Comparison of Lead Discharge From Conventional Leaded Brass Versus "No-Lead" Type Water Service Valves and Fittings

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Technical Report #02-097

July 2002

I. BACKGROUND AND INTRODUCTION

In recent years it has become recognized that exposure to lead, especially in infants and young children, causes permanent and essentially irreversible neurological damage leading to IQ reductions, attention deficit disorders, and aggressive behavior (1, 2, 3). In light of these research findings, in 1991 the US EPA set a Maximum Contaminant Level Goal (MCLG) of zero for lead, and very recent published research has documented measurable childhood IQ deficits at blood lead levels as low as 2.5 Φg/dL, a level previously believed to be well below the threshold for observable neurologic damage (4, 5).

Currently, most brass plumbing and water service parts are still being made from leaded brass alloys containing between about 2 and 7 percent lead. It is now well documented that these leaded brass parts discharge substantial amounts of lead into residential drinking water, especially when new, but even after years of in-line service (6, 7, 8, 9). A large comprehensive study in 1996 by Lytle and Schock, with the US EPA, found that virtually all such leaded alloys leached and discharged substantial concentrations of lead for extended periods (6). A series of experiments conducted by the UNC-Asheville Environmental Quality Institute (EQI) on water meters and valves documented that new leaded brass parts typically leach about 100 Φg/L of lead initially, with the levels typically decreasing to less than one-half of initial values within weeks, followed by a long-term stabilization at moderate lead discharge levels (5-30 Φg/L), depending on supply water corrosivity after about five months of service (7, 8, 9).

Another recent study by the EQI found that leaded brass curb valves and water meters in the Los Angeles public water system were still discharging high amounts of lead after two or more years of service. These discharges were calculated to be sufficient to cause significant exposures, measurable increases in blood lead levels, and IQ deficits among Los Angeles children (10, 11). Based on these findings, the City of Los Angeles Department of Water and Power is now only purchasing no-lead parts for their water distribution and delivery system.

With the national discontinuation of leaded plumbing solder in new buildings (1988), the virtual elimination of leaded brass in kitchen faucet fixtures (1996-1999), and most recently, the phase-out of leaded brass water meters in California (2001), residential exposure to lead from drinking water is decreasing significantly. However, with the elimination of lead from solder and many brass plumbing parts, lead discharge from leaded brass water meters and associated service parts such as curb valves, curb valve tail pieces, elbows, and corporation stops are now the greatest source of drinking water lead exposure in newer buildings. As noted above (10, 11), these remaining leaded-brass service parts are a significant source of childhood lead exposure, which would appear to be quite unnecessary given the increasing availability of no-lead alternatives.

The purpose of the research described herein was to test, quantify, and compare the lead discharge of 35 different representative conventional leaded-brass water service products containing between 2 percent and 7 percent lead with 12 similar products manufactured by Cambridge Brass, which employs a no-lead-added brass typically containing less than 0.1 percent lead as an incidental impurity.

II. METHODOLOGY

The testing methodology for this research was designed to match as closely as practicable the testing methodologies employed previously by the EQI for determining actual lead discharge from plumbing parts (9, 12).

The Cambridge Brass ``no-lead'' products tested by this research are listed and described in Table I below.

TABLE I. Description of Cambridge Brass Plumbing Products to be Tested for Lead Discharge Dynamics.

Lab ID #	***CB Product #***	***Product Description***
CB1	202NL-F3F3	3/4" Ball Valve Curb Stop FIP x FIP
CB2	203NL-F3F3	3/4" Ball Valve Curb Stop with Drain FIP x FIP
CB3	212NL-F3F3	3/4" Full Port Straight meter Stop FIP x FIP
CB4	262NL-F3F3	3/4" Minneapolis-style Ball Valve Curb Stop FIP x FIP
CB5	301NL-M3M3	3/4" Ball-type Main Stop MIP x MIP
CB6	210 NL-F4F4	1" Full Port Angle Meter Stop FIP x FIP
CB7	117NL-H3F3	3/4" Straight Coupling Comp x FIP
CB8	105NL-H3M3	3/4" Ell Coupling Cambridge Comp x MIP
CB9	150NL-H3H3	3/4" Service Tee Comp x Comp x Comp
CB10	202HL-H3H3	3/4" Ball Valve Curb Stop Comp x Comp
CB11	6020NL-207H3F3-00	3/4" Meter Setter
CB12	202NL-F7F7H	2" Ball Valve Curb Stop

The conventional leaded brass water service parts tested are listed and described in Table 2.

TABLE 2. Conventional Leaded Brass Water Service Parts Tested.

Lab Set ID #	***Manufacturer***	***Manufacturer ID #***	***Description***	***Sample Size***	***Notes***
13	Mueller	B-20283	3/4" FIP x FIP B/V Curb Stop	250 ml	
14	Mueller	H-15531	3/4" Comp x MIP Elbow CPLG	250 ml	
15	Mueller	H-15071	3/4" Comp x MIP Elbow CPLG	250 ml	
16	Mueller	B-20283	2" FIP x FIP B/V w/Handle	one liter	
17	James Jones	J-1943	3/4" MIP x MIP Main Stop	250 ml	
18	James Jones	J-1900	3/4" FIP x FIP F/Port Straight	250 ml	tested 4
19	James Jones	J-2619	3/4" Comp x MIP Elbow CPLG	250 ml	
20	James Jones	J-2607	3/4" Comp x FIP CPLG	250 ml	
21	James Jones	J-1900	2" FIP x FIP B/V w/Handle	one liter	
22	A McDonald	3131B	3/4" MIP x MIP Main Stop	250 ml	
23	A McDonald	6101	3/4" FIP x FIP B/V Curb Stop	250 ml	
24	A McDonald	6101W	3/4" FIP x FIP F/Port Straight MTR w/Lockwing	250 ml	tested 2
25	A McDonald	4779M-22	3/4" Comp x MIP Elbow CPLG	250 ml	
26	A McDonald	4754-22	3/4" Comp x FIP CPLG	250 ml	
27	A McDonald	6101ADD6120	2" FIP x FIP B/V w/Handle	one liter	
28	Ford	B11-333W	3/4" FIP x FIP F/PORT Straight MTR w/Lockwing	250 ml	
29	Ford	L84-33	3/4" Comp x MIP Elbow CPLG	250 ml	tested 4

30	Ford	C14-33	3/4" Comp x FIP CPLG	250 ml	
31	Ford	T444-333	3/4" x 3/4" Comp Tee	250 ml	
32	Ford	B11-777	2" FIP x FIP B/V w/Handle	one liter	
33	James Jones	J-1900	3/4" FIP x FIP B/V Curb Stop	250 ml	
34	James Jones	J-1949	3/4" Comp x Comp B/V Curb Stop	250 ml	
35	James Jones	J-2617	3/4" x 3/4" Comp Tee	250 ml	
36	Mueller	H-15381	3/4" x 3/4" Comp Tee	250 ml	
37	Mueller	B-24265	1" FIP x Meter Nut F/Port Angle Meter Valve	Dump & Fill	
38	Mueller	B-20200	3/4" FIP x FIP F/Port Straight MTR w/Lockwing	250 ml	
39	A McDonald	4760-22	3/4" x 3/4" Comp Tee	250 ml	
40	Mueller	B-20013	3/4" MIP x MIP Main Stop	250 ml	
41	Ford	BA13-444W	1" FIP x Meter Nut F/Port Angle Meter Valve	Dump & Fill	
42	Ford	B11-333	3/4" FIP x FIP B/V Curb Stop	250 ml	
43	Ford	FB500-3	3/4" MIP x MIP Main Stop	250 ml	
44	Mueller	B25170	3/4" FIP x Comp B/V Curb Stop	250 ml	
45	Ford	B44-333	3/4" FIP x Comp B/V Curb Stop	250 ml	
46	A McDonald		1" FIP x Meter Nut F/Port Angle Meter Valve	Dump & Fill	
47	A McDonald	6100-22	3/4" Comp x Comp B/V Curb Stop	250 ml	

After thorough rinsing and pre-conditioning as specified by NSF-61 Section 9 (13), the individual components (141 total) were plumbed with PVC or polybutylene connectors or adapters to the EQI lead-free research pressurized manifold system. An extraction water was prepared that closely simulates average California public water supply characteristics in terms of lead corrosivity (14). This water had an average pH of 8.04 (+ or - 0.3), mean hardness of 100 mg/L (as $CaCO_3$), mean alkalinity of 82.4 mg/L (as $CaCO_3$)(+ or - 5 mg/L) and total chlorine of 1.0 mg/L. Using laboratory pumps and timers, this extraction water was fed to the test parts with five water changes per day. Samples from the Cambridge Brass ''no-lead'' products were taken on each weekday morning for three weeks after a 16-hour overnight internal dwell time. The conventional brass products were sampled on Days 3, 4, 5, 10, 11, 12, 17, 18, and 19. On Days 17, 18 and 19, shorter dwell time samples were taken after 10 minutes, 30 minutes, and 2 hours. This short dwell time data enabled a calculation of the approximate total daily lead discharge from the parts and as well as the approximate ingestion by residence occupants. The lead discharge concentration data were statistically analyzed to determine a lead discharge AQ@statistic as defined for certification purposes by NSF (13). Thus, the experimental procedures used were virtually identified to NSF-61 Section 9 with the exceptions of 1) the parts were plumbed rather than just >dumped and filled=, 2) water hardness, alkalinity and total chlorine levels used were more representative of typical public water supplies than the levels specified under NSF, and 3) short dwell time samples were taken in addition to 16-hr. overnight dwell samples.

All samples were analyzed for total lead by graphite furnace atomic absorption spectrophotometry (GFAAS) with a NELAP national drinking water compliance certification lower reporting limit of 2.0 Φg/L, but an actual research method detection limit of about 0.5 Φg/L. Instrument readings of less than 0.5 Φg/L were reported and were used for statistical analyses to avoid the problems associated with truncated data sets.

III. RESULTS AND DISCUSSION

As expected, the lead discharges from the ''no-lead'' water service parts were relatively low. Lead discharge results are summarized in Table 3 with the complete data tabulated as Appendix A.

TABLE 3. Summary of 16-hour Dwell Lead Discharges (Φg/L)(250-mL samples).

Product ID#	Mean Internal Exposed Volume (mL)	Mean Lead Days 2-5	Mean Lead Days 9-12	Mean Lead Days 16-19	Overall Mean	1-L Adjusted Overall Mean	>Q= Stat
CB1	13.1	3.86	1.96	2.51	2.78	0.70	0.91
CB2	13.0	3.98	1.58	2.08	2.55	0.64	0.60
CB3	14.5	3.01	1.54	1.54	2.03	0.51	0.53
CB4	17.3	4.51	2.11	2.86	3.16	0.79	0.78
CB5	29.4	10.0	5.39	5.55	6.98	1.75	2.81
CB6	21.6	10.6	5.65	5.01	7.09	1.77	2.23
CB7	18.0	4.34	1.97	1.36	2.56	0.64	1.79
CB8	32.0	8.92	5.33	4.88	6.38	1.60	2.64
CB9	51.0	9.29	5.74	3.83	6.29	1.57	1.64
CB10	32.0	9.16	4.01	2.29	5.15	1.29	1.31
CB11*	159.	24.1	9.39	6.43	13.3	3.33	3.56
CB12**	185.	6.04	3.88	2.76	4.23	4.23	5.48

* Due to plumbing difficulties, CB11 was conditioned and tested using >Dump & Fill= protocol with water change and sampling procedures identical to plumbed pieces.
**One-liter samples taken because of large volume of part. One sample result of 0.0 was replaced with one-half the method detection limit (0.89 x .5 = .45).

Lead discharge concentrations of the parts shown in Table 3 decreased significantly over the three weeks of testing with Week 3 results giving a mean Pb concentration of 42 percent of Week 1 results. This initial rapid reduction is consistent with previous observations with brass water meters (7).

The lead discharge results for the conventional leaded-brass water service parts are summarized in Table 4 below and complete data are presented as Appendix B.

TABLE 4. Summary of 16-Hour Dwell Lead Discharges for Conventional Leaded-Brass Water Service Products (Φg/L)(250 mL Samples Unless Otherwise Noted).

Product ID#	Mean Internal Exposed Volume (mL)	Mean Lead Days 3-5	Mean Lead Days 10-12	Mean Lead Days 17-19	Overall Mean	1-L Adjusted Overall Mean	>Q= Stat
13	12.5	40.4	25.1	25.0	30.2	7.55	13.75
14	21	39.4	60.2	43.1	47.6	11.9	17.90
15	6.5	21.4	17.4	21.0	19.9	4.98	8.89

16	155	38.4	24.0	21.6	27.8	27.8	48.30
17	35	44.5	45.2	29.3	39.6	9.9	13.93
18	15	46.0	27.6	28.4	34.0	8.5	14.36
19	23	74.5	40.9	36.3	50.6	12.65	13.92
20	11	29.7	17.9	22.1	23.2	5.8	6.90
21	160	67.9	41.9	39.6	49.8	49.8	54.32
22	35	82.6	48.9	44.9	58.8	14.7	19.67
23	14	35.3	20.1	20.4	25.3	6.33	8.18
24	14	15.8	20.1	21.4	19.1	4.78	5.09
25	26	35.6	21.1	22.3	26.3	6.59	22.4
26	8	11.1	9.1	7.1	9.1	2.28	2.27
27	160	64.3	44.0	42.1	50.1	50.1	51.96
28	15.5	40.2	28.6	28.1	32.2	8.05	8.48
29	18	47.8	20.1	20.9	29.6	7.4	11.86
30	10	9.47	8.36	3.28	7.0	1.75	5.53
31	15	71.4	53.1	43.1	56.3	14.1	13.72
32	160	64.0	47.1	41.0	50.7	50.7	72.20
33	18	25.3	27.4	21.6	24.7	6.18	11.07
34	35	74.1	56.5	38.7	56.4	14.1	40.59
35	55	48.0	36.6	34.8	39.8	9.94	17.31
36	55	59.3	42.1	36.5	46.0	11.5	12.91
37	45	18.07	349.1	269.7	808.6	202.2	298.5
38	15	65.7	26.0	22.0	37.9	9.47	7.30
39	20	111.4	164.8	130.2	135.5	33.9	147.2
40	31	97.1	56.6	46.3	66.7	16.7	23.88
41	50	321.7	241.2	250.7	271.2	67.8	70.20
42	21	40.3	33.6	28.5	34.1	8.53	12.57
43	30	63.4	48.5	45.6	52.5	13.1	13.87
44	22	39.4	82.6	62.5	61.5	15.4	63.36
45	17	32.6	39.0	26.7	32.8	8.19	15.31
46	60	679.1	240.7	256.1	392.0	98.0	101.46

47	32	46.9	33.4	31.5	37.3	9.32	12.48

Table 5 shows comparisons between the ``no-lead'' type water service parts and their approximate counterpart manufactured from conventional leaded brass.

TABLE 5. Comparison of Lead Discharge (Φg/L) From ``no-lead'' Parts Versus Similar Leaded Brass Parts.

No-Lead Part ID #	Comparable Leaded Brass ID #s	>Q= Stat for No-Lead Part	Mean >Q= Stat for Leaded Brass Parts	Factor Difference in Lead Discharge
CB1	13, 23, 33, 42, 44, 45	0.91	20.7	22.8
CB2	13, 23, 33, 42, 44, 45	0.60	20.7	34.5
CB3	18, 24, 28, 38	0.53	8.81	16.6
CB4	13, 23, 33, 42, 44, 45	0.78	20.7	26.5
CB5	17, 22, 40, 43	2.81	17.8	6.35
CB7	15, 20, 26, 30	1.79	5.90	3.30
CB8	14, 19, 25, 29	2.64	16.5	6.25
CB9	31, 35, 36, 39	1.64	47.8	29.1
CB10	34, 44, 45, 47	1.31	32.9	25.1
CB12	16, 21, 27, 32	5.48	56.70	10.3
Mean				18.0

From Table 5 it can be seen that, as expected, the ``no-lead'' parts discharged much less lead than their conventional leaded brass equivalents under these test conditions. Depending on the part, the ``no-lead'' parts discharged anywhere between 3.30 and 34.5 times less lead with an average of 18.0 times less lead discharged.

Given that the lead content of the ``no-lead'' type water service fittings (mean = 0.07 percent; max = 0.1 percent) is so much lower than the corresponding conventional leaded brass fitting (range 2 percent to 7 percent; estimated mean approximately 5 percent), it might be expected that the difference in lead discharge would be significantly greater than the average factor of 18.0 which was observed. However, it has been previously noted by various researchers that, when brass alloys are melted and poured into molds, the lead (having a lower melting point and thus becoming less viscous in the alloy suspension) tends to migrate and concentrate at the interface of the mold, generally producing surface concentrations of about two to four times that of the bulk alloy. Thus, it might be expected that while the ``no-lead'' alloy parts would initially discharge a small to moderate amount of lead, the discharge from ``no-lead'' alloys would decrease more rapidly with time than would be observed with the higher lead alloy parts, given that only a small amount of total surface lead would be available for dissolution in the ``no-lead'' parts. An examination of the data indicates that this is quite likely the case. While the lead discharge from the ``no-lead'' parts decreased on average by 58 percent between Week 1 (Days 3-5) and Week 3 (Days 17-19), the discharge from the conventionally leaded-brass parts decreased by only

29.1 percent during the same period. Thus, calculations using the Day 19 data presented in Appendices A and B show that by Day 19 the leaded-brass parts were in fact on average discharging over 14 times more lead than the ``no-lead'' parts (see Table 6), while for Week 1 the average difference was a factor of 8.6. Over time, as the relatively small amount of initially accumulated surface lead dissolves out of the ``no-lead'' parts, this difference would be expected to become even greater, presumably stabilizing eventually at the approximate 50-fold difference represented by the respective lead content of the ``no-lead'' versus the typical 5 percent leaded-brass alloys.

TABLE 6. Comparisons of Lead Discharge From ``no-lead'' Versus Conventional Leaded-Brass Parts for Day 19 of Testing (Φg/L)

ANo-Lead Part ID #	Comparable Leaded Brass ID#s	Mean Pb Conc. for Leaded Brass Parts - Day 19	Mean Pb Conc. for ``no-lead'' Parts - Day 19	Factor Difference in Lead Discharge
CB1	13, 23, 33, 42, 44, 45	24.4	2.4	10.2
CB2	13, 23, 33, 42, 44, 45	24.4	2.0	12.2
CB3	18, 24, 28, 38	24.5	1.3	18.8
CB4	13, 23, 33, 42, 44, 45	24.4	2.6	9.4
CB5	17, 22, 40, 43	33.5	5.1	6.6
CB7	15, 20, 26, 30	13.2	1.3	10.2
CB8	14, 19, 25, 29	30.2	3.2	9.4
CB9	31, 35, 36, 39	66.5	2.6	25.6
CB10	34, 44, 45, 47	36.6	1.7	21.5
CB12	16, 21, 27, 32	37.1	2.0	18.5
			Mean Factor Difference	14.24

IV. SAMPLE CALCULATIONS OF LEAD EXPOSURE FOR RESIDENT IN HOME WITH LEADED-BRASS WATER SERVICE PARTS VERSUS ``NO-LEAD'' PARTS.

There are a number of methods for calculating and estimating the lead discharge and ingestion exposure from the installation of brass water service parts, and several of these have been described in some detail in previous EQI reports (e.g., 8, 10, 11). By necessity, any such calculations can only be approximate since water corrosivity varies considerably between public systems and households and individual water usage patterns will vary significantly from residence to residence. The lead discharge data developed from the current experiments was utilized to develop reasonable estimates of lead discharge and human consumption for an entire typical system of water service components as well as for each individual component as shown below. The following parameters, approximations, and assumptions were employed.

1. In a typical residence with four occupants, the water would be used on average about 30 times/day for drinking, cooking, washing, showers and toilet-flushing, etc., with these uses apportioned as: one overnight dwell, four 2-hour dwells, 15 30-minute dwells, and 10 10-minute

dwells.

2. On average, each resident would consume 2.0 liters/day of water between drinking and cooking.

3. Water ingestion would be apportioned as eight 250-ml faucet draws/day for each occupant with about an equal chance of receiving a dwell slug of 10-min., 30-min., 2-hr., and overnight (in reality, ingesting part of the overnight dwell slug would be less likely but consuming parts of dwell slugs of greater than 2-hour dwell times or 30-minute dwell times is more likely).

4. The 250-ml. sample taken from the laboratory plumbing set-up represents approximately the dispersion which would occur between the water part and the tap.

5. The average home has about 4.5 liters of water storage in the plumbing system (i.e., 80 ft. of one-half inch interior plumbing plus 20 ft. of three-fourths inch service line). Thus, combined with #4, there is about a 1/18 chance of getting the dwell slug from any given water service part in any particular 250 ml. tap-water draw.

6. Residence is served by the average California public supply water used in these experiments.

A. Total Daily Lead Discharge

(1) Typical combination of water service parts

A typical residential plumbing system with ``no-lead'' water service parts installed would be composed of Part Numbers 5, 7, 8, and 10 (see Table 1). Thirty daily water draws as distributed under Assumption #1 would result in a total daily discharge of 8.46 Φg, 7.80 Φg, 7.65 Φg, and 4.08 Φg from Parts Numbers 5, 6, 7, and 10, respectively for a total discharge of 28.0 Φg/day from the system during Days 17-19 of service. A comparable conventional leaded brass water service parts system would use Parts Numbers 17, 25, 29, and 47 (see Table 2). Again, using water draws with dwell times distributed as stated under Assumption #1, this system would produce a calculated daily lead discharge of 55.30 Φg, 41.77 Φg, 46.99 Φg and 61.06 Φg for Parts Numbers 17, 25, 29, and 47, respectively for a total discharge of 205.1 Φg/day during Days 17-19. Thus, the estimated lead ingestion attributable to water service parts would be about 86 percent less for a residence using ``no-lead'' parts.

B. Estimated Lead Ingestion

As noted above, the lead ingestion calculations assume that there is about a 1/18 probability of ingesting a water service part 250-ml dwell slug with each of the eight faucet draws per day. Considering that ingesting a dwell-slug of each of the experimental dwell times to be about equally likely, the daily ingestion from each part can be calculated as follows:

Ingestion (Φg/day) = Mean of Pb conc. of all four dwell times (Φg/L) x 0.25 L/draw x 8 draws/day x 1/18 probability of ingesting a dwell slug per draw.

This ingestion estimation is calculated for each individual water service part in Table 7 below.

TABLE 7. Calculated Daily Lead Ingestion for Various Brass Water Service Parts.

Lab ID# of Part	***Calculated Daily Lead Ingestion (Φg)***	**Lab ID# of Part**	**Calculated Daily Lead Ingestion (Φg)**
CB1	0.12	CB25	1.11
CB2	0.10	CB26	0.32
CB3	0.08	CB27	2.16
CB4	0.12	CB28	1.54
CB5	0.24	CB29	1.02
CB6	0.26	CB30	0.16
CB7	0.08	CB31	2.48
CB8	0.21	CB32	1.92
CB9	0.20	CB33	0.92
CB10	0.11	CB34	2.18
CB11	0.40	CB35	2.38
CB12	0.10	CB36	1.82
CB13	1.19	CB37	17.21
CB14	2.30	CB38	1.82
CB15	1.13	CB39	8.10
CB16	0.95	CB40	2.18
CB17	1.49	CB41	13.96
CB18	1.43	CB42	1.43
CB19	1.79	CB43	2.23
CB20	1.19	CB44	4.63
CB21	1.82	CB45	1.47
CB22	2.15	CB46	13.18
CB23	0.95	CB47	1.58
CB24	0.82		

The ingestion estimates shown in Table 7 are derived from the lead discharge data from Days 17-19 of these experiments. During the first few days of service, new water service parts could be expected to discharge (with resulting ingestion) considerably more lead than observed on Days 17-19, while at later service ages the expected discharge and ingestion exposure would be somewhat less. Previous experiments conducted by the EQI have demonstrated, however, that after Day 19, further discharge reductions are relatively minimal (7, 12). It should also be noted that in actual residential usage, there would typically be about four different water service parts in the system (i.e., a Main Stop at the junction with the public distribution line, two Elbow Couplings, and a Curb Stop with tail pieces). Thus, the actual lead ingestion associated with these water service parts will typically be about four times greater than that estimated for any one component. Proposition 65 sets daily exposure limits for consumer products and water discharges at 0.5 Φg/day, and it can be seen from Table 7 that nearly all of the leaded brass parts result in calculated exposures which significantly exceed this level. As noted previously, exposure calculations were made assuming an approximately equal likelihood of consuming a dwell slug of 10-minutes, 30-minutes, 2-hours, and overnight. Although in reality, consumption of the overnight dwell slug is somewhat less likely, it is highly probable that a large majority of the ingested slugs would have dwell times greater than 10 minutes or 30 minutes. Also, because the kinetics of lead build-up in the water is very non-linear (i.e., a substantial (20 to 50 percent) percentage of the overnight dwell slug concentrations builds up just in the first 10 to 30 minutes), it turns out that the Pb ingestion calculations are relatively insensitive to the assumptions made regarding the distribution of dwell slugs ingested. For instance, if it is assumed that the overnight dwell slug is almost never consumed, but that consumption of a 2-hour or 30-minute dwell slug is twice as likely as consuming a 10-minute dwell slug, the calculated daily ingestion is nearly the same.

V. SUMMARY AND CONCLUSIONS

In these experiments, new Cambridge Brass ``no-lead'' water service components (containing about 0.07 percent Pb as an incidental impurity) and comparable new conventional leaded brass (5 percent to 7 percent Pb) water service components were plumbed to the EQI lead-free research plumbing manifold and fed a water prepared to match average California public water supply water in terms of the parameters believed to affect corrosivity for lead. Initially, the leaded-brass components leached about 8.5 times as much lead as the ``no-lead'' parts, and by Day 19, the leaded-brass were on average discharging about 14 times more lead. It is likely that ultimately, as initially-available surface lead is dissolved, that the discharge may reach the 50 to 70 fold ratio, indicative of the relative lead contents of the ``no-lead'' and conventional leaded-brass alloys. Calculations made using common assumptions of residential water ingestion and usage patterns indicate that nearly all of the leaded-brass water service parts would result in ingestion exposure to residential building inhabitants which exceed the limits set by California=s Proposition 65.

ACKNOWLEDGMENTS

The UNC Asheville Environmental Quality Institute is a public university environmental research and education center dedicated to conducting independent, objective research for the public benefit. The EQI conducts independent research funded by government agencies, nonprofit organizations, or the private sector with the explicit written understanding that all work is carried out independently, without input from the funder, and that the EQI will disseminate the results of all such work without restriction. This particular research was funded by Cambridge Brass.

REFERENCES

1. Needleman, H.L. and C.A. Gatsonis. 1990. *Low-Level Lead Exposure and the IQ of Children: A Meta-Analysis of Modern Studies.* Journal of the American Medical Association, 263(5):673-678.

2. Schwartz, J. 1994. *Low-Level Lead Exposure and Children=s IQ: A Meta-Analysis and Search for a Threshold.* Environmental Research, 65:42-55.

3. Needleman, H.L. *et al.* 1990. *The Long-Term Effects of Exposure to Low Doses of Lead in Childhood: An 11-Year Follow-up Report*. New England Journal of Medicine, 322:83-88.

4. Schramm, M. and M. Watt-Morse *et al.* 2000. *Release of Stored Bone Lead During Pregnancy*. Journal of Epidemiology, November 2000.

5. Lanphear, B. 2001. *Cognitive Deficits Associated With Blood Lead Concentrations < 10 Φg/L in US Children and Adolescents*. Public Health Reports.

6. Lytle, D.A. and M.R. Schock. 1996. *Stagnation Time, Composition, pH and Orthophosphate Effects on Metal Leaching From Brass.* EPA/600/R-96≅103, September 1996.

7. Maas, R.P., S.C. Patch, D.M. Morgan and H. Kawaguchi. 1997. *Lead Leaching From Brass Water Meters Under Pressurized Flow Conditions*. Proceedings of the American Water Works Association 1997 Annual Conference, 589-602.

8. Maas, R.P., S.C. Patch, D.M. Morgan and S.C. Loucaides. 1999. *Lead Leaching From Los Angeles In-Service Brass Water Meters*. UNC Asheville Environmental Quality Institute Technical Report #99-068. 17p.

9. Maas, R.P. and S.C. Patch. 1999. *Lead Leaching From In-Service Residential Water Meters: A Laboratory Study.* Source (CA Section of AWWA), 100(3):27-28.

10. Maas, R.P. 2001. *Estimation of Human Lead Exposure From In-Spec (<6% Pb) and Out-of-Spec (> 6% Pb) Leaded Brass Curb Valves, Curb Valve Tail Pieces, Elbow Connector Nuts, Corporation Nuts and Corporation Threads,* April 30, 2001. 8p.

11. Maas, R.P. 2002. *Estimation of Human Lead Exposure from Leaded Brass Water Works Parts Installed in Residential Service.* UNC Asheville, EQI, April 2002. 9p.

12. Maas, R.P., A. Parker and S.C. Patch. 1998. *Lead Leaching From In-Service Leaded-Brass Water Meters*. NC Journal of the American Water Works Association, Vol. 1:270-279.

13. ANSI/NSF. 2001. *Section 9, Testing of Drinking Water Components*. Available from NSF, Ann Arbor, MI.

14. Maas, R.P. and M.S. LaGoy. 1999. *Survey of Average California Public Water Supply Corrosivity Characteristics.* UNC Asheville Environmental Quality Institute.