DETECTING LEAD IN HOUSEHOLD TAP WATER: SAMPLING PROCEDURES FOR WATER UTILITIES

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Executive Summary

What is the purpose of this paper?

In this paper, we present recommendations for how water utilities should sample household tap water as part of a program to monitor the levels of lead in their customers' drinking water.

Who should read it?

This paper is directed at municipal water utilities, who can use it to inform their own sampling protocols; state environmental protection agencies, who can use it to establish statewide guidance; and individual water utility customers, who can advocate that their utility amend its sampling methods.

What kind of sampling do we address in this paper?

Different people may sample and test water from different places and for different purposes. For example, some samples are taken in private homes while others are taken in public buildings such as schools. The purpose may be for a utility to determine whether it is complying with the federal Lead and Copper Rule or it may be for the people in an individual household to identify the level of risk they face from their tap water. This paper focuses primarily on sampling carried out by utilities in private homes for purposes of Lead and Copper Rule (LCR) compliance.

What do we recommend?

The paper's main recommendations are that water utilities should:

- ***Ensure that sampling sites genuinely represent at-risk homes:*** Water utilities should constantly reevaluate their sampling site selections to ensure that those homes do in fact contain lead pipes, lead solder, or a lead service line. If a water utility determines that one of its sampling sites does not have any lead plumbing, it should select another sampling site that comports with the requirements of the Lead and Copper Rule. Two ways to facilitate such substitutions are to identify as large a pool of eligible homes as possible and to ask customers to report any changes to their plumbing on sampling instruction forms.
- ***Determine the best time of year for sampling:*** Water utilities on a regular monitoring schedule should analyze data from their past samples to determine how the lead level in their customers' water fluctuates according to temperature. They should use these data to

determine the best time of the year to collect their samples. However, if after analyzing the data from its own past samples, a water utility on a regular monitoring schedule is still unsure about which time of the year is best to conduct sampling, it should default to sampling during warmer months.

- ***Collect additional samples:*** The Lead and Copper Rule requires that utilities collect only a relatively small number of samples. For example, for a city of more than 100,000, the utility must collect only 100 samples per testing period if on standard monitoring and 50 if on reduced monitoring. Such a small sample size might miss serious problems, especially if the most at-risk homes are not in the sampling pool. If a water utility would like to be more confident that it is detecting any elevated levels of lead that are present in its customers' water, it should collect and test additional samples, beyond the minimum number required by the Lead and Copper Rule.

- ***Institute a minimum nine-hour stagnation period:*** When water sits in a lead service line for long periods of time, more lead can leach into the water. To better reflect the highest level of lead to which residents will be exposed after sleeping or a day at work, water utilities should instruct residents to not to run their water for nine hours before collecting samples.

- ***Clarify that stagnation means no water use in entire house:*** It has been reported that residents are sometimes unsure about whether the stagnation period applies to the entire house or only to the tap from which samples are being taken. Water utilities should ensure that their sampling instructions make it as clear as possible that, during the stagnation period, no water can be used in the entire house.

- ***Instruct residents not to remove aerators:*** Lead sediment can build up in aerators attached to faucets, from which it can then be released into the water. Water utilities should specifically instruct residents not to remove aerators from their taps before collecting samples.

- ***Instruct residents to use a high flow rate when collecting samples:*** More lead can be released into water when the water passes through the pipe at a faster rate. Water utilities should therefore instruct residents to run their water at a high rate of flow when they collect their samples.

- ***Collect sequential samples:*** Even though samples taken to comply with the Lead and Copper Rule must be first-draw samples, water utilities are free to collect additional samples that do not rely on first-draw procedures. Because the timing of peak lead levels can vary based on factors like the size of the home and the length of the lead service line, first-draw samples do not always reflect the highest level of lead to which a resident might be exposed.

Water utilities should therefore instruct residents to collect a series of sequential samples to ensure that they do not underestimate the risk of lead poisoning.

Will a resident be safe from lead in water if his or her utility follows these recommendations?

Unfortunately, no. The only way to completely eliminate the risk of consuming lead in water is to remove lead service lines, fixtures, and solder. Removing all of them is an immense task; it is estimated that 6 million homes in the United States have lead service lines. In the meantime, water utilities attempt to minimize lead exposure by adjusting the pH of their water and adding chemicals called corrosion inhibitors to their water to minimize the transfer of lead from pipes into the water. A primary purpose of LCR testing is to assess the effectiveness of this corrosion control treatment.

These recommendations are designed to ensure that a utility will have an accurate measure of the highest level of lead in drinking water to which its customers may be exposed in the course of the ordinary use of water. If more than 10% of the samples taken by a utility contain lead at a concentration of 15 parts per million (ppm) or greater, then that utility will be in violation of the Lead and Copper Rule and will need to take corrective actions, ultimately including the replacement of lead service lines. But a utility is in compliance with the Rule even if some homes have more than 15 ppm of lead in their water. Moreover, just because there is less than 15 ppm of lead in someone's water, does not necessarily mean it is safe. Although EPA has decided to use 15 ppm as a benchmark for determining which utilities will have to take corrective actions, the agency has concluded that no level of lead in water is safe. In the end, the only way to ensure that there is no danger from lead in drinking water is to remove lead service lines, lead fixtures, and lead solder.

Although replacing lead plumbing is the only way to fully eliminate the risk of lead poisoning, customers can still reduce their risk of exposure to lead by "flushing the lines" after the water has sat unused in the plumbing for several hours. To flush their lines, customers should run the water at a high rate of flow for three minutes before filling a glass of drinking water. Because more lead leaches into the water the longer it has sat stagnant in the plumbing, flushing the lines is especially important when the water in the house has not been used for several hours. Therefore, flushing the lines is particularly important after returning home from work and after first waking up in the morning.

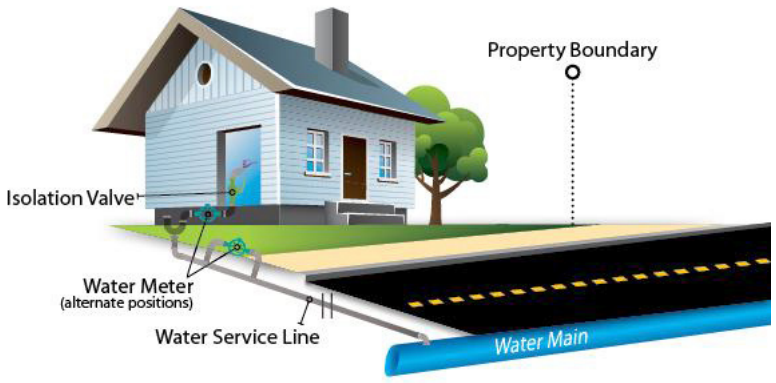
How did we develop these recommendations?

We spoke with stakeholders and reviewed the Lead and Copper Rule, EPA guidance, state guidance, the scientific literature, and published recommendations from groups such as the National Drinking Water Advisory Council.

INTRODUCTION

Recent events have brought much-needed attention to the dangers of lead in our country's water supply. Ingesting lead can cause very serious health risks, including decreased kidney function, increased blood pressure, and neurological damage. Infants and children are particularly vulnerable. Over the past decade, several cities across the country—most prominently Flint, Michigan—have experienced public health crises caused by unsafe levels of lead in drinking water. Because elevated levels of lead in drinking water can be so dangerous, it is important that sampling and testing protocols be implemented in a way that minimizes the chance that serious lead contamination goes undetected.

Under the federal Safe Drinking Water Act, water utilities must periodically collect and test water samples from some of their customers' homes to determine how much lead is in the water. Sampling must be carried out in homes rather than at the water treatment plant because the primary source of lead in drinking water is the lead service lines that connect individual homes to the water mains. The rules governing these tests are set forth in the Lead and Copper Rule ("LCR"), a regulation promulgated by the U.S. Environmental Protection Agency ("EPA").[1] The samples are often collected by a water utility's customers and then delivered to the utility to complete the laboratory analysis.



Source: Massachusetts Water Resource Authority (MWRA), What You Need to Know About Lead in Tap Water, available at http://www.mwra.com/04water/html/qual6leadinfo.htm#leadservicelines.

These tests are crucial in protecting residents from lead poisoning. Depending on when and how the samples are collected, the concentrations of lead measured in the water can vary significantly. For example, the time of year during which samples are collected, the temperature of the water, the length of time the water has remained in the lead service line before the sample is taken, and the rate of flow of water through the tap all can have significant impacts on the levels of lead detected in the water.

According to EPA, the tests are supposed to assess the so-called "worst case" scenario, the highest level of lead to which a resident may be exposed during routine household use.[2] By mandating the collection of samples that reflect the worst case scenario, the Lead and Copper Rule increases the likelihood that water utilities are alerted to the presence of dangerous concentrations of lead if they exist.

Unfortunately, the Lead and Copper Rule is not perfect and it sometimes allows the use of sampling procedures that might not detect dangerous levels of lead. In recent years, most notably in Flint, Michigan, it has come to light that some water utilities have collected water samples in ways that are inconsistent with the Lead and Copper Rule or with the worst case scenario philosophy underlying it.[3]

Water utilities should therefore think carefully about which sampling procedures are most likely to produce accurate samples that correctly reflect the true level of lead in their customers' water. State environmental agencies should also carefully consider which sampling procedures are likely to be most effective. These agencies can assist water utilities in many ways, including by issuing guidance documents to instruct water utilities on how to carry out water sampling. These documents are very important resources for water utilities to draw upon when designing their methods. By working together to implement the best sampling procedures, water utilities and state agencies can reduce the risk of lead poisoning.

This paper is intended to help water utilities and state agencies choose the sampling procedures that are most likely to protect residents against lead poisoning as utilities carry out their LCR-mandated testing. Based on a review of the Lead and Copper Rule, EPA guidance, state guidance, the scientific literature, and published recommendations from groups such as the National Drinking Water Advisory Council, as well as conversations with stakeholders, we recommend best practices for sampling protocols to best ensure the safety of a water utility's customers. The recommendations incorporate guidance from the Massachusetts Department of Environmental Protection ("MassDEP") and are therefore targeted at Massachusetts water utilities in the first instance. For the most part, however, the recommendations are equally applicable to water utilities in other states. **Our recommendations are directed only towards the sampling of residential homes. Other sampling procedures may be more appropriate for other sites such as schools or hospitals.**

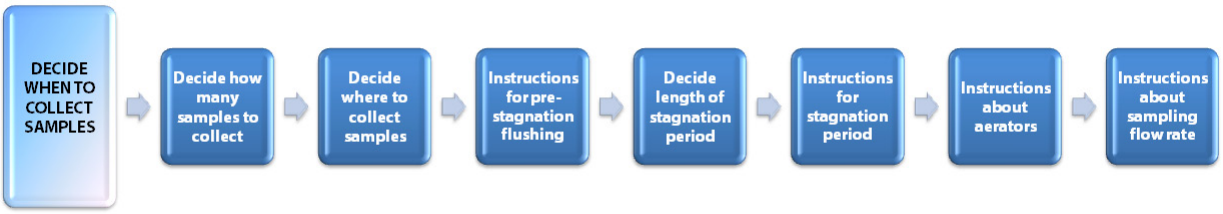
This paper is divided into two main sections. The first section addresses elements of a sampling protocol for which water utilities are free to adopt our recommendations for the samples that they collect for Lead and Copper Rule compliance purposes. The second section addresses areas in which water utilities cannot adopt different sampling procedures for purposes of LCR compliance, although they are free to adopt these practices for samples taken for other purposes.

For each topic, we first explain what is required under the Lead and Copper Rule and what flexibility, if any, the LCR leaves for water utilities; then describe MassDEP's guidance on the topic; and finish by identifying the best practices available to water utilities for addressing that element of water sampling. In determining what counted as best practices, we were guided by the "worst case scenario" philosophy behind the Lead and Copper Rule. Thus, we selected the sampling methodology that was most likely to detect the highest levels of lead to which a resident could expect to be exposed through ordinary use of the water.

PART I: TOPICS ON WHICH WATER UTILITIES MAY ADOPT OUR RECOMMENDATIONS FOR PURPOSES OF LCR SAMPLING

We list our recommendations below according to a sequence following a rough flow chart of the decisions a utility must make in designing and carrying out a sampling program.

A. At what time of the year should utilities collect samples?



When developing a sampling protocol, water utilities must first decide when to collect the samples. This decision can have important implications for the sampling results because temperature can affect the rate at which lead in service lines or fixtures leaches into the water.

LCR Requirements. The Lead and Copper Rule provides that water utilities on a "standard monitoring" schedule must collect their samples during two six-month monitoring periods in each year. The first occurs between January and June, the second between July and December. Water utilities on a "reduced monitoring" schedule, which requires them to sample "annually or less frequently," are required to "conduct the lead and copper tap sampling during the months of June, July, August, or September" (except under special circumstances in which the state approves a different sampling period).[4]

What flexibility do water utilities have in addressing this issue? Because each of their monitoring periods lasts a full six months, water utilities on a standard monitoring schedule have a good deal of flexibility regarding the time of the year in which to collect samples. Although water utilities on a reduced monitoring schedule have considerably less flexibility, they still have discretion about when to collect samples within a four-month period. Moreover, reduced monitoring systems may be given more flexibility if their state's primacy agency permits them to deviate from the usual summer sampling schedule.

Massachusetts Guidance. MassDEP has reiterated the LCR requirements precisely, mandating a six-month period for water utilities on a standard monitoring schedule, while requiring that water utilities sampling "annually or less frequently" must collect their samples during the summer

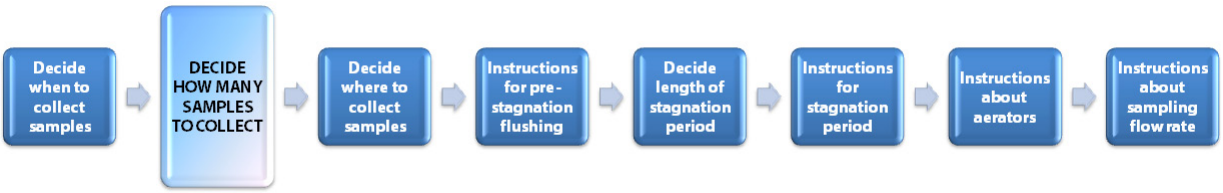
months.[5] For a reduced monitoring water utility to deviate from the summer sampling requirement, its alternative sampling plan must be "approved in writing by MassDEP."[6] MassDEP has not released any formal guidance adding additional requirements, although it does work with some water systems on an individual basis to encourage them to conduct their sampling during specific months within the broader monitoring period described in the LCR.

Best Practices. The conventional view is that more lead leaches into the water when temperatures are higher.[7] EPA implicitly supports this view when requiring reduced-monitoring systems to sample during the summer (to fulfill the "worst case" sampling philosophy) and when recommending that only cold water be used for cooking or drinking (to reduce lead exposure).[8]

Recent research, however, has complicated the picture. For example, one important study found that "in some cases, higher temperatures do not invariably increase lead in the water," suggesting that the mechanisms governing "particulate-lead release may be different than for soluble lead release."[9] This means that the same temperature may not have an identical effect on different water systems. Additionally, some research suggests that orthophosphate (a chemical used for corrosion control treatment) "reacts more quickly at higher temperatures, so reduction in lead levels" due to corrosion control "may take longer in colder months than in warmer months."[10] Despite these recent complications, it remains clear that many (though not all) water systems experience higher levels of lead during the summer months.

Given this uncertainty, EPA has recommended that water utilities on a regular monitoring schedule "collect water quality and lead . . . data throughout the year to determine their own trends."[11] This is the best approach. However, if after analyzing the data from its own past samples, a water utility on a regular monitoring schedule is still unsure about which time of the year is best to conduct sampling, it should default to sampling during warmer months. Similarly, MassDEP should encourage water utilities on regular monitoring schedules to collect their samples throughout the year to determine their own seasonal trends. However, if those trends are unclear, MassDEP should encourage the water utility to sample during the summer.

B. How many homes should be sampled?



Once a water utility determines when to conduct its sampling, it must then decide how many samples to collect. This is an important decision; because most lead leaches into a customer's water from the home's individual service line,[12] the lead levels found in one home's sample are not necessarily representative of lead levels in another home's water. As a result, the more homes a utility samples, the more confident it can be that the water in all of its customers' homes is safe.

LCR Requirements. The number of homes that must be sampled under the Lead and Copper Rule is determined by the size of the water system. Section 141.86(c) includes the following table:

System size (number of people served)	Number of sites (standard monitoring)	Number of sites (reduced monitoring)
>100,000	100	50
10,001 to 100,000	60	30
3,301 to 10,000	40	20
501 to 3,300	20	10
101 to 500	10	5
≤100	5	5

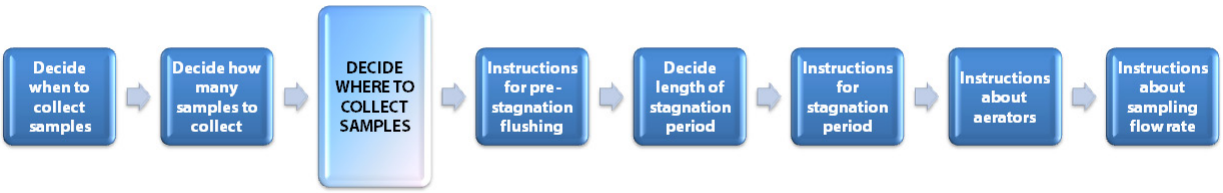
What flexibility do water utilities have in addressing this issue? The table only reflects the minimum number of samples that must be collected. The Lead and Copper Rule explicitly permits water systems to collect additional samples (but prohibits them from discarding the additional samples once they have been collected).[13]

Massachusetts Guidance. In a recent guidance document, MassDEP "strongly recommends that water utilities identify alternate LCR sampling sites," going on to suggest that "a good practice is to identify at least 50% more alternate sampling sites than the required number of primary sites."[14] However, MassDEP does not advise water utilities to actually sample more than the minimum number of sites required by the Lead and Copper Rule.

Best Practices. Most of the other topics in this paper lend themselves to a "best practices" analysis that can be guided primarily by scientific evidence. The number of homes to sample is different. It is primarily a policy decision. More samples are more likely to detect lead if it is there. The decision comes down to how much risk a water utility or a state is willing to tolerate.

It is important to note, additionally, that errors made in identifying homes at high risk for lead are more likely to skew the sampling results if the number of homes sampled is relatively small.[15] If a water utility would like to be more confident that it is detecting any lead that is present within its customers' water, it should collect and test additional samples, beyond the minimum number required by the LCR. MassDEP should encourage water utilities to conduct—and provide funding for—additional sampling.

C. How should water utilities select which houses to sample?



A water utility's service area will typically include a mixture of some newer homes that have no lead service lines or fixtures as well as older homes with lead service lines and/or lead plumbing fixtures or solder. Homes with no lead service lines or fixtures are obviously not at risk of lead poisoning. Taking samples from such homes will not provide information about the effectiveness of a utility's corrosion control treatment and will artificially lower the average lead levels detected. It therefore does not make sense to take samples from such homes. As a result, it is very important for water utilities to carefully select homes that are likely to have lead plumbing.

LCR Requirements. The Lead and Copper Rule outlines a two-step approach for determining which homes to sample. First, the water utility needs to complete a "materials evaluation" in which it reviews a series of records to identify houses that have lead service lines.[16] To make this determination, it is supposed to begin by reviewing the information gathered by the water utility itself, pursuant to 40 C.F.R. § 141.42(d) (which requires water utilities to gather information on whether their distribution systems include lead, copper, galvanized piping, cast iron, steel, or asbestos cement pipes). If (and only if) the information gathered by the Section 141.42(d) records proves insufficient to identify the requisite number of sampling sites, the water utility is supposed to review the following information to identify additional sites: plumbing codes and permit records, distribution system inspection records, and the results of any past analyses of water quality.[17]

Second, once the materials evaluation has been completed, the water utility is supposed to identify houses that either (a) contain lead pipes, and/or (b) contain copper pipes with lead solder installed after 1982, and/or (c) are served by a lead service line.[18] If a water system contains lead service lines, half of its samples must be from sites with lead service lines and half of its samples must be from sites that contain lead pipes (or copper pipes with lead solder)."[19]

Does this procedure allow flexibility for public water systems? Yes. As a general rule, the LCR requires a water utility to "collect each first-draw tap sample from the same sampling site from which it collected a previous sample."[20] In other words, water utilities are instructed to continue taking samples from the same sites that they sampled in the previous monitoring period, if possible. If a resident who participates in the sampling during one monitoring period refuses to allow his or her water to be resampled during the next one, then the utility must select an alternative sampling site that meets all the normal criteria for choosing sampling sites (described above) and in addition is "within reasonable proximity of the original site."[21]

This framework appears to allow utilities very little flexibility in modifying their sampling pool—intentionally so, to prevent utilities from removing homes with high lead levels. However, a more basic requirement of the LCR is that the sampling sites must contain a lead service line, lead pipes, or copper pipes with lead solder.[22] Therefore, if a home was erroneously placed in the sampling pool and does not in fact contain any lead plumbing or solder, it is not a valid location from which to draw a sample.

Massachusetts Guidance. Massachusetts has not produced any guidance that augments LCR procedure for determining which homes to sample.

Best Practices. Water utilities choose the initial pool of homes to sample by selecting homes that they believe are likely to contain lead pipes, lead solder, or lead service lines. But the information that the water utilities use to make that determination (including plumbing codes, permit records, and so on) may not be entirely accurate. Moreover, many of these sources of information can only indicate which homes are *likely* to have lead in their plumbing, which means that water utilities cannot be certain that all the homes that they choose to test do in fact have lead pipes or lead service lines.

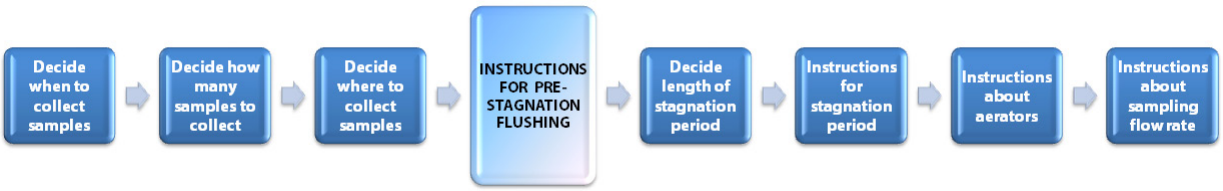
Water utilities should therefore constantly reevaluate their sample selections to ensure that those sites do in fact have lead pipes, lead solder, or lead service lines. If residents are willing to allow employees of a water utility into their basement, water utilities should conduct scratch tests to determine whether the house has lead plumbing. If a water utility has reason to believe that one of the homes it included in the initial sampling pool does not contain lead plumbing, it should find another suitable sampling location.

In addition, it may be possible for a water utility to infer that a home does not contain lead plumbing even without directly testing the pipes. For example, the detection of exceedingly low or nonexistent levels of lead in repeated samples could indicate that a home does not contain lead plumbing. In such circumstances, a water utility should obtain agency approval to remove that site from the sampling pool and select another suitable site that complies with the requirements of 40 C.F.R. § 141.86(a).

Two other changes in practice can also help ensure that all samples are taken from the high-risk, tier one pool of homes. First, water utilities should identify as large a pool of qualifying homes as possible, so that they will always have other tier one homes available if the resident of a home in the current sampling pool refuses to provide a sample. Some water utilities have reported difficulties in identifying replacement sampling sites, leading to widely-criticized practices such as taking samples from the homes of utility employees.[23] Identifying alternate sites in advance can allow utilities to avoid such recourses.

Second, to help water utilities keep track of which homes have lead plumbing, sampling instruction forms should ask residents to describe any recent changes that have been made to their household plumbing systems. If those changes involved removing lead pipes, water utilities should continue to sample that site for at least one monitoring period to ensure that the recent changes did in fact remove all lead from that customer's plumbing. (This is particularly important for homes that have undergone a *partial* lead service line replacement, which can at least temporarily increase lead levels in water.) After determining that the recent plumbing changes did in fact remove all lead pipes and fixtures from that home, the water utility should begin sampling a new home instead. MassDEP's recommended sampling instructions already provide a section in which residents are asked about any recent changes in their home plumbing system.[24] Water utilities should be sure to include such a section on their own sampling instructions.

D. Should pre-stagnation flushing be permitted or endorsed?



Running water from the taps for several minutes before beginning the stagnation period is known as "pre-stagnation flushing." This practice tends to clear out some lead from the plumbing system, thereby decreasing the amount of lead found in samples collected after the stagnation period. Some water utilities have instructed residents to engage in pre-stagnation flushing, reasoning that it results in greater uniformity among sampling conditions and provides a more accurate measure of how much lead accumulates during the stagnation period.[25] However, because many residents do not flush the lines before water stagnates during routine household use, pre-stagnation flushing before collecting samples risks underestimating customers' true lead exposure.

LCR Requirements. The LCR is silent on whether sampling procedures should include pre-stagnation flushing.

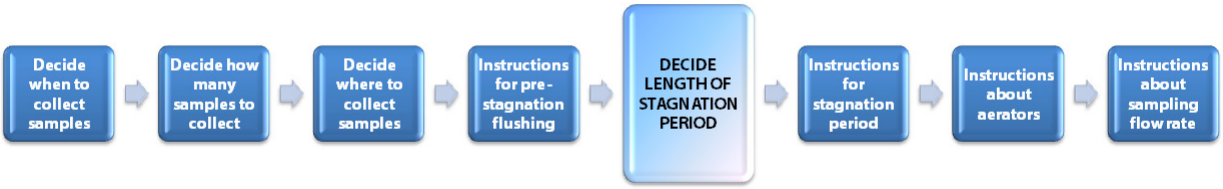
EPA Guidance. In a recent guidance document, EPA takes the position that the best sampling procedures avoid pre-stagnation flushing, and recommends that sampling instructions provided to residents do "not contain a pre-stagnation flushing step."[26]

What flexibility do water utilities have in addressing this issue? Water utilities retain flexibility for two reasons. First, the EPA guidance is nonbinding and water utilities are therefore not obligated to follow it. Until recently, some states still recommended flushing the line before beginning the stagnation period. Second, the EPA guidance recommends only that the instructions should not affirmatively direct residents to engage in pre-stagnation flushing. Water utilities are therefore acting consistently with the guidance if they either instruct residents not to pre-flush their taps or if they say nothing about the issue in their instruction forms. This distinction is particularly important given that the Lead and Copper Rule instructs water utilities to sample the same houses in successive monitoring periods.[27] If the instruction form from previous monitoring periods told residents to flush the line beforehand, they may automatically do so again unless the new instruction form explicitly prohibits pre-stagnation flushing.

Massachusetts Guidance. MassDEP's recommended sampling instruction form specifically directs residents not to flush the line before beginning the stagnation period.[28]

Best Practices. It is widely agreed that pre-stagnation flushing tends to reduce the levels of lead found by the sampling (especially when the lines are flushed at a faster flow rate).[29] Therefore the best practice is for water utilities to provide instruction forms that specifically instruct residents not to flush the lines before beginning the stagnation period.

E. How long should the stagnation period be?



The longer water is allowed to stagnate in the pipes (especially the service line), the more lead is likely to leach into the water. The duration of the stagnation period, therefore, can drastically influence the amount of lead present in a sample.

LCR Requirements. The Lead and Copper Rule requires the stagnation period to be "at least six hours."[30]

What flexibility do public water systems have in addressing this issue? The LCR does not provide an upper limit on the stagnation period, allowing public water systems to instruct residents to let water stagnate for longer.

Massachusetts Guidance. MassDEP's recommended sampling instructions mirror the LCR's language, directing residents to avoid using water for "at least six hours" prior to conducting the sampling.[31]

Best Practices. The rate at which lead leaches into the water may not always be constant. For example, some research has suggested that the rate depends on the type of pipe, with "fresh lead pipes" taking as little as eight to twenty-four hours to reach "an approximate state of equilibrium," but with "older, encrusted pipes" potentially taking "considerably longer."[32] However, even if the rate at which lead leaches into stagnating water may not always be constant, there is general agreement that longer stagnation periods will increase the quantity of lead found in the sample.

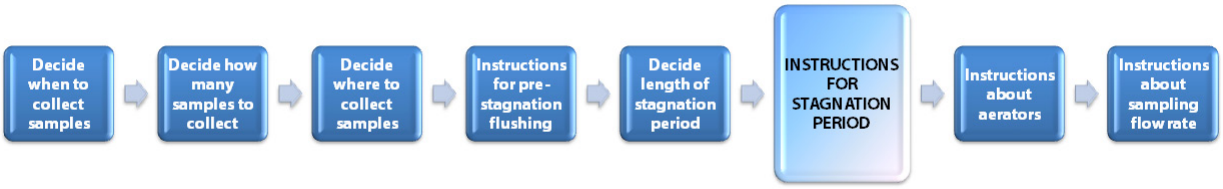
EPA has explained that the purpose of sampling under the Lead and Copper Rule is to determine the highest level of lead to which a resident would be exposed during normal household use. Therefore, the optimal stagnation period should mirror the longest time period in which water is ordinarily stagnating during routine household use. In most households, the longest period of time in which a home's water system is likely to go unused is either when the occupants are sleeping or when they are at work. In either case, the length of time for which the water system goes unused could routinely reach nine hours.

There are some potential downsides to lengthening the stagnation period. Many water utilities already have difficulty finding customers willing to collect samples for them. A longer stagnation period is less convenient for customers, and might make it harder for water utilities to find enough people willing to collect samples. Furthermore, customers may be less likely to comply with a longer stagnation period. The longer the stagnation period, the greater the likelihood that a resident might accidentally flush a toilet or fill a glass of water. Residents who briefly used water during the stagnation period may not fully understand the importance of allowing the water to stagnate fully and how even a small amount of water use might drastically alter the results of the sample. They might therefore decide to take the sample anyway, rather than beginning an entirely new stagnation period.

Despite these concerns, a stagnation period of at least nine hours is the best approach. Because a typical water utility customer could routinely go for nine hours without using water, a stagnation period of six hours is not entirely consistent with the LCR's "worst case" scenario principle. Additionally, the concerns that customers may be less likely to comply with a longer stagnation period could be addressed by emphasizing to customers the importance of the stagnation period

and how easily it can be disrupted by any water use. Water utilities should provide residents with an instruction form that directs them not to use the water for nine hours before sampling and clearly explains why. We also recommend that state regulators, including MassDEP, issue guidance encouraging water utilities to adopt a nine-hour stagnation period.

F. How should the instructions describe the stagnation period?



In addition to determining the duration of the stagnation period, water utilities should think carefully about the precise way in which they describe it to their customers. The stagnation period is interrupted if any water is used in any part of the house. Unfortunately, some sampling instructions do not make that entirely clear, and could be interpreted to require residents to stop using water only from certain faucets in the house.

LCR Requirements. The Lead and Copper Rule describes the stagnation interval as a period in which the water has "stood motionless in the plumbing system of each sampling site for at least six hours."[33]

EPA Guidance. EPA's recommended sampling instruction form includes three descriptions of the sampling period. These descriptions differ in subtle but important ways. First, the form instructs residents to collect water "*from a tap* that has not been used for at least six hours."[34] (Emphasis added.) Second, it maintains that "there must be a minimum of six hours during which there is no water used from the tap where the sample will be collected *and any taps adjacent or close to that tap*." (Emphasis added.) Third, it suggests that "to ensure *the water* has not been used for at least six hours, the best time to collect the samples is either early in the morning or in the evening upon returning from work." (Emphasis added.) A resident might get a different impression of the nature of the stagnation period depending upon which of these descriptions s/he focused on. The first description suggests that the stagnation period only involves a moratorium on using water from the specific tap that will be used for the sampling. The second description suggests that the ban extends only to the specific tap used for sampling and other nearby taps (which implies that residents could flush a toilet without disrupting the stagnation period). The third description indicates that the stagnation period involves a general prohibition on any water use in the whole house.

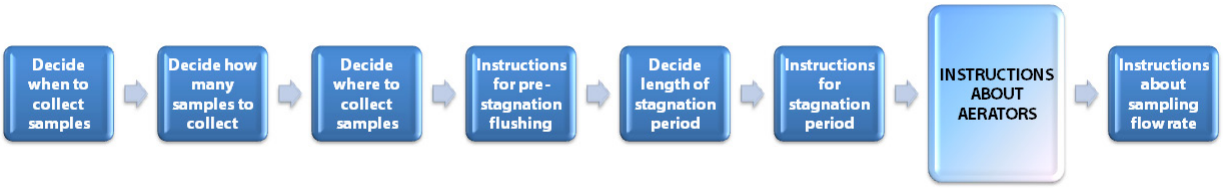
What flexibility do public water systems have in addressing this issue? By referencing the "plumbing system" as a whole, the Lead and Copper Rule does indicate that the stagnation period

involves a moratorium on all water usage from any source in the whole house. But, although the LCR itself includes this description of the stagnation period, it contains no requirement as to the precise language that water utilities should use to describe it to their customers.

Massachusetts Guidance. MassDEP's recommended sampling instructions state that there must be "no water use" during the period before sampling.[35]

Best Practices. Instructions should define the meaning of stagnation very precisely. In particular, the instructions should make it clear that the stagnation period involves a prohibition on using any water in the whole house, not just the individual faucet being sampled. Although MassDEP's recommended sampling instructions are largely clear and accurate, they could be slightly improved. It is conceivable that a resident might interpret the "no water use" provision to apply only to the tap from which they are sampling. A better practice would be to indicate that during the stagnation period, residents should not use any water in the entire house (including all faucets, toilets, showers, baths, etc.). We recommend that water utilities ensure that their sampling instructions make this as clear as possible. In addition, state agencies such as MassDEP should revise their recommended sampling instructions to clarify that no water should be used in the entire house during the stagnation period and encourage any water utility that uses unclear sampling instructions to revise them.

G. Should aerators be removed before sampling?



Removing the aerator from a faucet can affect the amount of lead that leaches into the water. Water utilities should therefore consider whether or not to instruct residents to remove the aerator before collecting a sample.

LCR Requirements. The LCR itself does not address this question.

EPA Guidance. EPA released a guidance document in 2006 which states that "public water systems should not recommend that customers remove or clean aerators prior to or during the collection of tap samples for lead."[36] This approach was reaffirmed in 2016 in a subsequent memorandum.[37]

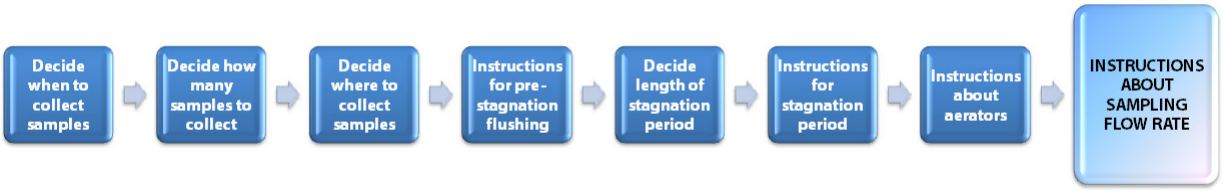
What flexibility do public water systems have in addressing this issue? Neither the 2006 nor the 2016 guidance documents are formally binding on water utilities, which are therefore not in violation of the LCR if they instruct their customers to remove aerators before sampling. Moreover, EPA

merely recommends that water utilities do not recommend the removal of aerators; it does not state that water utilities should affirmatively instruct residents *not to* remove them.

Massachusetts Guidance. MassDEP's recommended sampling instructions direct residents not to remove the aerator before collecting the sample.[38]

Best Practices. Aerators can accumulate significant quantities of lead sediment over time. As this sediment builds up, it can begin to leach into the water coming out of the faucet. Removing aerators before collecting a sample is likely to reduce the amount of lead that is detected in the water sample.[39] The National Drinking Water Advisory Council therefore recommends that aerators should not be removed prior to sampling.[40] We agree; because residents who have aerators on their taps will routinely drink water that passes through the aerator, water utilities should instruct residents not to remove the aerator before collecting samples. MassDEP's recommended sampling instructions are exemplary in this regard.

H. What should the flow rate be during sampling?



"Flow rate" refers to how much water exits the faucet in a particular period of time when a sample is being collected. It can have a dramatic impact on the amount of lead sediment collected by the water as it passes through a lead service line. Water utilities should therefore think carefully about how their sampling instructions discuss flow rate.

LCR Requirements. The Lead and Copper Rule does not address flow rate.

EPA Guidance. In February 2016, EPA released a memorandum which addressed, among other issues, the topic of "bottle configuration." In the memorandum, EPA recommended the use of "wide-mouth bottles" for collecting samples. It went on to explain that wide-mouth bottles "allow for a higher flow rate during sample collection which is more representative of the flow that a consumer may use to fill up a glass of water."[41] A "higher flow rate," the memorandum observed, "can result in greater release of particulate and colloidal lead." EPA has thus recognized the value of using a sufficiently high flow rate to fill sampling bottles, although it did not specifically recommend that residents be instructed to use a particular flow rate when taking samples.

What flexibility do public water systems have in addressing this issue? The EPA memorandum is nonbinding guidance so there is currently no explicit requirement that wide-mouth bottles be used and no formal requirement that the instructions advise residents to fill the bottles quickly. Water utilities are therefore free to provide either narrow- or wide-mouth bottles to their customers. Water utilities also have flexibility as to whether or not their sampling instructions direct residents to use a faster or slower flow rate.

Massachusetts Guidance. MassDEP's recommended sampling instruction form indicates that wide-mouth bottles are preferable because "they allow for a higher flow rate."[42] As with EPA's guidance, however, the form never explicitly instructs residents to fill the bottle quickly; while the attentive reader may infer to do so, some residents might not.

Best Practices. EPA's guidance reflects the understanding that a faster flow rate is likely to reveal higher lead levels, which are more representative of the lead levels present in routine use. This understanding has a great deal of scientific support. Studies have found that sampling at a low flow rate may significantly underestimate the amount of lead present in many circumstances.[43] For example, one study determined that, under some conditions, the detected level of "lead was as much as 99.9% lower at the lower flow" rate.[44]

The National Drinking Water Advisory Council maintains that flow rate should mirror "normal household use."[45] The problem with this approach, however, is that it is ambiguous: a resident may use different flow rates for different activities. For example, a resident may fill a glass of water more slowly than a tea kettle or coffee pot. If instructed to mirror normal household use, a resident may fill the sample bottles as they would a glass of water and thus inadvertently underestimate the level of lead to which they are routinely exposed. The best practice is therefore for water utilities to specifically direct residents to collect their samples with a high flow rate. We recommend that MassDEP and other regulatory agencies revise their recommended sampling instructions to include such a direction.

I. Should the sampling instructions specifically address multiple-family residences?

Massachusetts has many two-, three- and four-family homes. According to data from the 2015 American Community Survey, 10.4% of occupied housing units in Massachusetts are two-unit structures, compared to 3.6% for the United States as a whole; for three- and four-unit structures, the numbers are 10.6% and 4.4%.[46]

The Lead and Copper Rule instructs water utilities to sample multiple-family residences only if there are an insufficient number of suitable single-family residences to choose from or when multiple-family residences comprise at least 20% of the structures served by that water utility.[47] Based on the state-wide averages, there are presumably many communities in Massachusetts where the number of

multiple-family residences exceeds the 20% threshold. Yet instruction forms typically address only single-family homes and it is not clear whether utilities are including multiple-family homes in their sampling pools.[48]

LCR Requirements. There is no provision of the LCR that discusses whether or not water utilities should specifically address multiple-family residences in their sampling instructions.

What flexibility do public water systems have in addressing this issue? Water utilities are free to include specific instructions for the occupants of multiple-family residences.

Massachusetts Guidance. Massachusetts offers no specific guidance on this point and its recommended sampling instructions include no mention of multiple-family residences.

Best Practices. Water utilities with a high percentage of multiple-family homes should ensure that their instruction forms address such homes. In states like Massachusetts that have a large percentage of two-, three- and four-family homes, state agencies should provide guidance on sampling from such homes.

Multiple-family homes often have a single plumbing system that services all the residents. Water use in one unit will therefore disrupt the stagnation period if a sample is being taken in another unit. As a result, if samples are to be taken from such homes, then the instruction forms should make it clear that the stagnation period applies to the entire building and that no water should be used in the entire building during the stagnation period. Such an instruction would obviously be impossible to implement in larger buildings, but should be practicable in smaller multi-family structures.

PART II: TOPICS ON WHICH WATER UTILITIES MAY ADOPT OUR RECOMMENDATIONS ONLY FOR PURPOSES OF ADDITIONAL SAMPLING

A. Should residents rely on "first-draw" sampling?

Collecting the first water to leave the tap is known as "first-draw" sampling. Water that has been in contact with lead plumbing or fixtures for extended periods of time is likely to exhibit the highest concentration of lead. Depending on the primary source of lead in a particular home—either fixtures within the house or the lead service line coming from the street—this highest-risk water will be at a different point in the plumbing system. As a result, in some homes the first-draw sample may not accurately measure the highest amount of lead to which a resident might be exposed during routine household use.

LCR Requirements. The Lead and Copper Rule requires that all samples that are used to measure compliance must be first-draw samples.[49] EPA defines a first-draw sample to be "a one-liter sample of tap water . . . that has been standing in plumbing pipes for at least 6 hours and is collected without flushing the tap."[50]

Does this procedure allow flexibility for public water systems? No, except to the extent that "without flushing the tap" is somewhat ambiguous. It could mean either that the water used for the sample must be literally the first water to leave the tap or that the sample must be taken without thoroughly flushing the tap. EPA currently interprets it in the former fashion ("Open the faucet and collect the first water out of the tap."),[51] but has adopted the latter interpretation in the past ("If you are collecting a first-flush sample for lead/copper, allow the water to run just a bit before collecting the sample but do not flush the lines.").[52]

Massachusetts Guidance. Although MassDEP's guidance does not use the words "first-draw," following the suggested sampling instruction form would result in sampling the first water to exit the tap.[53]

Best Practices. The first-draw procedure has been heavily criticized. Researchers have pointed out that first-draw samples and subsequent samples may detect different levels of lead.[54] Some studies suggest that first-draw samples are likely to significantly underestimate the lead concentration in water.[55] But this does not mean that first-draw samples *always* underestimate the level of lead in the water. For example, one extensive study of the water in Seattle's public schools found "the highest lead concentrations . . . in the first-draw samples" collected from certain kinds of "end-use plumbing

configurations" (meaning specific models of fountain spigots, connective piping, and shutoff valves).[56] Researchers are still struggling to understand the precise conditions under which first-draw sampling is effective. EPA's Science Advisory Board has suggested that "first-draw samples are well suited for determining the concentrations of lead released from plumbing materials in the faucet and . . . fittings under the sink" but that first-draw samples may be poorly suited for detecting lead released from lead service lines.[57]

Because the effectiveness of first-draw sampling may vary so widely depending upon a number of conditions, the best practice would be to take a series of sequential samples. Researchers at Virginia Polytechnic Institute have proposed such a procedure in which three sequential samples are taken (first-draw, forty-five seconds, two minutes).[58] To carry out such a sequential sampling protocol, water utilities would provide three wide-neck bottles to residents and direct them to run the water for two straight minutes, collecting samples at these three time intervals.

Although samples taken for Lead and Copper Rule Water compliance must be first-draw samples, utilities are free to collect additional, non-first-draw samples for other purposes. Given that non-first-draw samples can potentially reveal dangerous levels of lead that first-draw samples may miss, water utilities can further protect the health of their customers by collecting sequential samples. Some water utilities in Massachusetts, like the Cambridge Water Department, already allow residents to request that their water be tested outside the LCR compliance process.[59] Such samples do not have to follow the LCR's first-draw requirement.

B. Should sampling be conducted with hot or cold water taps (or both)?

Some sinks have separate hot and cold water taps; residents taking a sample from such a sink will need to choose which tap to use. When taking a sample from a sink with a single tap, a resident will also need to choose whether to run the water hot or cold.

LCR Requirements. The LCR requires samples to be collected from the cold-water faucet.[60]

Does this permit flexibility for public water systems? No, the Lead and Copper Rule permits no flexibility on this point.

Massachusetts Guidance. Massachusetts's suggested sampling procedures instruction form specifically directs residents to collect cold-water samples.[61]

Best Practices. As mentioned above when discussing seasonal variations in sampling results, higher water temperatures tend to reveal higher levels of lead under certain conditions. However, few people use the hot water faucet for drinking or cooking. It would be a waste of resources to test all hot

water faucets separately (especially since lead does not get absorbed through the skin in baths and showers).[62] These resources would be better spent on more testing for cold water faucets. Therefore, we do not recommend that water utilities adopt any additional or different practices with regard to sampling from hot water taps.

Even if water utilities do not collect hot water samples, however, they should make a concerted effort to educate their customers thoroughly on the increased dangers from consuming hot water and of the importance of flushing the lines thoroughly after using hot water. This is an important area where water utilities can better protect their customers' health by going above and beyond the minimum requirements of the Lead and Copper Rule.

CONCLUSIONS

This paper has outlined a number of important ways in which water utilities can improve their sampling methods to better ensure the safety of their customers. The Massachusetts Department of Environmental Protection and other state environmental agencies can play a crucial role in encouraging water utilities to take these steps, even though some of them are not formally required by the Lead and Copper Rule. It is important to bear in mind that the LCR represents a baseline; it embodies *minimum* federal standards to which all water utilities must adhere. But water utilities are permitted and encouraged to take additional steps to protect their customers from lead poisoning. Improving the procedures with which they collect samples is an important step that water utilities can take to more accurately detect dangerous levels of lead.

Endnotes

[1] Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper, 56 Fed. Reg. 26,460 (June 7, 1991).

[2] *Id.* at 26,514.

[3] *See, e.g.*, Flint Water Advisory Task Force, *Final Report* (Mar. 2016), *available at* https://www.michigan.gov/documents/snyder/FWATF_FINAL_REPORT_21March2016_517805_7.pdf.

[4] 40 C.F.R. § 141.86(d)(4)(iv).

[5] 310 C.M.R. § 22.06B(7)(d)(4)(d).

[6] MassDEP, *Lead and Copper Rule (Revised Requirements)*, http://www.mass.gov/eea/agencies/massdep/water/drinking/lead-and-copper-rule-revised-requirements.html (last visited July 27, 2017).

[7] Marc Edwards, Failure of the US Centers for Disease Control (CDC) and the U.S. Environmental Protection Agency (EPA) to Protect Children from Elevated Lead in Drinking Water (Mar. 15, 2016), 3 *available at* https://oversight.house.gov/wp-content/uploads/2016/03/Marc-Edwards-Final-3-15-2016.pdf.

[8] Anahad O'Connor, *The Claim: Never Drink Hot Water from the Tap*, N.Y. Times, Jan. 29, 2008, https://www.nytimes.com/2008/01/29/health/29real.html.

[9] Sheldon Masters, Gregory Welter & Marc Edwards, *Seasonal Variations to Lead Release in Potable Water*, 50 Envtl. Sci. Technol. 5269, 5275 (2016).

[10] EPA, *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems* (Mar. 2016), *available at* https://www.epa.gov/sites/production/files/2016-03/documents/occtmarch2016.pdf.

[11] *Id.*

[12] The service line is the pipe that connects the water main (which runs underneath the street) to the plumbing system in an individual home. Each house generally has its own service line.

[13] 40 C.F.R. § 141.86(e).

[14] MassDEP, *Guidance for Public Water Systems: Lead and Copper Rule (LCR) Updates* (July 2016),

available at http://www.mass.gov/eea/docs/dep/water/drinking/alpha/i-thru-z/lcrupdatesltr.pdf.

[15] See the discussion on page 13 for more information on sampling site selection.

[16] 40 C.F.R. § 141.86(a).

[17] *Id.* § 141.86(a)(2).

[18] *Id.* §§ 141.86(a)(3) – 141.86(a)(6).

[19] *Id.* § 141.86(a)(8).

[20] *Id.* § 141.86(b)(4).

[21] *Id.*

[22] *Id.* § 141.86(a)(3).

[23] *See, e.g.*, Jessica Glenza, *Chicago Used Water Department Employees' Homes to Test for Lead,* The Guardian (Feb. 19, 2016), https://www.theguardian.com/us-news/2016/feb/19/chicago-water-department-testing-lead-flint-michigan.

[24] MassDEP, *Chain of Custody and Home Sampling for Lead and Copper Instruction Form* (June 2016) [hereinafter, MassDEP, *Home Sampling Form*], *available at* http://www.mass.gov/eea/docs/dep/water/approvals/year-thru-alpha/e-thru-l/lcrcoc.pdf.

[25] *See* Oliver Milman & Jessica Glenza, *Philadelphia's Water-testing Procedures are "Worse than Flint"—Expert*, The Guardian (Jan. 28, 2016) (quoting Gary Burlingame, director of the bureau of laboratory services at Philadelphia Water as saying that "that pre-flushing of the faucets is done because 'you want to normalize all the homes to the same conditions'"), https://www.theguardian.com/environment/2016/jan/28/philadelphia-water-testing-crisis-flint-health-risk.

[26] EPA, *Clarification of Recommended Tap Sampling Procedures for Purposes of the Lead and Copper Rule* (Feb. 2016) [hereinafter, EPA, *Clarification*], *available at* https://www.epa.gov/sites/production/files/2016-02/documents/epa_lcr_sampling_memorandum_dated_february_29_2016_508.pdf.

[27] 40 C.F.R. § 141.86(b)(4).

[28] MassDEP, *Home Sampling Form*, *supra* note 24.

[29] Oliver Milman & Jessica Glenza, *At Least 33 US Cities Used Water Testing "Cheats" Over Lead Concerns*, The Guardian (June 2, 2016), https://www.theguardian.com/environment/2016/jun/02/lead-water-testing-cheats-chicago-boston-philadelphia.

[30] 40 C.F.R. § 141.86(b)(2).

[31] MassDEP, *Home Sampling Form*, *supra* note 24.

[32] Michael Schock, *Causes of Temporal Variability of Lead in Domestic Plumbing Systems*, 15 Envtl. Monitoring & Assessment 59, 62 (1989).

[33] 40 C.F.R. § 141.86(b)(2).

[34] EPA, *Suggested Directions for Homeowner Tap Sample Collection Procedures* (Feb. 2016), *available at* https://www.epa.gov/sites/production/files/documents/LCR_Sample_Form.pdf.

[35] MassDEP, *Home Sampling Form*, *supra* note 24.

[36] EPA, *Management of Aerators During Collection of Tap Samples to Comply with the Lead and Copper Rule* (Oct. 2006), *available at* https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100NEFU.txt.

[37] EPA, *Clarification*, *supra* note 26.

[38] MassDEP, *Home Sampling Form*, *supra* note 24.

[39] Marc Edwards, *Failure of the US Centers for Disease Control (CDC) and the U.S. Environmental Protection Agency (EPA) to Protect Children from Elevated Lead in Drinking Water* (Mar. 15, 2016), 5 *available at* https://oversight.house.gov/wp-content/uploads/2016/03/Marc-Edwards-Final-3-15-2016.pdf.

[40] Stephen Estes-Smargiassi, *NDWAC Recommendations Related to Lead Service Line Replacements* (2016), 19 *available at* http://www.waterrf.org/resources/expertsymposiums/Lists/PublicExpertSymposiums/Attachments/27/LC-Estes-Smargiassi.pdf.

[41] EPA, *Clarification*, *supra* note 26.

[42] MassDEP, *Home Sampling Form*, *supra* note 24.

[43] *See, e.g.,* Brandi Clark, Sheldon Masters & Marc Edwards, *Profile Sampling to Characterize Particulate Lead Risks in Potable Water*, 48 Envtl. Sci. Technol. 6836, 6837 (2014).

[44] Sheldon Masters, Jeffrey Parks, Amrou Atassi & Marc Edwards, *Inherent Variability in Lead and Copper Collected During Standardized Sampling*, 188 Envtl. Monitoring & Assessment, 177, 11 (2016).

[45] Estes-Smargiassi, *supra* note 40.

[46] Data were generated using the Census Bureau's American FactFinder interface at https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml and selecting the Physical Housing Characteristics for Occupied Housing Units table.

[47] 40 C.F.R. §§ 141.86(a)(3) – 141.86(a)(6).

[48] The City of New Bedford, Massachusetts, Department of Public Infrastructure does not take samples from multi-family homes because "There would be no way to ensure we'd be testing the first flush, with so many people in a tenement, you couldn't get everyone to agree to not use the water at the same time," according to Commissioner Ron Labelle. Eric Bosco, *Fight to Keep New Bedford's Water Safe Ongoing, but no Testing in Multifamily Homes Leaves Big Question Mark*, New Bedford Standard-Times, Mar. 19, 2016, http://www.southcoasttoday.com/news/20160319/fight-to-keep-new-bedfords-water-safe-ongoing-but-no-testing-in-multifamily-homes-leaves-big-question-mark.

[49] 40 C.F.R. § 141.86(b).

[50] *Id.* § 141.2. Water utilities that "do not have enough taps that can supply first-draw samples" are exempt from this requirement if they get permission from the state. *Id.* § 141.86(b)(5). For the most part, however, first-draw samples are the norm.

[51] EPA Region 8, *Quick Guide to Drinking Water Sample Collection* 5 (2d ed. 2016) ("Open the faucet and collect the first water out of the tap."), *available at* https://www.epa.gov/sites/production/files/2015-11/documents/drinking_water_sample_collection.pdf; *accord* EPA, *3Ts for Reducing Lead in Drinking Water: Testing – How to Sample?,* https://www.epa.gov/dwreginfo/3ts-reducing-lead-drinking-water-testing#howtosample (last visited Mar. 12, 2017) ("A 'first draw' is the water that is the first to come out of the tap after the period of inactivity.").

[52] EPA Region 8, *Quick Guide to Drinking Water Sample Collection* 5 (2005) ("If you are collecting a first-flush sample for lead/copper, allow the water to run just a bit before collecting the sample but do not flush the lines."), *available at* http://www.emsl.com/PDFDocuments/SamplingGuide/EPA%20samplingprocedures.pdf.

[53] MassDEP, *Home Sampling Form*, *supra* note 24.

[54] National Drinking Water Advisory Council, *Report of the Lead and Copper Working Group to the National Drinking Water Advisory Council* 30 (2015), 30 *available at* http://www.awwa.org/Portals/0/files/legreg/documents/NDWACRecommendations.pdf.

[55] Miguel Del Toral, Andrea Porter & Michael Schock, *Detection and Evaluation of Elevated Lead Release from Service Lines: A Field Study*, 47 Envtl. Sci. Technol. 9300, 9302 (2013).

[56] Glen Boyd, Gregory Pierson, Gregory Kirmeyer & Ronald English, *Lead Variability Testing in Seattle Public Schools*, 100 J. – Am. Water Works Ass'n 53, 63 (2008).

[57] EPA Science Advisory Board, *Evaluation of the Effectiveness of Partial Lead Service Line Replacement* (2011), 58 *available at* https://www.epa.gov/sites/production/files/2015-09/documents/sab_evaluation_partial_lead_service_lines_epa-sab-11-015.pdf.

[58] Lisa Riordan Seville, Hannah Rappleye, Stephanie Gosk & Kevin Monahan, *Lead in Your Water: Are Federal Tests Missing Poison in the Pipes*?, NBC News (Aug. 3, 2016), http://www.nbcnews.com/news/us-news/lead-your-water-are-federal-tests-missing-poison-pipes-n621736.

[59] Cambridge Water Dept., *Test My Water*, https://www.cambridgema.gov/Water/wateroperationsdivision/testmywater (last visited July 27, 2017).

[60] 40 C.F.R. § 141.86(b)(2).

[61] MassDEP, *Home Sampling Form*, *supra* note 24.

[62] EPA, *Basic Information About Lead in Drinking Water*, https://www.epa.gov/ground-water-and-drinking-water/basic-information-about-lead-drinking-water#skin (last visited July 27, 2017).