THE Water Research FOUNDATION®

Lead and Copper Corrosion: An Overview of WRF Research

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THIS OVERVIEW PROVIDES A LIST of ongoing and completed Water Research Foundation (WRF) research projects related to Lead and Copper corrosion.

Background

IN 1991, THE U.S. ENVIRONMENTAL Protection Agency (EPA) published the LCR, which established that all community water systems (CWSs) and non-transient non-community water systems (NTNCWSs) would be subject to the rule requirements. The primary purpose of the LCR is to protect public health by minimizing lead (Pb) and copper (Cu) levels in drinking water. Pb and Cu enter drinking water mainly from corrosion of Pb- and Cu-containing plumbing materials. A unique aspect of the LCR is that lead and copper have action levels (AL) of 0.015 mg/L for lead and 1.3 mg/L for copper, and therefore do not have Maximum Contaminant Levels (MCLs). The action level for lead is a screening technique for optimal corrosion control based on treatment feasibility, and is not a health-based threshold. The action level for copper does have a health reference based on the prevention of nausea. Copper also has a secondary MCL (SMCL) of 1.0 mg/L, which is based on aesthetics (taste and staining). Table 1 highlights the different regulatory levels of Pb and Cu.

Table 1. Lead and copper regulatory framework

	Copper	Lead
AL (mg/L)	1.3	0.015
Health Based Action Level	Yes	No
MCL	N/A	N/A
MCLG (mg/L)	1.3	0
SMCL (mg/L)	1.0	N/A

The LCR requires a one-liter first draw sample to be taken after a minimum six-hour stagnation time, and homeowners are allowed to take this sample at the customer tap. The LCR has a sample site tiering system, prioritizing the selection of sampling sites based on the likelihood of the sites to release lead and copper. If an action level is exceeded in more than ten percent of samples collected at customers' taps, then further action is required. These additional actions can include source water monitoring and treatment, public education, and lead service line replacement. The EPA provides more information on the Lead and Copper Rule on their website. In January 2021 a revised Lead and Copper Rule was published in the Federal Register. On June 10, the EPA extended the effective date of the LCR revisions to December 16, 2021. This overview paper will be updated once the revised LCR has been finalized.

Since the late 1980s, WRF has funded over 50 research projects related to lead and copper corrosion valued at more than 20 million. All projects with Pb and Cu corrosion implications are listed below.

List of Published and Ongoing Research Projects

THIS LIST CONTAINS PUBLISHED and ongoing WRF research projects related to lead and copper corrosion. The project titles contain hyperlinks that will direct you to the WRF project page. From the project page on the WRF website, you can view general project information and download reports for completed projects. If available, you can also view project updates, the scope of work, webcast recordings, and other project-related resources. Project pages can also be found by typing the project number in the search bar from the waterrf.org homepage.

Report Title	Year Published	Project #	Principal Investigator
Using Phosphate-Based Corrosion Inhibitors and Sequestrants to Meet Multiple Water Treatment Objectives	research ongoing	5119	TBD
Guidance for Using Pipe Loops to Inform Lead and Copper Corrosion Control Treatment Decisions	research ongoing	5081	Cornwell (Cornwell Engineering Group)
Analysis of Corrosion Control Treatment for Lead and Copper Control	research ongoing	5032	Cornwell (Cornwell Engineering Group)
Development of a Community-Based Lead Risk and Mitigation Model	research ongoing	4965	Cornwell (Cornwell Research Group)
Evaluating Key Factors that Affect the Accumulation and Release of Lead from Galvanized Pipes	research ongoing	4910	Edwards (Virginia Tech)
Full Lead Service Line Replacement Guidance	2021	4713	Brown (Cornwell Engineering Group)
Evaluation of Lead Pipe Detection by Electrical Resistance Measurements	2020	4698	Jallouli (Imperia Engineering Partners)
Service Line Material Identification Techniques	2020	4693	Bukhari (American Water)

Report Title	Year Published	Project #	Principal Investigator
Processes Controlling the Time for Orthophosphate to Achieve Effective Corrosion Control	2019	4686	Giammar (Washington University in St. Louis)
Corrosion of Nonleaded Pump Impeller Alloys in Chlorinated Potable Water	2018	4658	Edwards (Virginia Tech)
Evaluation of Flushing to Reduce Lead Levels	2018	4584	Cornwell (EET)
Optimization of Phosphorus-Based Corrosion Control Chemicals Using a Comprehensive Perspective of Water Quality	2017	4586	Cantor (Process Research)
Evaluation of Lead Service Line Lining and Coating Technologies	2017	4351	Randtke (University of Kansas)
Evaluation of Lead Line Sampling Strategies	2015	4569	Cornwell (EET)
Controlling Lead in Drinking Water	2015	4409	Brown (EET)
Non-Intrusive Methodology for Assessing Lead and Copper Corrosion	2014	4317	Edwards (Virginia Tech)
The Performance of Non-Leaded Brass Materials	2014	4191	Klinger (TZW)
Application of Filters for Evaluating Lead and Copper Concentrations in Tap Water	2013	4415	Cantor (Process Research Solutions)
Galvanic Corrosion Following Partial Lead Service Line Replacement	2013	4349	Welter (O'Brien and Gere)
Distribution System Water Quality Control Demonstration	2012	4286	Cantor (Process Research Solutions)
Is NSF 61 Relevant for Chloraminating Utilities?	2012	4243	Sandvig (The Cadmus Group)
Lead (IV) Oxide Formation and Stability in Drinking Water Distribution Systems	2012	4211	Giammar (Washington University in St. Louis)
Comparison of Zinc vs. Non-Zinc Corrosion Control for Lead and Copper	2011	4103	Schneider (American Water)
Copper Pitting and Brass Dezincification: Physical and Chemical Effects	2011	4289	Edwards (Virginia Tech)
Lead and Copper Corrosion Control in New Construction	2011	4164	Edwards (Virginia Tech)
Chloride to Sulfate Mass Ratio (CSMR): Changes from Water Treatment and its Impact on Lead Leaching in Potable Water	2010	4088	Edwards (Virginia Tech)
Influence of Water Chemistry on the Dissolution and Transformation Rates of Lead Corrosion Products	2010	4064	Giammar (Washington University)
Contribution of Galvanic Corrosion to Lead in Water After Partial Lead Service Line Replacements	2010	4088b	Edwards (Virginia Tech)
Secondary Impacts of Corrosion Control on Distribution System and Treatment Plant Equipment	2010	4029	Grigg (Colorado State University)
Investigation of Stannous Chloride as an Inhibitor of Lead Corrosion	2010	3174	Hozalski (University of Minnesota)
The Role of Free Chlorine, Chloramines, and NOM in the Release of Lead into Drinking Water	2009	3172	Valentine (Iowa State University)
Decision Tool to Help Utilities Develop Simultaneous Compliance Strategies	2009	3115	Schendel (Malcolm Pirnie, Inc.)
Impact of Phosphate Corrosion Inhibitors on Cement-Based Pipes and Linings	2008	4033	Atassi (CDM) and Edwards (Virginia Tech)
Performance and Metal Release of Non-Leaded Brass Meters, Components, and Fittings	2007	3112	Sandvig (HDR/Economic and Engineering Services, Inc.)
Impact of Change in Disinfectants on Lead, Brass, and Copper Components in the Distribution System - (2 Reports) *Part 1 (Literature Review)* *Part 2 (Lab, Pipe Loop and Field Studies)*	Part 1-2006 Part 2-2010	Part 1-91152 Part 2-3107	Boyd (HDR)
Non-Uniform Corrosion in Copper Piping - Monitoring Techniques	2008	3109	Edwards (Virginia Tech)
Contribution of Service Line and Plumbing Fixtures to LCR Compliance Issues	2008	3018	Kirmeyer (HDR/Economic and Engineering Services, Inc.)
Assessment of Non-Uniform Corrosion in Copper Piping	2008	3015	Edwards (Virginia Tech)
Enhanced Coagulation Impacts on Water Treatment Plant Infrastructure	2004	2687	Edwards (Virginia Tech)

Report Title	Year Published	Project #	Principal Investigator
Optimizing Chloramine Treatment (2nd Edition)	2004	2760	Kirmeyer (Economic and Engineering Services, Inc.)
Optimizing Corrosion Control in Water Distribution Systems	2004	2648	Duranceau (Boyle Engineering Corp.)
Post-Optimization Lead and Copper Monitoring Strategies	2004	2679	Kirmeyer (Economic and Engineering Services, Inc.)
Role of Phosphate Inhibitors in Mitigating Lead and Copper Corrosion	2001	2587	Edwards (Virginia Tech)
Distribution System Water Quality Changes Following Corrosion Control Strategies	2000	157	Kirmeyer (Economic and Engineering Services, Inc.)
Lead Pipe Rehabilitation and Replacement Techniques	2000	465	Kirmeyer (Economic and Engineering Services, Inc.)
Corrosion and Metal Release for Lead-Containing Plumbing Materials: Influence of NOM	1999	182	Korshin (University of Washington)
A General Framework for Corrosion Control Based on Utility Experience	1997	910	Reiber (HDR Engineering)
Internal Corrosion of Water Distribution Systems	1996	725	N/A
Role of Inorganic Anions, NOM, and Water Treatment Processes in Copper Corrosion	1996	831	Edwards (University of Colorado – Boulder)
Innovative Techniques for Lead Service Line Location	1995	813	Weston Solutions, Inc.
Development of a Pipe Loop Protocol for Lead Control	1994	604	Kirmeyer (Economic and Engineering Services, Inc.)
Chloramine Effects on Distribution System Materials	1993	508	Reiber (HDR Engineering)
Evaluation of the Effects of Electrical Grounding on Water Quality	1994	714	CH2M Hill
Lead Control Strategies	1990	406	EES, Inc.