Elevated Lead in D.C. Drinking Water: A Study of Potential Causative Events

EPA is releasing a report with the results of an extensive study evaluating factors that contributed to elevated levels of lead in drinking water for many residents served by the District of Columbia Water and Sewer Authority in the early part of the decade. EPA identified the need to perform this analysis to document, to the extent possible, the cause or causes of elevated lead in D.C. drinking water in order to help other water utilities avoid similar situations.

Why did EPA do this study?

The District of Columbia Water and Sewer Authority (DCWASA) owns and operates a system that delivers water produced by the U.S. Army Corps of Engineers Washington Aqueduct (WA) to customers in Washington, D.C. During compliance monitoring for the Lead and Copper Rule (LCR) in July 2000 through June 2001, DCWASA exceeded the 15-μg/L action level (AL) for lead at the 90th percentile in home tap sampling. DCWASA repeatedly exceeded the AL during subsequent monitoring through the period ending in December 2004. EPA decided to have an independent in-depth analysis performed that would document and determine, to the extent possible, the source(s) and cause(s) of elevated lead levels at Washington, D.C. consumers' taps.

What did the study find?

The authors concluded that a combination of factors – not a single source or a single causative event – contributed to the problematic release of lead in water at consumers' taps in the D.C. Water and Sewer Authority (DCWASA) system. The primary source of lead release was attributed to the presence of lead service lines (LSLs) in the DCWASA service area. Since the mid-1990s, three notable occurrences in the DCWASA system likely contributed to elevated lead releases during 2000 through 2004:

(1) Increased chlorine residual dosing in the mid-1990s
(2) pH variations and low operating pH in the distribution system
(3) Conversion from free chlorine to chloramines for final disinfection

Why was the free chlorine residual increased in the mid-1990s?

In the mid-1990s, the concentration of residual free chlorine was increased to 4.0 mg/L, and subsequently maintained in the range of 2.2 to 3.2 mg/L, for the purpose of controlling coliform occurrence in the water distribution system.

How did high free chlorine residual contribute to the elevated lead levels?

Relatively high free chlorine concentrations likely facilitated the formation of Pb(IV) scales in the form of lead dioxide (PbO_2) in lead service lines. The conventional understanding that forms the basis for the LCR assumes the presence of Pb(II) as the dominant scales. Lead scales on the interior of lead service lines are likely comprised of various forms of lead, including both Pb(II) and Pb(IV), and the chemical composition of the scales likely changes with varying water quality conditions. Lead dioxide scales generally exhibit relatively low lead solubility under high oxidation reduction potential along with normal ranges of pH and alkalinity in public water systems when compared with Pb(II) compounds. Once the oxidation reduction potential of the water decreased (caused by the switch from high free chlorine to chloramines) it likely changed the nature of the predominant scale from Pb(IV) to Pb(II) and thus facilitated an increase in the release of lead from the lead service lines into the water at consumers' taps. Oxidation reduction potential provides an indication of a solution's ability to oxidize or reduce another material.

How did pH levels contribute to the elevated lead levels?

The pH of the water is an important factor in the control of lead solubility. The pH of the distributed water in Washington, D.C. exhibited seasonal variations that fluctuated from approximately 7.0 to 8.9 during 1992 to 2004. The pH levels at the lower end of this range are not considered optimal for lead corrosion control based on the conventional understanding of lead solubility per the LCR, assuming that Pb(II) is the dominant form of scales.

In Washington D.C., relatively high free chlorine concentrations applied to the service area during the mid-1990s likely facilitated the formation of Pb(IV) as the dominant scale. Pb(IV) exhibits relatively low lead solubility at the lower pH levels experienced in the DCWASA system. Consequently, lead levels were low during LCR compliance monitoring during the mid-1990s.

How did the conversion to chloramines contribute to the elevated lead levels?

This conversion facilitated a reduction in oxidation reduction potential (ORP) to a range that favors the predominance of Pb(II) scales. Pb(II) species generally are highly influenced by low and fluctuating pH levels. This conversion from free chlorine to chloramines likely facilitated the release of lead in water while the system was operating with fluctuating pH conditions that were, at times, lower than what would have been expected to control Pb(II) solubility.

Why did the Washington Aqueduct switch from free chlorine to chloramines for final disinfection?

The residual disinfectant conversion was implemented primarily for the purpose of lowering disinfection byproducts to avoid health risks associated with these byproducts. There are a number of operational and compliance benefits to using chloramines. Chloramines can provide the following benefits:

- Since chloramines are not as reactive as chlorine, they form fewer disinfection byproducts. Some disinfection byproducts, such as the trihalomethanes (THMs) and haloacetic acids (HAAs), may have adverse health effects and are closely regulated.
- Because a chloramine residual is more stable and longer lasting than free chlorine, it provides better protection against bacterial regrowth in systems with large storage tanks and dead-end water mains.

- Chloramines, like chlorine, are effective in controlling biofilm, which is a coating in the pipe caused by bacteria. Controlling biofilm also tends to reduce coliform bacteria concentrations and biofilm-induced corrosion of pipes.
- Because chloramines do not tend to react with organic compounds, many systems will experience fewer taste and odor complaints when using chloramines.
- Chloramine technology is relatively easy to install and operate. It is also among the less expensive disinfectant alternatives to chlorine.

Because of this switch, THM levels reported by DCWASA have decreased from a high quarterly average value of 84 ppb in 1999 to 46 ppb in 2006. The highest single samples collected by the utility also decreased from 207 ppb in 1999 to 85 ppb in 2006.

What have DCWASA and WA done to address the problem of elevated lead levels?

DCWASA and WA, in conjunction with the USEPA and a Technical Expert Work Group, conducted a series of studies to identify solutions to reduce and control lead levels at consumers' taps. As part of these studies, DCWASA conducted a partial system application of the corrosion inhibitor orthophosphate in a portion of the distribution system beginning on June 1, 2004. Based on results of this demonstration test, orthophosphate was subsequently added as treatment at the WA water treatment facilities to cover the entire DCWASA system beginning August 23, 2004 for the purpose of lowering lead levels at the tap. Based on recent compliance monitoring information, DCWASA has been below the LCR lead action level since the first full monitoring period after commencing system-wide addition of orthophosphate.

What is EPA doing to make sure this does not happen again?

EPA is addressing concerns with the impact of treatment changes on corrosion control in the proposed short-term revisions to the LCR and in the *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules*. One of the proposed revisions to the LCR requires that systems provide advanced notification prior to and receive State approval for treatment changes or additions of new water sources. The rule was proposed in 2006 and should be released as final in the fall of 2007.

The *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules* (http://www.epa.gov/safewater/disinfection/stage2/compliance.html) provides recommendations to systems that are switching to a different residual disinfectant in order to minimize increases in the rate of lead and copper corrosion:

- The water system should perform an optimal corrosion control treatment study prior to introducing chloramines into the distribution system.
- Add chemicals to the finished water to form a protective coating on the pipes, such as an orthophosphate corrosion inhibitor.
- Optimize the chloramination process to minimize the possibility of nitrification that can reduce pH and increase corrosion.

Also, in addition to its own research, EPA is evaluating studies from the open literature to determine how changes in treatment can impact the corrosion of lead in pipes and household plumbing.

Do the report findings or recommendations suggest any major problems with the Lead and Copper Rule?

The report findings do not suggest that there are problems with the LCR. However, EPA is identifying research needs associated with the impacts of treatment changes on lead corrosion in drinking water systems and the formation of different types of lead scale formation. EPA will consider new information and research findings when making long-term changes to the rule. EPA is addressing concerns with the impact of treatment changes on corrosion control in the proposed short-term revisions to the LCR and in the *Simultaneous Compliance Guidance Manual for the Long Term 2 and Stage 2 DBP Rules.*

How did EPA assure an independent review for this study?

EPA contracted with an engineering firm to analyze the data and draw conclusions for the report. Additionally, prior to completion of the report, it underwent an independent peer review. The final document incorporates the comments received as a result of the peer review and includes the actual comments from peer reviewers in an appendix.

Where can I find additional information?

The report, *Elevated Lead in D.C. Drinking Water: A Study of Potential Causative Events*, is available on EPA's Web site on the Lead and Copper Rule page at http://www.epa.gov/safewater/lcrmr/lead_review.html. The site also includes summaries of EPA's evaluation of monitoring data for utilities provided by state drinking water programs and summaries of expert workshops conducted through 2005. The site also has links to EPA's proposed revisions to the LCR and guidance to help implement the rule.