THE Water Research FOUNDATION

Lead & Copper

THE CHALLENGE

The primary drinking water corrosion contaminants of concern from service lines and household plumbing are lead and copper. Lead is a toxic metal that can be harmful to human health even at low exposure levels. Because it is persistent, it can bioaccumulate in the body over time. Young children are particularly vulnerable to lead because the physical and behavioral effects of lead occur at lower exposure levels in children than in adults. A dose of lead that would have little effect on an adult can have a significant effect on a child. Excess amounts of copper can also pose health problems. People who drink water containing copper in excess of 1.3 mg/L may experience short-term nausea, while long-term exposure can affect the liver and kidneys.

Lead is rarely found in source water and usually enters drinking water through corrosion of service lines and household plumbing. Lead at the tap can come from a variety of sources, including lead service lines (LSLs), lead piping inside the home, lead-based solder, and brass components. The concentrations of lead and copper in water are regulated by the U.S. Environmental Protection Agency's (EPA) Lead and Copper Rule (LCR).

THE RESEARCH

Since the late 1980s, WRF has funded over 50 research projects related to lead and copper corrosion valued at approximately $20M. This body of research provides an understanding of the issues surrounding lead and copper corrosion and the LCR. Topics covered in this portfolio include LCR compliance, corrosion control strategies, water chemistry effects on corrosion, treatment impacts on lead and copper corrosion, and material effects on lead and copper release.

Because of the important public health implications of lead and copper in drinking water, WRF has partnered with EPA, UK Water Industry Research (UKWIR), the American Water Works Association (AWWA), and the National Science Foundation (NSF) on this research.

In addition, WRF is a member of the Lead Service Line Replacement Collaborative, which brings together public health, utility, environmental, consumer, and housing organizations to advocate for full replacement of LSLs through collective local efforts. The Collaborative disseminates information on LSL replacement practices and provides guidance on developing service line inventories, communication resources, policies, and more.

Occurrence and Compliance

In 1991, EPA published the LCR, which is meant to protect public health by minimizing lead and copper levels in drinking water. Since that time, it has undergone several revisions. However, even before the original release of this rule, WRF has been at the forefront of the issue, helping water utilities understand the presence of these compounds in our water systems, prevent leaching, comply with current and pending regulations, and ultimately protect public health.

LEAD & COPPER REGULATORY FRAMEWORK

	Lead	Copper
Action Level	**0.015 mg/L (based on treatment feasibility)**	**1.3 mg/L (based on prevention of potential health problems)**
Maximum Contaminant Level	**N/A**	**N/A**
Maximum Contaminant Level Goal	**0**	**1.3 mg/L (based on prevention of potential health problems)**
Secondary Maximum Contaminant Level	**N/A**	**1.0 mg/L (based on aesthetics or taste and staining)**

Source: U.S. Environmental Protection Agency. 2008. *Lead and Copper: A Quick Reference Guide.* EPA 816-F-08-018.

In 1990, WRF took the proactive step of publishing *Lead Control Strategies* (406). At the time, EPA guidance on LCR treatment plans was lacking, and this guidance manual filled the gap by helping utilities develop lead control strategies. The project identifies potential sources of lead in customer plumbing and variables that control the rate of leaching and lead in water samples, including the age and type of material, workmanship, size of pipe, water quality, size of the water sample, and stagnation time. The manual also provides practical considerations for controlling lead leaching from chemical treatment processes. The research determined that the most important water quality parameters for lead solubility are pH, alkalinity, dissolved inorganic carbonate, and orthophosphate levels. The manual recommends controlling lead with pH adjustment, alkalinity adjustment, and orthophosphate addition.

Lead in drinking water at the customer tap is almost exclusively the result of water contact with lead-containing components in the distribution system or household plumbing. If these lead-containing materials are present in the system, and the water causes corrosion through contact, lead can be released in a soluble or insoluble form, depending on the water chemistry. In 2015, WRF released *Controlling Lead in Drinking Water* (4409), which helps utilities understand why lead is present at the tap and how it can be prevented—breaking down the chemistry of the water that determines both of these factors. The research explores water chemistry parameters (e.g., pH, alkalinity, disinfectant residuals) and describes how they can be manipulated or accounted for in drinking water systems to control lead levels at the customer tap. The most common methods to minimize lead in drinking water are adjusting the water chemistry to produce stable water quality conditions that inhibit lead release, high-velocity flushing (especially inside the home) to remove particulate lead, and removing service lines and plumbing materials that contain lead. The report also describes an example of a lead service line replacement strategy.

Corrosion Control Strategies

To control corrosion and minimize lead levels in drinking water, utilities have several treatment strategies to choose from, including (but not limited to) flushing and treating with phosphate-based chemicals. However, water quality differences can significantly impact the effectiveness of these strategies.

Evaluation of Flushing to Reduce Lead Levels (4584) assesses the impact of high-velocity flushing (HVF) on the removal of lead from service lines and premise plumbing, and the subsequent impact on at-the-tap lead concentrations. The goals of the project were not only to see if HVF could successfully reduce lead levels at the tap, but also to see how frequently flushing needs to be repeated to maintain lead reduction. The research includes guidance to help utilities perform in-home tap flushing following a service line disturbance (i.e., a partial or full service line replacement). It also addresses flushing duration, frequency, and different options depending on the type of lead being released (dissolved or particulate).

The research shows that HVF is not recommended for houses without a preceding disturbance (e.g., lead service line replacement or other triggering disturbance), under the conditions tested in this study, since HVF creates disturbed conditions that would otherwise not be present. HVF is, however, recommended following partial or full lead service line replacement. The data from this study indicate that the use of HVF after these types of disturbances results in lower lead levels at consumer faucets, but not always right away—some time may elapse before improvements in lead levels are detected. Therefore, consumers should be instructed to take precautionary measures until the data indicate that lead levels have been reduced.

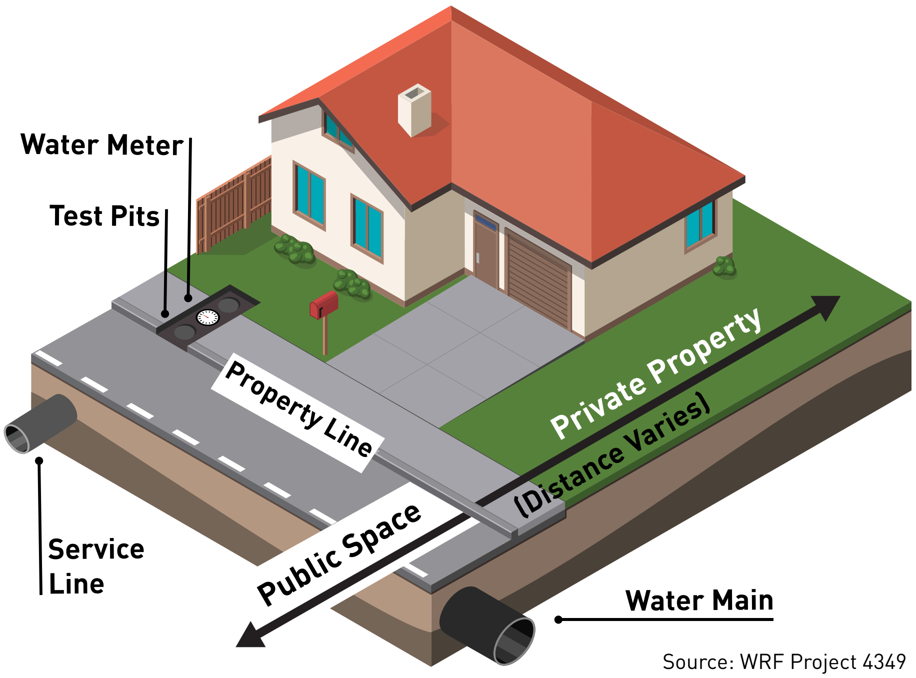
Many utilities rely on phosphate treatment strategies to protect against corrosion and lead leaching into distribution systems, but drinking water utilities are beginning to realize that the use of these chemicals can have unintended consequences for wastewater treatment plants downstream. In 2017, WRF published *Optimization of Phosphorus-Based Corrosion Control Chemicals Using a Comprehensive Perspective of Water Quality* (4586). This project assesses the impact of phosphates on the environment and on wastewater treatment facilities after the phosphates have left the drinking water system. The findings emphasize a comprehensive perspective for control of distribution system water quality issues, including lead and copper release. In this perspective, all distribution system water quality issues are interrelated; they are all manifestations of the complex interactions between a complex solution of water and a complex composition of pipe wall accumulations.

Utilities contemplating the use of a phosphate-based corrosion-control chemical should begin a dialogue with the associated wastewater treatment facility personnel. The report lists steps for evaluating the impact of corrosion-control strategy on meeting phosphorus discharge limits. Utilities should consider the impact of the phosphate on the receiving body of water, especially using the phosphorus discharge limits determined by regulatory agencies.

Service Lines and Plumbing Fixtures

Lead service lines (LSLs) and plumbing fixtures are a topic of high interest for utilities, and a top priority for WRF research. *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* (3018) helps utilities understand the contributions that various lead-based materials in premise plumbing may have on lead levels measured at the tap, specifically premise piping, service lines, faucets, and meters. The research found that lead source contributions are influenced by the physical characteristics of the source (i.e., length, diameter, surface area, etc.), water quality conditions, water use and hydraulic patterns, and mixing and dilution effects as the water flows during sampling.

The most effective way to reduce the total mass of lead measured at the tap is to replace the entire lead service line, followed by replacing lead sources in the premise plumbing, the faucet, and then the meter. Replacement of faucets and end-use fittings may or may not improve lead levels at the tap; however, it may be appropriate at sites without lead service lines that experience elevated lead levels in



Source: WRF Project 4349

FIGURE 1. SERVICE LINE OWNERSHIP
The ownership of service lines between the utility (public space) and homeowner (private property) presents a challenge to full service line replacement.

first-draw samples. Elevated lead levels may occur immediately after lead source replacement and may persist for longer periods, dependent on the materials and water quality at each site, and the amount of disturbance during replacement.

Under the current LCR, water systems that are unable to reduce their lead levels after implementing various treatment techniques are required to replace at least 7% of LSLs in their distribution system annually. A water utility is only required to replace sections of service lines that it owns. If a system does not own the entire LSL, then the system is not required to replace the privately owned portion. This results in a partial lead service line replacement (PLSLR). Figure 1 highlights the discrepancy between utility and privately owned service lines. In this example, service line ownership changes at the property line. This is a simplified representation and the actual ownership can vary by utility.

Lead and copper will continue to be concerns as long as drinking water pipes and fittings contain those materials.

WHAT'S NEXT?

In 2017, WRF initiated a research priority area specifically dedicated to lead and copper management. This research will continue to evaluate service line disturbance challenges, explore corrosion control methods, investigate remediation strategies for large buildings with lead problems, assess sampling protocols for lead and copper, and provide resources for utilities to communicate with their stakeholders on lead and copper issues.

An ongoing project funded in this area, *Full Lead Service Line Replacement Guidance* (4713) is evaluating strategies to reduce lead exposure after conducting full lead service line replacements (FLSLRs). The research will provide accurate and easily understood guidance and reference materials for staff at any U.S. or Canadian water system to use when planning and implementing FLSLRs. The research team will conduct a literature review of current information related to limiting lead release following lead service line disturbances and evaluate the effectiveness of flushing to reduce lead exposure following FLSLRs at single-family homes. The research will also identify lessons learned from utilities that have monitored lead release following FLSLRs. Participating utilities will conduct field studies at over 100 locations during this project. This project is scheduled to be completed in 2020.

While it is well known that lead exposure at customer taps can come from lead pipes, leaded solder, and brass fittings and fixtures, galvanized iron pipes (GP) can also contribute to lead exposure at customer taps. Recent studies have shown the potential for GPs to be a source of lead, especially if the GPs are downstream of a source of lead. However, even if there is no upstream lead source, GPs can contain up to 2% lead in the zinc coating and contribute to lead in drinking water levels. In addition, accumulated lead can remain in GPs after the removal of any upstream lead sources. Funded in 2018, *Evaluating Key Factors that Affect the Accumulation and Release of Lead from Galvanized Pipes* (4910), will develop cutting-edge tools to evaluate links between GPs and lead release. The research team will scientifically assess customers' concerns related to GP corrosion and possible association with lead in water, characterize the nature of iron and lead release to drinking water from known sources, and examine iron and lead release from GP using bench-scale testing. In addition, public education materials will be developed related to GP and lead release.