Executive Summary

Evaluation of Lead Service Line Lining and Coating Technologies

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Quick Facts

- Lining or coating technologies can effectively reduce or eliminate the release of lead from LSLs and may be useful in reducing exposure to lead.
- PET lining, epoxy coating, and polyurea/polyurethane coating are deemed especially promising and are therefore recommended for consideration.
- Potential benefits of lining and coating include reasonably long service lives; cost savings relative to LSLR; fewer and shorter disruptions to traffic; reduced damage to landscaping and driveways; less potential for damage to other utility lines; and facilitating delay of LSL replacements until they can be more efficiently and more cost-effectively performed.
- Recommendations are provided for water utilities, consultants, property owners, regulators, and manufacturers.

Objectives

The primary objectives of this research project were: (1) to evaluate lead service line (LSL) lining and coating technologies as alternatives to full or partial LSL replacement, and as a means of protecting and repairing copper service lines (CSLs); and (2) to provide information and recommendations to water utilities, engineering consultants, consumers, property owners, state and provincial regulators, and other stakeholders to assist them in making informed decisions regarding lining and coating of both lead and copper service lines. To accomplish these primary objectives, the investigators sought, as a secondary objective, to obtain and evaluate information on many different aspects of linings and coatings, including the following:

- Effectiveness in preventing lead release from LSLs and reducing tap-water lead levels
- Advantages and disadvantages for full versus partial LSL replacement
- Commercial availability, suitability for use in small-diameter pipes, and utilization of materials certified for use in contact with potable water
- Potential, upon installation and after aging, to leach organic and inorganic chemicals of concern with respect to water quality
- Long-term effectiveness and durability
- Ability to control internal water-service-line corrosion, prevent metal release from both service lines and the scales inside them, and repair service-line leaks
- Costs to both utilities and property owners, especially relative to the cost of LSL replacement
- Engineering feasibility, commercial availability, certification, and property access issues

Background

Water service lines are the pipes extending from water mains to residential dwellings or commercial buildings. Generally, the portion of pipe from the water main to the property line is the responsibility of the public water system, while the section of pipe from the property line to the building is generally the responsibility of the property owner. However, there are exceptions. For example, customers served by Denver Water own the entire service line, and the Lansing (MI) Board of Water and Light owns their service lines from the main to the water meter inside the house. Water service lines made from lead or copper are referred to as lead service lines (LSLs) and copper service lines (CSLs), respectively; and, as they corrode, they can release lead or copper into the water supply, potentially in excess of allowable concentrations.

In the United States, the Lead and Copper Rule (LCR), promulgated by EPA under the Safe Drinking Water Act (SDWA), established an action limit (AL) of 15 µg/L for lead and an AL of 1.3 mg/L for copper. These ALs are based on the 90th percentile of first-draw tap-water samples collected, after a stagnation period of at least 6 hours, from homes with higher risk of lead exposure due to the presence of an LSL or relatively new lead solder. Public water systems exceeding the AL must take corrective action, which may include corrosion control treatment, public education, and/or lead service line replacement (LSLR). The maximum acceptable concentration (MAC) of lead in drinking water under Canadian guidelines is currently 10 µg/L, which is intended to apply to the average concentration in distributed water, typically based on samples collected after the faucet is flushed and prior to the water being taken for analysis or consumption. However, a new guideline of 5 µg/L has been proposed that would include sampling the water using a random daytime or a 30-minute stagnation sampling approach.

Older cities in some regions of the United States and Canada still have many LSLs in place. Cornwell et al. (2016) estimate there were 10.2 million LSLs in service when the LCR was promulgated in 1991, with approximately 6.1 million remaining in service and about 30% of community water systems having at least some LSLs in their system. The LCR does not require public water systems in the United States to replace the customer-owned portion of an LSL, and many public water systems are prohibited from performing work on private property at city or utility expense. Many utilities performing LSLRs, whether on a mandatory or voluntary basis, offer property owners an opportunity to sign an agreement to pay to replace their portion of the LSL at the same time, which reduces the cost. However, most property owners choose not to replace their LSLs, so the overwhelming majority of LSLRs in most cities to date has been partial LSLRs.

In recent years, it became increasingly clear that LSLs can contribute significantly to tap-water lead levels, that partial LSLRs can temporarily increase tap-water lead levels, and that lead may pose greater health risks than previously believed. For these and other reasons, a recent report by the LCR Working Group of the National Drinking Water Advisory Committee (NDWAC) in the United States recommended full replacement of LSLs, to the building wall, over a 30-year front-loaded timeframe (EPA 2015a and 2015b). This group also concluded that "[minimizing] exposure to lead in drinking water is a shared responsibility; public water systems, consumers, building owners, public health officials and others each have important roles to play."

The NDWAC report did not address linings and coatings, nor is it clear whether they will be addressed in future LCR revisions or, if they are addressed, what the relevant provisions will be. However, developing an LSLR program that ultimately replaces all LSLs all the way to the building wall, which necessarily includes LSLs on private property, will pose challenges for every public water system in the United States that has LSLs in its service area. This project provides information and recommendations intended to help all stakeholders evaluate the advantages and disadvantages of lining and coating technologies and to determine if such technologies would be helpful in planning or revising an LSLR program to meet the challenges facing their communities.

Approach

To accomplish the project objectives stated above, the investigators:

- Gathered, reviewed, and critically evaluated published and unpublished articles and reports regarding lining and coating of water service lines and the technologies and materials used
- Sought and obtained information from water utility personnel (e.g., utility and distribution system superintendents); consulting engineers; technical experts having specialized knowledge in relevant subdisciplines; state regulatory agencies and regulatory agencies outside the United States; NSF International (NSF) and other organizations involved in product certification; and manufacturers of lining and coating technologies and their representatives
- Identified issues stakeholders should consider before lining or coating LSLs, and developed a list of criteria for evaluating lining and coating technologies
- Identified lining and coating technologies potentially suitable for controlling lead release from LSLs and evaluated them with respect to their availability, effectiveness, cost, ease of installation, suitability for use in contact with potable water, estimated and warranted service life, potential impacts on water quality, and other advantages and disadvantages
- Identified three promising technologies and conducted laboratory studies on two of them – epoxy coating and polyethylene terephthalate (PET) lining – focusing primarily on their effectiveness in controlling lead and copper release and their potential to leach chemical constituents that might be of concern with respect to health or water quality (the third technology is relatively new and samples of the material used could not be obtained.)
- Based on the results of the above efforts, developed general recommendations for all stakeholders, and more specific recommendations for water utilities and their consultants, consumers and property owners, state and provincial regulators, and manufacturers and contractors.

Results and Conclusions

Three currently available lining or coating technologies can effectively reduce or eliminate release of lead from LSLs, are expected to have a long service life, and can potentially result in significant cost savings and other benefits relative to LSL replacement, depending on site-specific conditions. Other possible benefits include fewer and shorter disruptions of vehicular and pedestrian traffic; reduced damage to landscaping, trees, sidewalks, and driveways; less potential for damage to other utility lines (gas, electric, phone, cable, sewers); and facilitating delay of LSL replacements until they can be more efficiently and more cost-effectively performed in concert with future main rehabilitation or replacement projects. Thus, lining and coating technologies are potentially useful tools for reducing public exposure to lead in drinking water. Public water systems and property owners should be encouraged to evaluate their use, to the extent permitted by applicable regulations, in situations where significant cost savings and/or other benefits can be realized; and, where applicable, to incorporate their use into well organized, system-wide LSLR programs to help minimize costs and maximize benefits.

Three technologies are deemed to be especially promising and are therefore recommended for consideration by both public water systems and property owners: PET lining, epoxy coating, and polyurea/polyurethane coating. Each can effectively reduce or eliminate lead release, is commercially available, and is, or has been, certified for use in contact with potable water in the United States, Canada, and/or the UK. Each of these technologies involves materials that could potentially affect water quality by leaching certain constituents into the water; but that is true of every material that is used, or could conceivably be used, in water service lines. This issue has been effectively addressed for many years by requiring any material that may come into contact with potable water in a public water system to be certified as meeting NSF/ANSI Standard 61 (NSF 2016a).

Laboratory Experiments on Epoxy-Coated LSL and CSL Sections

The effectiveness of an epoxy coating in limiting lead release from LSLs was demonstrated in fill-and-dump experiments on 4-foor (ft.) lengths of LSLs. Lead in samples from a heavily disturbed, uncoated control LSL section ranged from 1,200 to 25,000 µg/L, whereas lead was non-detectable (≤0.5 µg/L) in 16 of 27 samples drawn from the epoxy-coated LSL sections. Only one sample (from the first extraction of one pipe section) had a lead concentration exceeding the AL, and when the same pipe section was extracted twice more, neither sample contained a detectable amount of lead. Epoxy coating also effectively limited release of copper from epoxy-coated CSL sections.

Freshly applied epoxy coatings exposed to chlorinated extraction water exerted a strong demand for free chlorine, with most of the chlorine being consumed in 6 hours (h). Similar results were observed for combined chlorine, for pipe sections stored wet or dry for 7 months, and for pipe sections repeatedly exposed to high concentrations of free chlorine. A significant chlorine demand associated with a lining or coating could potentially influence biofilm growth, disinfection byproduct formation, or other water quality parameters in a service line or downstream interior plumbing. The chlorine demand of the uncoated control pipe sections in the initial fill-and-dump experiments was similar to that observed in the epoxy-coated pipe sections, suggesting that, at least in some cases, the chlorine demand associated with an epoxy coating may have little or no net impact on water quality.

Freshly applied epoxy coatings leached an average of 0.58 mg/L of total organic carbon (TOC) into two extraction waters prepared using reagent water, but there was no significant change in average TOC concentration in dechlorinated pH 8 tap water. TOC leaching from epoxy coatings into water is expected to decrease to negligible levels over time.

Low concentrations of bisphenol A diglycidyl ether (BADGE) and two BADGE hydrolysis products were found to leach from freshly applied coatings of a BADGE-based epoxy. Two epoxy-coated pipe sections were stored wet for 7 months, with the water replaced with fresh reagent water every 7 days. When these pipe sections were again extracted, BADGE and one hydrolysis product were not detected in any of the samples, and the second BADGE hydrolysis product was detected in only a single sample, at a concentration slightly above the detection limit.

Leaching of BADGE is already addressed in NSF/ANSI Standard 61 (NSF 2016a), but additional experiments were conducted to examine: (1) how fast BADGE and bisphenol-F diglycidyl ether (BFDGE, another common epoxy ingredient) were hydrolyzing, which would affect human exposure to these compounds and their hydrolysis products;

(2) whether these compounds were reacting with free or combined chlorine to form byproducts; and (3) whether bisphenol A (BPA) was hydrolyzing or reacting with chlorine and therefore going undetected.

BADGE hydrolysis was studied as a function of pH (2–12) and temperature (15–40 °C). BADGE hydrolyzed to BADGE-H2O and then to BADGE-2H2O, the major end product under these conditions. Experimentally measured BADGE hydrolysis rates agreed well with modeled rates; thus, the model can be used to estimate BADGE concentrations remaining in water over time, facilitating exposure assessments. The half-lives of BADGE at pH 7 and 15, 25, 35, and 40 °C were found to be 11, 4.6, 2.0, and 1.4 days, respectively. At 25 °C and pH 2–12, BFDGE hydrolyzed at a rate very similar to that of BADGE, with a half-life of 5 days at pH 7 and 25 °C. No hydrolysis or decay of BPA was observed for reaction times up to 30 days for pH values of 2–12 at 25–40 °C.

Chlorination of bisphenols and BADGE was investigated using free chlorine and combined chlorine. BADGE was unreactive with free or combined chlorine at pH values of 7.6–9.0 at 25 °C, but the bisphenols reacted relatively rapidly with free chlorine at pH values of 3–12 at 10–25 °C. Estimated BPA half-lives for a free chlorine residual of 1 mg/L as Cl¬2 ranged from 3–35 minutes at pH values of 6–11 over the temperature range of 10–25 °C, but half-lives of 1–10 days were estimated for a monochloramine residual of 3.5 mg/L as Cl2 under similar conditions. These results, and a model based on them, can be used to characterize the concentrations of bisphenols and BADGE in drinking water distribution systems after leaching from epoxy coatings, thereby facilitating future risk assessments.

Laboratory Experiments on PET-Lined LSL and CSL Sections

In fill-and-dump experiments on PET-lined LSL and CSL pipe sections, very high lead and copper concentrations were found in samples drawn from the unlined (control) sections; lead increased by 1,400–21,000 µg/L, and copper by 310–910 µg/L, respectively. Only trace amounts of lead were found in the samples from PET-lined pipe sections. In one experiment, the average lead concentration in samples from PET-lined LSLs was 1.2 µg/L, and the average in samples from PET-lined CSLs was 1.3 µg/L. In a second experiment, the average lead concentration found in samples from PET-lined LSLs was 1.9 µg/L, and the average in samples from PET-lined CSLs was 1.0 µg/L. The lead levels found in both experiments were only slightly above the method detection limit (0.5 µg/L) and about an order of magnitude lower than the AL for Pb (15 µg/L). The investigators believe the traces of lead found in these samples came from the fittings used on the ends of the pipe sections (any effects of which would have been accentuated on relatively short LSL sections) and from inadvertent contamination during sample collection and handling, and not from lead permeating through the PET lining, which would not be expected to occur.

Samples from one experiment on PET-lined pipe sections were also analyzed for antimony (Sb), a common PET ingredient. Sb was detected in all but two samples, but the concentrations were very low. The average increase in Sb using dechlorinated pH 8 tap water as the extraction water was only 0.09 µg/L; the increases using chlorinated pH 8 and low pH (6.5) extraction waters were 0.09 and 0.29 µg/L, respectively; and the median increase for both LSLs and CSLs was 0.13 µg/L. The antimony concentrations in all of the samples were not only well below the MCL (6 µg/L) but also below the concentrations found in samples from the unlined LSL control section (0.42–3.94 µg/L). Thus, PET liners can actually reduce exposure to Sb if there is Sb present in the pipe being lined, as was the case in this study. PET liners and epoxy coatings can also serve as effective barriers against numerous other traces constituents found in pipe deposits.

There was no significant increase in TOC associated with the PET liners. None of the 10 phthalate esters determined using GC-MS, and none of the 3 phthalic acids determined using LC-MS/MS, were detected in any of the extraction water samples, nor were these compounds detected in solvent extracts of an unexpanded section of PET liner. The PET liners exhibited very little chlorine demand in the first set of fill-and-dump tests; only about half of the initial free chlorine residual of 2 mg/L as Cl2 was consumed after 96 hours. In subsequent tests, the chlorine demand dropped to less than 0.1 mg/L in 24 hours.

Experiences in the United States, Canada, and Elsewhere

When evaluating new technologies, or when developing or revising a program to address a complex and important challenge, it is often helpful to consider the experiences of others – what they have tried, what worked well and what did not, what could be done differently or better in the future, and what aspects or program elements are most applicable to the local situation being addressed. For this reason, brief case studies were prepared to describe the challenges faced by eight utilities in the United States and Canada in dealing with their LSLs, and to describe practices and experiences in other countries in lining, coating, and replacing lead and copper water service lines.

Over the past two decades there have been demonstration trials of PET lining and epoxy coating installations in LSLs in a number of locations in the United States, Canada, and elsewhere around the globe. More recently, a new polyurea/polyurethane coating designed for use in LSLs has been successfully demonstrated and approved for use in the UK. In the United States and Canada, few lining or coating installations in LSLs have been left in place, since most were done solely for demonstration purposes. In other locations, outside North America, larger trials have been conducted, and greater numbers of linings or coatings have been installed in LSLs that remain in service. One manufacturer reports having installed more than 100,000 PET liners in LSLs in France, and manufacturers of two different coating technologies (one using an epoxy product and the other a polyurea/polyurethane product) are reported to have recently signed contracts for tens of thousands of installations in the UK.

What is clear from these trials and installations, based on lead levels measured before and after the linings or coatings were installed, is that linings and coatings can and do effectively reduce lead leaching from LSLs. What is less clear is how many linings and coatings installed in LSLs remain in service, how long they have remained in service, and how well they have performed over time with respect to both effectiveness in controlling leads levels and physical durability. Attempts to obtain such information from utilities, manufacturers, and the literature were largely unsuccessful, apparently because retrospective studies on linings and coatings installed in LSLs are rare. However, the limited information available from studies of lined or coated LSLs, and from other studies involving related applications (e.g., epoxy coating of water mains), indicates that PET liners and epoxy coatings are durable and can be expected to remain effective for very long periods of time. These technologies are old enough that some installations have now been in place for more than 30 years, and manufacturers report that they are holding up well, although those contacted by the investigators said they were not aware of any retrospective studies on older installations of their products. The investigators have identified this as a research need that could potentially be addressed by well-designed surveys.

Applications/Recommendations

General Recommendations to All Stakeholders

It is now widely believed that no safe level of lead in drinking water can be established, that the public health goal for lead should therefore be zero, and that the health risks of lead exposure are greatest for those least able to protect themselves (i.e., those still in the womb, infants, toddlers, and young children). NDWAC (EPA 2015a) recommended removal of all lead services lines, all the way to the building wall, over a 30-year timeframe, and concluded that "[minimizing] exposure to lead in drinking water is a shared responsibility; public water systems, consumers, building owners, public health officials and others each have important roles to play." The authors agree with this assessment, recommend that all stakeholders give it careful consideration, and also recommend that manufacturers of LSL lining and coating systems be counted among the "others [having] important roles to play."

Linings and coatings can effectively reduce exposure to lead, on either a short-term or long-term basis, and should be considered by all stakeholders as viable tools that can be used for that purpose, where appropriate, taking their pros and cons into consideration on a site-specific basis. Any system-wide lead control or LSLR program is going to be full of challenges, and linings and coatings can potentially play an important role in meeting some of those challenges in a timely and cost-effective manner. Besides reducing exposure to lead, linings and coatings may also provide other water-related benefits, including:

- Corrosion control
- Leak repair
- Improved hydraulics (flow and pressure)
- Elimination of metal leaching from scale deposits
- Less favorable conditions for biological growth
- Improved aesthetic quality of water (taste and odor, clarity, color)

Other potential advantages of linings and coatings include:

- Fewer and shorter disruptions of vehicular and pedestrian traffic
- Reduced damage to landscaping, trees, sidewalks, and driveways
- Less potential for damage to other utility lines (gas, electric, phone, cable, sewers)
- Increased property value (relative to leaving an LSL in service)
- Cost savings relative to LSL replacement, especially where service lines are buried deep in the ground to avoid freezing, where the soil or subsoil is rocky, or where other factors render less expensive replacement methods impractical
- Facilitating delay of LSL replacements until they can be more efficiently and more cost-effectively performed in concert with water main rehabilitation and replacement projects

Potential disadvantages of linings and coatings include:

- Resurfacing of a lead problem in the future, if the lining or coating deteriorates, even if that happens many decades later, since the LSL remains in place
- Uncertainty regarding their service life, which though expected to be very long is likely to be known with less certainty than that of a new copper service line (though perhaps with no less certainty than the service life of alternative water service line materials, such as plastic pipe, being used or considered for use because of the high cost of copper)
- Any monitoring that may be required to verify continued performance
- Disparities between anticipated service life and warranty period
- Failure to meet future regulatory requirements
- Leaching of traces of various constituents into the water

Linings and coatings could potentially leach chemical constituents into the water, or fail to meet future regulatory requirements, but that is true of every material that is used, or potentially could be used, in water mains, service lines and interior household plumbing. The leaching concern is currently and effectively addressed by requiring materials in contact with drinking water, including plumbing materials and linings and coatings, to be certified as meeting NSF/ANSI Standard 61. The known health risks of lead exposure far exceed those associated with traces of other constituents that may leach from other plumbing materials, including linings and coatings. Thus, concerns about leaching of trace chemicals should not be used as an excuse to avoid lining or coating an LSL to reduce exposure to lead. Nevertheless, reasonable caution is recommended in selecting materials for applications involving materials that are difficult and expensive to replace, such as water service lines and household plumbing, in contrast to materials used above ground, such as exposed process piping and water treatment chemicals, which can be more readily replaced if the need arises.

Public water systems should recognize that the cost of replacing the privately-owned portion of an LSL will be very significant to most homeowners, especially those in less affluent neighborhoods. At the same time, public water systems need to recognize, and help property owners recognize, that the cost of replacing an LSL is typically modest compared to other costs of property ownership such as painting a house or building; putting new shingles on a roof; or replacing a major component of an aging heating, ventilating, and air conditioning system. Public water systems can help mitigate the impacts of LSLR expenses on property owners using creative financing arrangements, such as adding a small monthly charge to their water bill.

To minimize the cost of a full LSLR program, all stakeholders should work cooperatively to plan and implement a proactive system-wide approach, taking advantage of economies of scale and maximizing the productivity of the various work crews involved in scheduling, site preparation, traffic control, installation, and road and sidewalk repair. The approaches used by public water systems in Madison (WI), Lansing (MI), and Saskatoon (SK) are excellent examples of how to plan and implement a system-wide approach.

In planning a system-wide LSLR program, all stakeholders should evaluate using lining and coating technologies, if permitted under all applicable regulations, in locations where they have potential to generate significant cost savings or to provide other benefits. Examples include:

- Congested urban areas, where construction activities and traffic disruptions need to be minimized
- Locations where installing a new service line poses a safety risk, e.g., puncturing a gas line, cutting into an underground electrical wire, or damaging a communications cable serving a large office building
- LSLs connected to a water main, perhaps one in a congested urban area, that is not scheduled to be replaced for another 30-50 years
- Homes for which LSLR would pose a significant risk of damage to landscaping, other utility lines, or structures

Recommendations to Water Utilities and Their Consultants

Public water systems with LSLs should take the lead in working with all stakeholders to cooperatively plan and implement a proactive, system-wide LSLR program. The managers and employees of a public water system usually have a wealth of knowledge about their system and are already in communication with most, if not all, of the other stakeholders, who will be looking to the public water system to provide leadership. They will also bear primary responsibility for paying for the LSLR program and fairly allocating the costs among the rate payers.

Public outreach will be an extremely important means of informing consumers and property owners about their "shared responsibility," including financial responsibility for replacing privately owned portions of LSLs. Public water systems should provide information for consumers and property owners that emphasizes the importance of shared responsibility for minimizing exposure to lead, engages them in the planning process for the service area, clearly informs them about plans and progress to date, recommends actions they can or should take, and starts a dialog about possible financing options. Public water systems should recommend full LSLR, where reasonably possible, to consumers and building owners.

Public water systems developing (or revising) an LSLR program should involve regulatory stakeholders from the beginning of the planning process and maintain their involvement into the implementation phase. In the United States, the applicable regulations associated with the LCR are in flux, so all stakeholders, most especially public water systems with LSLs, would be well advised to keep abreast of proposed or newly promulgated regulations. Until the regulatory picture is clear, public water systems should approach with caution their use of any lining or coating system as part of their compliance strategy.

Public water systems are responsible not only for meeting the requirements of the LCR, but also for meeting state and local regulations, including building codes, that apply to their LSLR programs. State primacy agencies in the United States, and provincial regulatory agencies in Canada, may adopt policies or regulations that differ from those established or recommended at the federal level. As always, public water systems are strongly encouraged to ensure that any materials in their system, including linings and coatings, are certified to NSF/ANSI Standard 61 by an accredited certification body, and in most states and provinces this is legally required. Public water systems should also require post-installation testing of LSL linings and coatings for tap-water lead levels, adequate flow, and integrity (e.g., visual inspection using a high resolution mini-camera).

Public water systems should also engage manufacturers (or vendors) of lining and coating systems in the planning process, as well as contractors – if they plan to hire contractors to perform some or all of the work instead of doing all the work in-house using their own crews. The potential cost savings and other benefits associated with lining and coating technologies can be more effectively realized if they are evaluated ahead of time and incorporated into the program in an organized fashion, rather than considering them on a case-by-case basis, as individual situations are encountered where they might be advantageous. Both manufacturers and contractors are likely to have some excellent suggestions as to how a public water system can maximize the cost savings associated with lining and coating technologies.

For specific situations where full LSLR does not appear to be technically feasible, or economically or socially acceptable, lining or coating the customer-owned portion of the LSL should be considered as an option, if allowed under applicable regulations. During the planning process, public water systems should identify potential needs and/or opportunities for use of linings and coatings to reduce short-term and/or long-term exposure to lead, such as avoiding:

- Disturbances of historic sites or structures
- Environmental damage (e.g., to mature trees)
- Traffic disruption
- Interference with, or damage to, other utilities (gas, phone, cable, sewer, electric)

If such needs and/or opportunities exist for using linings or coatings, public water systems should take the lead in exploring them with all other stakeholders. As part of the exploration process, public water systems should assess their customers' attitudes on the following issues:

- Importance of (and willingness to pay for) minimizing exposure to lead
- Expected length of service interruptions for LSL replacements, linings, and coatings
- Disruptions to yards, trees, driveways, sidewalks, etc.
- Potential cost savings associated with linings or coatings
- Expected service life of new service lines versus lined or coated service lines
- Concerns about materials used in service lines

Epoxy coatings have been used in building plumbing systems for many years, in many countries, including the United States. However, the purpose of such coatings usually has little to do with lead. Coatings have primarily been used in building plumbing systems to control corrosion, repair leaks (especially pin-hole leaks in copper pipe), and improve the aesthetic quality of the water. Due to the growing recognition that lead can be released from interior plumbing, especially from corroded galvanized pipes, use of epoxy coatings primarily for lead control in buildings is likely to become more common in the future. While interior plumbing in buildings is not the responsibility of public water systems, building owners, public health officials, building inspectors, and others are likely to look to water utilities for information and guidance on lead control, use of epoxy coatings, potential impacts of materials on water quality, and related topics. Public water systems should strive to become more familiar with such matters to better serve their customers, and as a sign of their commitment to provide their communities with safe drinking water.

Recommendations to Consumers and Property Owners

The overwhelming majority of stakeholders are consumers and/or property owners, which could be collectively referred to as the water system's customers or the public; and they have a lot at stake. Consumers' health may be adversely affected by elevated lead levels, and property owners are usually financially responsible for replacing, lining, or coating the privately-owned portions of their LSLs. Consumers include not only bill-paying customers, but also children, tenants whose water bills are included in their rent, school teachers and students, occupants of office buildings (who may live outside the service area), visitors, and other members of the general public. The first thing consumers (especially bill-paying customers) and property owners should do is develop a general knowledge of drinking water in their communities, including lead levels in residences, schools, and office buildings. In most cases, this can be accomplished by reviewing the water system's annual Consumer Confidence Report (CCR) and other information posted on the system's website. Many water systems in communities with LSLs have posted at least some information about lead control on their websites; if not, consumers and property owners should request that they do so.

Home and building owners should determine whether or not they have LSLs. Materials developed to assist public water systems in developing LSLR programs also provide guidance for property owners to assist them in determining whether a home or other building has an LSL (AWWA 2014a). In many cases, this information will be available on the public water system's website if there are LSLs in their service area; if not, property owners should request that this information be made readily available. Property owners who have LSLs should consider full LSLR. Even though full LSLR is not currently mandated, it is a wise thing to do to protect themselves and their families, or their tenants or other occupants, as well as guests and future residents or occupants, from unnecessary exposure to lead. Property owners should recognize that although replacing their portion of an LSL is expensive, the cost is typically modest compared to other costs of home or building ownership. Full LSLR might also improve the value of the property in the long run. It would not be surprising to see, in the near future, information about LSLs included on disclosure forms for real estate transactions or included as part of property inspections. If full LSLR is not technically feasible, or economically or socially acceptable, property owners should investigate the possibility of lining or coating their portion of the LSL.

Many public water systems have already reached out to consumers and property owners, by means of billing inserts or website postings, to inform them about lead in their community, lead monitoring results, the presence or absence of LSLs in their service area, corrosion control practices, the status of any system-wide plans for lead control, any financial incentives or financing arrangements that are available to property owners wanting to replace their portion of an LSL, and recommendations for limiting exposure to lead, especially inside homes and buildings. Consumers and property owners whose water systems have not provided this information should request it, if LSLs are known to be present within the service area. Property owners with LSLs should consider taking advantage of any financial incentives their water systems offer to help property owners pay to replace their portion of an LSL.

Disturbing an LSL and/or the plumbing connected downstream from it is likely to cause temporarily increased lead levels that may persist for a month or two and perhaps as long as a year. Possible causes of disturbances include full or partial LSLR, lining or coating an LSL or a portion of it, and various other construction activities in the vicinity of an LSL, such as landscaping, foundation repair, or sprinkler installation. In the event of such a disturbance, consumers or property owners with LSLs should monitor their tap water for lead and/or filter their water (specifically the water used for drinking, cooking, and preparing beverages) using a filter designed (and certified to NSF/ANSI Standard 53 [NSF 2016b] for lead removal) to remove both particulate and dissolved lead, until the lead level is consistently within the recommended limits. Consult the public water system's website (or contact them directly if necessary) for information about lead monitoring (which they may be able to assist with, especially if they were involved in the disturbance, e.g., an LSLR) and for recommendations regarding filtration. All interior water lines should be thoroughly flushed any time a service line (whether or not it is an LSL) or other component of a plumbing system in a home or building is worked on by a plumber or contractor.

In homes and buildings having interior water lines heavily encrusted with lead-bearing deposits, especially interior plumbing made of galvanized iron pipe, the deposits may be releasing more lead into the water than an LSL, even if the LSL is the source of the lead that slowly built up inside the pipes over many years. Consumers and property owners who encounter such situations should either replace their interior plumbing with lead-free materials, coat their interior water lines to prevent lead leaching, or purchase NSF 53 certified water filters and carefully follow the operating and maintenance instructions.

Recommendations to State and Provincial Regulators

State and provincial regulators should assist public water systems in developing LSLR programs and other lead control strategies that minimize public exposure to lead in drinking water, meet all applicable regulations, and effectively utilize available tools that can contribute to this effort at a reasonable cost. Consistent with the NDWAC recommendations (EPA 2015a, b), full LSLR should be the preferred option for controlling lead associated with LSLs.

When replacing an LSL does not appear to be technically feasible, or economically or socially acceptable, lining or coating LSLs should be considered as an option, if allowed under applicable regulations. State and provincial regulators should help make both current and proposed regulations, including the aspects listed below, clear to other stakeholders with respect to both utility-owned and privately-owned segments of LSLs:

- Are linings and coatings allowed and, if so, under what conditions, and how are lined or coated LSLs treated with respect to compliance requirements?
- If full LSLR is mandated, will exceptions or exemptions be granted permitting the use of linings and coatings in situations where exposure to lead can be more rapidly controlled; where significant savings can be realized; or where damage to historic sites, landscaping, structures, or other utility lines can be avoided?
- If public water systems and/or property owners can apply for exception or exemptions, will they be permanent or temporary, and what criteria will be used to decide whether to approve exceptions or exemptions?
- What monitoring requirements apply to lined or coated LSLs?

Recommendations to Manufacturers and Contractors

Manufacturers of lining and coating technologies, and their representatives, including local contractors licensed to install their products, should familiarize other stakeholders with their technologies, the potential benefits they can provide, and the situations in which they are most likely to provide significant cost savings or other benefits. As manufacturers know, and should be prepared to help public water systems and other stakeholders recognize, LSL lining and coating costs depend heavily on the number of LSLs to be lined or coated, where they are located, and how they are scheduled. In other words, there are significant economies of scale involved, and much greater cost savings can be realized if the LSLs can be lined or coated as part of a well-organized, system-wide program that most likely will also include full and/or partial LSLRs.

To promote their products while also helping communities minimize exposure to lead in drinking water, manufacturers of linings and coatings and their representatives are encouraged to:

- Recognize that a disparity between the expected service life of a product and the warranty period can be a stumbling block for other stakeholders
- Document and publicize supporting information regarding product service life
- Consider increasing warranty periods, when appropriate, and finding creative ways to share real or perceived financial risks in partnership with other stakeholders
- Continue to develop new or improved products and faster, better, and less disruptive installation methods
- Encourage public water systems to adopt a proactive system-wide approach for controlling lead release from LSLs, and to take advantage of the potential cost savings and other benefits of lining and coating technologies
- Consider installing sampling taps at selected locations to facilitate performance monitoring of lined or coated LSLs, since tap-water samples may be contaminated with lead from sources other than the LSLs, making it difficult to document the true effectiveness of linings or coatings

- Place a permanent tag on a lined or coated water service line to alert water utility crews, residents, and plumbers to the need to properly handle it when making repairs to the service line or other pipes, fittings, or devices connected to it

Related WRF Research

- Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues, project #3018
- Controlling Lead in Drinking Water, project #4409
- Evaluation of Lead Sampling Strategies, project #4569
- Galvanic Corrosion Following Partial Lead Service Line Replacement, project #4349

