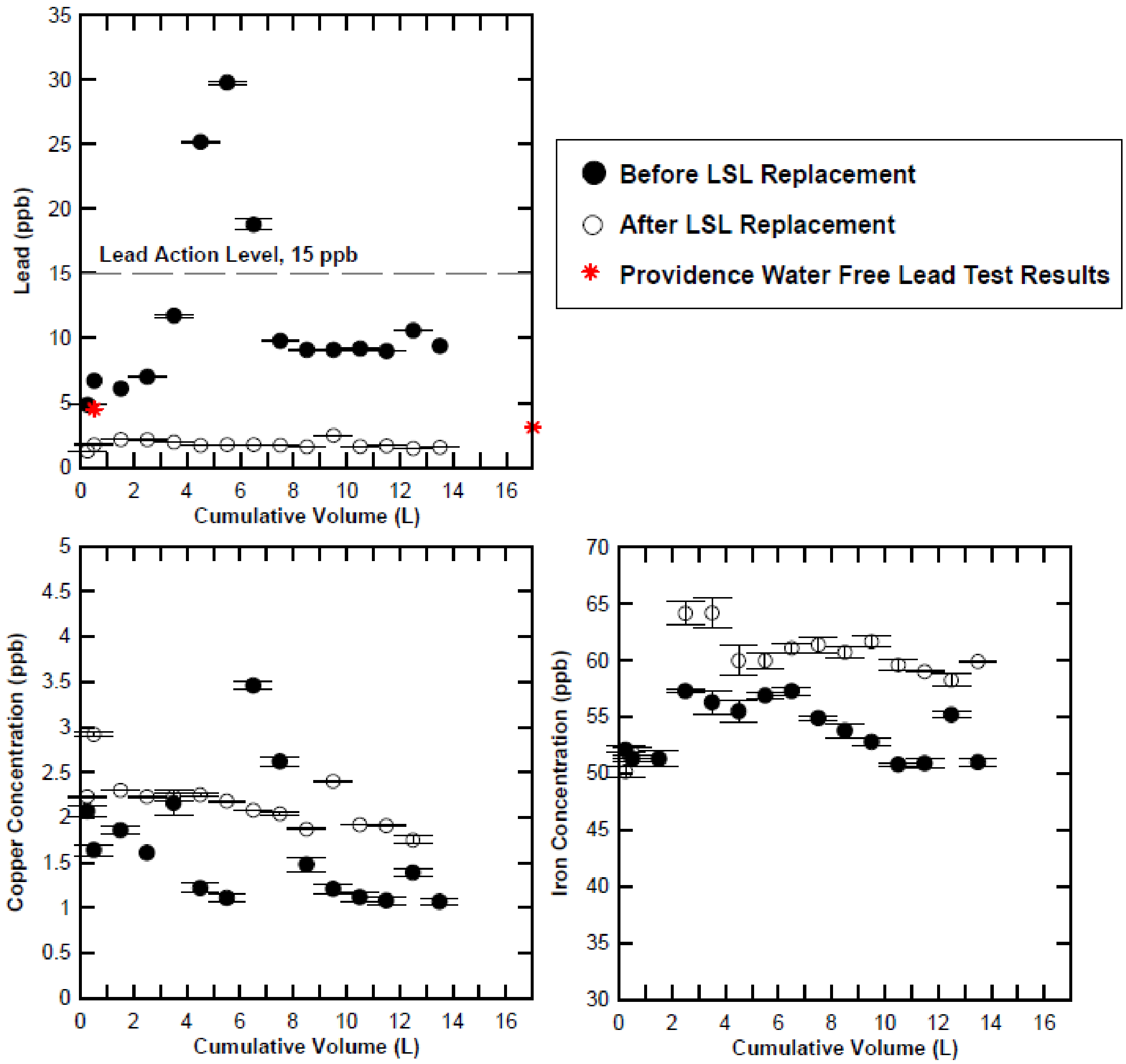

Figure 4: Metal concentrations before and after LSL replacement

WHAT I LEARNED

A homeowner's decision to replace their lead service line can be confounded by many factors, including an understanding of the science of lead in drinking water, the relative importance of different exposure risks to lead in the home, the physical replacement procedure, and the costs. I made my decision to replace my LSL from a uniquely informed perspective, however, most customers don’t have this advantage or investigative resources. I hope that my experience helps utilities better relate to homeowners and communicate information they find helpful.

Over the last several years, PW has increased outreach on LSL replacements, yet many of my neighbors have chosen not to have theirs replaced. This is evident on the PW lead service online LSL locator, where of the 35 houses on my street, most built before 1940, only 9 have “suspected of confirmed non-lead or other material”, indicating they have likely replaced their original LSL. The other houses in my area have “suspected or confirmed lead” according to the public records available online. This highlights the need for more and better communication by utilities to homeowners about the risks of lead exposure and any financial incentives they offer to ease the financial burden of replacement.

Although free lead tests are offered by the PW to homeowners, these can underestimate lead exposure from drinking water based on the results of my own case study. The lead concentrations in Figure 4 clearly illustrate this, where the red asterisks represent the test kit samples below the lead action level. Risk of lead exposure can be masked depending on the sampling procedure if the elapsed volume at the time of the sample does not contain high concentrations of lead. This result may be confusing and misleading to customers who are trying to assess the risks of lead exposure from their water and do not understand why concentrations may vary.

Withdrawing sequential volumes of samples from the faucet in this case fully captured the water quality changes at the faucet after stagnation, helping to characterize the exposure patterns of peak lead levels. It was evident from our sequential sampling approach that the highest concentrations of lead occurred between 3 and 7 L of sequential volumes for this particular home.

Before my LSL was replaced, lead concentrations exceeded the lead action level of 15 ppb, which, while not a violation, represents higher lead exposure risk. Sample methods that include only first draw and 5 minute flush samples (approximately 17 L of cumulative volumes for this home) did not capture the spike of lead at the faucet and therefore did not indicate an exposure risk. This sampling method could allow a utility to meet SDWA requirements, even if consumers are exposed to periodic elevated lead levels once a day or more. However, comparing results from sequential sampling to the first draw and 5-minute flush method confirms that the utility's advice to consumers is useful, namely, that flushing water for 5 minutes decreases the risk of lead exposure (Providence Water). However, it falls to the consumer to remember the 5-minute flush protocol after stagnation, which can be hard to remember and/or cumbersome for some consumers or difficult to follow for small children.

My story highlights the water quality benefits of complete LSL replacements to homes where legacy LSLs have already been partially replaced by the water utility. The most significant water quality benefit after the LSL replacement was the decrease in lead concentrations after a period of stagnation to a maximum concentration of only 1.8 ppb. Although there is still a small amount of lead in the drinking water in this home, likely due to lead solder in the original interior plumbing, the risk of higher lead concentrations occurring at my tap was greatly reduced by removing my LSL. I have peace of mind knowing that the lead levels at the taps in my house will be low, and I don't need to remember to flush out my plumbing after stagnation. I hope my example helps utilities better communicate with local homeowners about the risks of lead service lines and the benefits of replacing them.

ACKNOWLEDGEMENTS

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