Lead and Copper Corrosion Control in New Construction [Project #4164]

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OBJECTIVES:
This purpose of this project was to develop guidance to install and commission new building plumbing systems and specifically answer the following questions:

- What flushing recommendations would remove ammonia, zinc, and high chloride due to flux from plumbing lines, along with metallic debris and solvents?
- Can more frequent flushing assist in passivation of lead leaching from new brass?
- To what extent do residual PVC solvents and flux contribute to initiation of nitrification in premise plumbing?
- Do current shock chlorination practices damage plastic and/or copper plumbing systems?

BACKGROUND:
The USEPA Lead and Copper Rule (LCR) targets lead leaching in older high risk homes containing lead solder and lead pipe, although it is acknowledged that these older homes tend to be amongst the lowest risk test sites relative to copper leaching or lead leaching from brass (USEPA 1993). Indeed, there have been several recent cases in which new buildings and homes in a potable water distribution system tested for lead and copper well over USEPA action limits, yet the utility was complying with the LCR via optimized corrosion control (a couple of these are detailed in Chapters 4 and 7 of this report). Moreover, the Lead and Copper Rule does not address problems such as copper pinhole leaks or dezincification of brass, which are important emerging concerns even in new construction. In some cases, optimal corrosion control will reduce the extent of these problems, but in other instances (such as higher pH), the optimal corrosion control program could exacerbate certain types of copper problems including blue water and pinhole leaks (Edwards et al. 2000, Rushing and Edwards 2004, Lytle and Schock 2008).

Beyond lead and copper corrosion, it is believed that new plumbing construction practices can cause problems with drinking water aesthetics (taste and odor) and contribute to reduced lifetime of the plumbing system. The installation procedures, types of materials used, and flushing protocols following post-installation can influence the persistence of these problems, as well as the general corrosivity of the water in new plumbing. Many of these problems might be avoided if useful guidance became available on how to install and commission such systems.

Shock chlorination is a practice used to disinfect water mains after installation or repair. This procedure is guided by the ANSI/AWWA C651 Standard that specifies methods of disinfection. All methods include exposing the pipe to very high levels of chlorine, up to 300 mg/L. This
practice is now starting to be required by building codes for new construction. The corrosivity of the water and the plumbing material can influence whether required chlorine residuals can be maintained over the specified time.

From a utility perspective, in a few cases it appears that changes in disinfectant regime from chlorine to chloramine has hindered the passivation of newer copper pipes, relative to older pipes in the distribution system once exposed to free chlorine. The result is that some neighborhoods of newer homes have persistent problems with blue water and blue staining due to high copper leaching.

**APPROACH:**
Three phases of research were conducted for this project. The first examined the efficacy of flushing to remove residual flux, debris, and solvents from plumbing lines, and developed flushing protocols that can passivate brass and copper surfaces soon after installation. A second phase of research examined aspects of microbial growth in plumbing with and without residual flux, debris, or solvents, to quantify the extent to which these constituents can initiate microbial re-growth problems such as nitrification. The final phase of research evaluated the practice of shock chlorination disinfection of premise plumbing (i.e., exposing premise plumbing to solutions containing 50 to 200 mg/L Cl₂ for 3 to 24 hours exposure). Additional case studies were conducted to evaluate such problems as high copper levels in new premise plumbing and to establish the best type of corrosion inhibitor to limit galvanic corrosion.

**RESULTS/CONCLUSIONS:**
Flux used in plumbing systems can contribute to corrosion of copper and brass plumbing materials. Although there were large variations between flux types (some are water-soluble, some are petroleum-based and therefore not water-soluble), if not promptly flushed from lines, water-soluble fluxes tended to cause greater amounts of metal leaching, weight loss, and water discoloration. Specifically, the ASTM B813 compliant fluxes (water-soluble or water-flushable after soldering) usually caused the highest amounts of metal leaching if not flushed from lines. ASTM B813 compliant fluxes resulted in copper levels well over the USEPA action limit and zinc and chloride levels higher than the recommended secondary standard. The presence of flux can also remove residual disinfectant, and therefore, could indirectly contribute to microbial growth.

It is imperative that flux and metallic debris be flushed from any premise plumbing system prior to use. In this work, the research team found that flushing water through the system at 3 fps for 30 to 120 minutes completely removed ASTM B813 compliant flux. Traditional petroleum-based flux persisted in piping joints even after flushing at 7 fps for 6 hours. It is recommended that the latter type of flux should not be used in copper plumbing systems. Metallic debris can also be readily flushed from the system if water velocity is above 3.6 fps. Petroleum-based flux could possibly be flushed with hot water but this was not tested in this study.

In a new building, collected water lead levels in 1 liter samples in a real-world case study were sustained at 50–300 ppb for at least 4 months even in flushed samples. The problem was associated with low alkalinity, relatively high pH treated water, using chloramine as a secondary disinfectant with orthophosphate/polyphosphate inhibitor. Other exacerbating factors included
in-line devices with high lead (despite being NSF certified), presence of trapped particles on
strainers with relatively high lead content, and a high water age in plumbing lines.

Overuse of plumbing flux, coupled with inadequate flushing of plumbing lines, can create a
situation with high levels of ammonia in building plumbing systems, which allow nitrifying
bacteria to proliferate. Resulting water quality problems in buildings can include exceedance of
the 1 mg/L nitrite standard, higher levels of lead and copper leaching, higher levels of bacteria,
and more rapid loss of disinfectant. Once again, problems can be reduced by following
guidelines that minimize flux use and that carefully rinse plumbing.

A one time shock chlorination of new plastic pipe at 200 mg/L as Cl₂ for 3 hours or 50 mg/L as
Cl₂ for 24 hours (the two most commonly used shock chlorination criteria described by various
plumbing codes) is not helpful for plastic pipe, but no evidence could be found of serious
damage. However, if shock chlorination is repeated, prolonged, or conducted at high
temperatures, more significant deterioration of pipe can occur.

Although shock chlorination does not benefit copper piping, no evidence could be found of
serious damage from one time shock chlorination. Copper can directly consume chlorine to
various degrees dependent on water quality, and because required levels of Cl₂ are not always
maintained, this can create some problems with clearing pipe systems for use if the rate of decay
is too high. To reduce the rate of decay in order to maintain targeted levels of Cl₂ residual in
most cases, pH can be increased to pH 9 or greater, or 1 mg/L orthophosphate can be added

Blue water can result from high levels of copper in water. A pH adjustment and/or
orthophosphate addition may be required to reduce copper leaching from new premise plumbing
depending on water quality. In other instances, however, copper can consume chlorine residual
for an extended period of time. Prolonged flushing may allow a scale-layer to form that prevents
excessive copper leaching and the consumption of chlorine disinfectant.

The following are conclusions from the project:

• If lead leaching is an issue in a newly commissioned plumbing system, a multi-faceted
  approach that includes comprehensive testing may be necessary to remediate problems since
  the root cause may be a result of installation procedures, plumbing system design, lead
  leaching propensity of the installed brass devices, corrosivity of the water relative to new
  brass, or commissioning procedures. Factors that contribute to lead problems include high
  lead content of brass valves, relatively high corrosivity of water towards leaded brass valves
  or solder, trapped lead-bearing particulates on strainers, aerators, or in the plumbing system,
  or nitrification because the resulting lower pH might result in excessive metal leaching or
  reduced rates of passivation.

• The improper use of petroleum-based flux in plumbing systems, or failure to promptly flush
  flux from the plumbing lines, can cause a variety of problems with drinking water affecting
  aesthetics, health, and corrosivity due to high metal leaching and possible promotion of
  microbial growth.
Flushing of ASTM B813 compliant flux and metallic debris can be accomplished using water at or above 3.6 fps; however, petroleum-based flux cannot be flushed from plumbing systems with ambient temperature water, which can create long-term problems.

The inadequate flushing of flux from a plumbing system can lead to the proliferation of nitrifying bacteria. Nitrification can create higher levels of lead and copper at the tap and allow higher levels of microbial growth within the plumbing system.

One time 50 to 200 mg/L shock chlorination does not seriously damage plastic piping or copper tube; however, repeated shock chlorination events are not recommended because significant deterioration may occur.

Pipe material has a strong influence on the level of chlorine demand and associated ability to meet required levels of disinfectant residual after shock chlorination. In a comparison of copper, brass, cross-linked polyethylene (PEX), and chlorinated polyvinyl chloride (CPVC), copper exerts the highest chlorine demand while CPVC exerts the lowest. Copper exerts a higher demand because chlorine is a strong oxidizer and the copper is subject to some oxidation whereas the CPVC is not. Chlorine is consumed as it is reduced.

When shock chlorination is employed to disinfect plumbing waters with pH levels 9 and above, chlorine residuals tend to be held better than with waters at lower pH levels. Orthophosphate addition significantly reduced the rate at which chlorine disappears from some waters.

**APPLICATIONS/RECOMMENDATIONS:**
By utilizing and applying the information in this report, stakeholders can reduce problems associated with new copper, plastic, and brass plumbing systems. Stakeholders include plumbers, building managers, regulatory agencies, and code administrators.

**Plumbers**
This study resulted in several findings that plumbers should be aware of when installing new plumbing or repairing plumbing. First, plumbers should only use ASTM B813 compliant flux when joining copper pipe and fittings. Petroleum-based flux should never be used as it cannot be flushed out of pipes in most cases. Attempts should be made to minimize the flux use even when using ASTM B813 compliant flux. After work is completed, excess flux should be wiped away. Plumbing lines should be flushed after installation at 3.6 fps or above for 30 minutes to remove most debris and residual ASTM B813 compliant flux. A commissioning schematic for copper systems to assist plumbers is depicted in Figure ES.1 in the report.

**Building Managers**
Building managers should specify that plumbers use ASTM B813 compliant flux, valves certified by NSF 61 Section 8 and Section 9, and thoroughly flush the plumbing lines. In some situations these steps are not adequate to prevent elevated lead and copper in water of new construction. While additional flushing protocols can reduce the likelihood and severity of problems if they occur, the only way to be sure water is safe is to test it before buildings are occupied. While shock chlorination does not seem to severely damage plumbing, steps should be taken to minimize the duration of exposure to the high chlorine within the guidelines. If not required by the plumbing code, shock chlorination is not recommended.

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Regulatory Agencies and Code Administrators

Regulatory agencies and/or code administrators should re-evaluate the amount of lead allowed in brass or bronze plumbing fittings classified as ‘lead-free’ (which means they are allowed to contain up to 8% lead) and associated leaching standards. As an alternative, ‘low-lead’ fittings could be specified as these typically contain 0.1–0.25 % lead. While existing standards are adequate in most circumstances, in the presence of flux, reduced water flow, and moderately corrosive water, it is possible to generate very high levels of lead in water while meeting the plumbing code. These unusual cases exceed levels set by the USEPA and could put the public at risk even though they quite possibly could have passed NSF 61 certification.

The rationale behind application of shock chlorination to premise plumbing disinfection should also be evaluated. While the practice makes sense for water mains due to proximity to dirt/sewage and use of materials that are resistant to chlorine corrosivity, there is no basis for applying shock chlorination to building plumbing systems.

Because lead leaching from brass tends to decrease with age, testing of homes at least two decades old as specified by the USEPA LCR will provide little insight to lead problems that may exist for brass in new construction. When the USEPA LCR was implemented in 1991, the leaded brass in the tested homes could be as little as 5 years of age. At that time, there was a lesser divergence in age between brass in homes of the LCR sampling pool and brass in new construction, but this age gap now exceeds 20 years. In the meantime, the plumbing code, standards, and regulations for leaded brass have not advanced to the point that problems have been eliminated in new construction.

In summary, several items should specifically be addressed by committees assigned to evaluate LCR revisions. These include the requirements for ‘lead free’ brass, LCR testing in newer homes, and possible requirements for flux to limit its ability to leach lead and copper from plumbing.

MULTIMEDIA:
A brochure was produced as part of this project. This brochure provides guidance to plumbers, building managers, regulatory agencies, and code administrators on installation of premise plumbing for new construction. A strategy is outlined to test, remediate, and mitigate plumbing issues in new buildings.

PARTICIPANTS:
Participants in this project included the University of North Carolina at Chapel Hill, Orange Water and Sewer Authority, Copper Development Association, Oatey Corporation, Plastics Pipe Institute, WaterOne, and Integrated Building and Construction Solutions (IBACOS).