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Understanding how brass ball valves passing certification testing can cause elevated lead in water when installed

Simoni Triantafyllidou [a], Meredith Raetz [b], Jeffrey Parks [a], Marc Edwards [a,*]

[a] Department of Civil & Environmental Engineering, Virginia Polytechnic Institute and State University (Virginia Tech), 407 Durham Hall, Blacksburg, VA 24061, USA

[b] Malcolm Pirnie – The Water Division of Arcadis, Arlington, VA 22201, USA

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ABSTRACT

The lead leaching potential of new brass plumbing devices has come under scrutiny as a significant source of lead in drinking water (>300 μg/L) of new buildings around the world. Experiments were conducted using ball valves that were sold as certified and known to have caused problems in practice, in order to better understand how installed products could create such problems, even if they passed "leaching tests" such as National Sanitation Foundation (NSF) Standard 61 Section 8. Diffusion of lead from within the device into water when installed can increase lead leaching by orders of magnitude relative to results of NSF testing, which once only required exposure of very small volumes of water within the device. "Normalization" of the lead-in-water result tended to produce estimates of lead concentration that were much lower than actual lead measured at the tap. Finally, the presence of flux could also dramatically increase lead leaching, whereas high water velocity had relatively little effect.

1. Introduction

Lead has been traditionally added to brass plumbing devices to reduce leaks by sealing micropores, to reduce corrosion of the alloy and increase product life, and to lubricate castings thereby increasing machining rates and lowering production costs (Sandvig et al., 2007; Showman, 1994; OECD, 1994). "Lead-free" brass, which is specified for drinking water plumbing fixtures, is currently allowed to contain up to 8% lead by weight in the United States (US EPA, 1987), although "non-leaded" brasses (≤0.25% lead by weight) have recently been developed and will become mandatory for drinking water applications in the US by 2014 (US Congress, 2010).

The presence of lead in brass plumbing devices creates the potential for contamination, and a substantial fraction of lead detected in potable water has been attributed to brass devices (AWWARF and DVGW-TZW, 1996). Early work indicated that about 1/3 of the lead in first-draw samples came from brass in homes with lead solder, and virtually 100% of the lead in water of homes plumbed with galvanized or plastic pipe/fittings came from brass (Gardels and Sorg, 1989). Other researchers have drawn very strong circumstantial ties between lead in water and brass (Kimbrough, 2001). Although a recent study suggested that brass faucets and water meters were a minor source of lead in much older US homes sampled under the Environmental Protection Agency (EPA) Lead and Copper Rule (AWWARF, 2008), very high and persistent levels of lead (>300 μg/L) were documented in water of new buildings where leaded brass was the only significant source (Elfland et al., 2010). Problems with new leaded brass devices are not

* Corresponding author. Tel.: +1 540 231 7236; fax: +1 540 231 7916.
E-mail address: edwardsm@vt.edu (M. Edwards).

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limited to the US (Elfland et al., 2010), since sampling of new homes in the Netherlands revealed that 75% of first-draw and 30% of flushed water samples exceeded the 10 μg/L World Health Organization lead standard, due to brass faucets with a maximum allowable lead content of 3.5% (Slaats et al., 2007).

In Europe a standardized certification test (named EN 15664) was recently proposed to assess the safety of metallic plumbing products (Slaats, 2011), and another standardized test (named prEN 16057) was proposed to ensure that surface lead on products will be adequately low (4MS Joint Management Committee, 2011). In the US, the NSF/ANSI 61 Standard has been used voluntarily for more than 2 decades by utilities, regulatory agencies, and/or manufacturers to assure customers that certified products will not create health risks (NSF, 2010). Lead, amongst other contaminants that are considered in the NSF 61 Standard and its European equivalent, poses great concern due to increasing evidence of harm from low-level lead exposure (Canfield et al., 2003; Bellinger and Needleman, 2003). Section 8 of the NSF/ANSI 61 standard is specific to "in-line" components/plumbing devices, which are used to measure or control the flow of water and are downstream of the water main and before Section 9 brass devices (i.e., faucets and fixtures). Devices covered by Section 8 include backflow preventers, pressure regulators, compression fittings, strainers, check valves, curb stops, water meters corporation stops, valves and fittings, and meter couplings. Section 9 refers to "end point" devices, which are installed in the last 1 L of the water distribution system and are covered by a different test protocol (Table 1) (NSF, 2007; Triantafyllidou and Edwards, 2007).

Testing of brass products covered by Section 8 requires exposure to two types of synthetic extraction water (i.e., pH 5 and pH 10 water) under a specified protocol, followed by statistical analysis of the lead leaching results (Table 1). If the calculated concentration of lead is below 15 μg/L (or 5 μg/L after 2012) after consideration of normalization, Section 8 products can become NSF certified as long as they also contain less than 8% lead by weight as currently specified by US law (US EPA, 1987) (Table 1). But problems with very high lead in new construction were recently attributed to devices that were sold as being Section 8 certified in the US (Elfland et al., 2010). These ball valves released lead in excess of 100 μg/L even in flushed water samples, months of remedial flushing could not reduce the high concentrations of lead below 15 μg/L in 1 L first-draw samples, and in-line strainers were found to be clogged with lead-bearing plumbing debris (Elfland et al., 2010). It is recognized that compromises are necessary in any certification test, and that the actual concentrations of metals detected are controlled by the test protocol. Some key factors in the NSF Section 8 protocol include chemistry (corrosivity) of the two extraction waters, flow conditions, rinsing of product, duration of the test, duration of the contact time of test water and product before sampling, normalization factors, and reproducibility (Table 1). Such factors were also considered in developing a European standard (Slaats, 2011).

Up until 2010 the NSF/ANSI 61 test allowed exposure of small brass devices to the extraction water(s) "in-the-product", in order to quantify lead leaching (NSF, 2007). The actual measured concentration of lead leached to the water was then "normalized" to account for differences between laboratory testing and actual field conditions and project the possible "at the tap" concentration in a 1 L sample collected for human consumption or regulatory compliance. For example, after a stagnation event in a small Section 8 device such as a ball valve, it was assumed that the water in the valve would

Table 1 – Summary of test protocol for Section 8 and Section 9 product certification under NSF/ANSI Standard 61 (NSF, 2007; Dudi et al., 2005; Triantafyllidou and Edwards, 2007).

Step	Section 8 protocol	Section 9 protocol
Number of devices from product line tested	One	>Three for lead testing
Rinse	Flush with tap water, followed by a rinse with 3 volumes of reagent water, to remove debris. Water is discarded	
Conditioning	Expose for 16 days with 12 water changes @ 23 °C. Discard water	Fill with test water and hold until the beginning of the exposure series. Day 1 and Day 2 exposure water is discarded
Time frame of exposure to synthetic extraction water(s)	Expose for 12–16 h @ 23 °C (Water analyzed)	19-day exposure protocol. Waters from 16-h exposures on Day 3, 4, 5, 10, 11, 12, 17, 18, and 19 are analyzed
Synthetic extraction water(s)	pH 5.0 water: 203.25 mg/L $MgCL_2$, 347.25 mg/L NaH_2PO_4 (77 mg/L as P), 2.0 mg/L as Cl_2 pH 10 water: 476.75 mg/L sodium borate (110.4 mg/L-B), 2.0 mg/L as Cl_2	pH 8.0 water: 500 mg/L as $CaCO_3$, 2.0 mg/L as Cl_2
Normalization	Normalization equation provides an estimate of potential "at the tap" concentrations based on the level of contamination identified during laboratory testing	A normalization equation is used
Acceptance criteria	TAC[a] of 15 μg/L for lead, reduced to 5 μg/L after 2012	Q statistic of 11 μg/L for lead, reduced to 5 μg/L after 2012[b]

a TAC: Total allowable concentration.
b With the exception of supply stops, flexible plumbing connectors and miscellaneous components, for which Q statistic for lead will be set at 3 μg/L after 2012.