Utility Profile

Source water	Groundwater (100%) – 24 wells
Treatment	Chlorine and fluoride addition at each well
Corrosion Control Treatment	None. Full Lead Service Line Replacement Program Implemented to meet requirements of the LCR
Daily demand	32 MGD average day demand
Service line ownership	Customer-owned from curb-stop to building Utility owns from main to curb-stop
Lead Service Lines	1574 utility owned lead service lines 1358 customer owned lead service lines
Type of replacement program	Full Lead Service Line Replacement: Full lead service lines replaced as part of on-going program to meet requirements of the LCR

INTRODUCTION

Madison Water Utility provides groundwater from a deep sandstone aquifer to over 60,000 service locations. Average water use is about 32 million gallons per day (Madison Water Utility, 2006a). The water is pumped from 24 wells that range from 500 to 1130 feet deep. It is stored in 31 reservoirs and flows through about 810 miles of water main. Water treatment consists of chlorine addition to achieve 0.2 mg/L free chlorine and fluoride addition to achieve 1.1 mg/L. This chemical addition is performed at each well house.

Lead was commonly used for water service lines from 1882, the inception of Madison Water Utility, through 1927. Eleven thousand lead water service lines were installed during this time period. From the 1930s to 1960s, the Utility began replacing lead services on a small scale. Some lead services were replaced with copper when they leaked or when customers reported a low flow problem. During the 1970s, the Utility began replacing lead services when streets were reconstructed. In the late 1980s, Utility crews began replacing lead services during street resurfacing jobs. (Madison Water Utility, 2006b)

Hersey water meters, some of which used lead weights, were used from about the 1940s through the 1960s. The last of the lead-weight Hersey meters were replaced sometime in the 1990s. In about 2004, Madison Water Utility switched to non-leaded "EnviroBrass®" meters from Badger Meter, Inc. Older meters are still refurbished and reused, but when a meter is replaced after a lead service replacement the new meter is always non-leaded. Brass Mueller corps and curb stops used in the Madison Water Utility distribution system contain about 5% lead (Madison Water Utility, 2006b).

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

HISTORY OF LEAD CORROSION CONTROL IN MADISON

Corrosion control investigations were initiated after Lead and Copper Rule sampling in 1992 indicated a ninetieth percentile lead concentration of 16 µg/L. The recommendations from the corrosion control studies were to skip the chemical alteration of the water as prescribed by the Lead and Copper Rule and move directly to a control step allowed in the Rule only if chemical treatment fails. That control step is the replacement of lead water service lines. The arguments for making this bold step were:

- Because of the water's potential for precipitating calcium, pH adjustment was not chemically viable.
- Because the water comes from twenty-four distinct sources with no common treatment or storage facilities, alkalinity adjustment was not economically viable.
- Sodium silicate did not show any benefit in jar tests. Plus, there was little information on the use of sodium silicates.
- Polyphosphates increased the lead concentration in the water.
- Orthophosphates successfully lowered the lead levels. (Cantor, et. al., 2000), however, the Madison Metropolitan Sewage District had recently completed the installation of a biological phosphorus removal system that depended on a particular ratio of organic matter to phosphorus. If phosphorus was to be added to the drinking water, the removal system would not work properly and a chemical phosphorus removal system would need to be added. In addition, the water that would runoff directly to the lakes would carry phosphorus with it.

The Wisconsin Department of Natural Resources (WDNR) agreed that removing lead water service lines as a means of corrosion control was the only reasonable option available and further required that Madison achieve "optimal corrosion control" where the ninetieth percentile lead concentration is to be 5 µg/L.

ESTABLISHING COMPLETE LEAD SERVICE LINE REPLACEMENT

In order to achieve the goal of 5 µg/L ninetieth percentile lead concentration, however, the WDNR required the utility to remove the complete lead service line. This presented a problem in that the water utility owns the water service line up to the curb stop at a private building and the property owner owns the service line from the curb stop to the building. Property owners would have to be encouraged to replace their portion of the service line and the cost of doing so would need to be addressed.

These were the considerations taken into account by the Madison Water Utility and the Madison Common Council. They concluded that replacement of the customer side of lead service lines in the City was of benefit not only to each individual customer, but to the utility and community as a whole in meeting state and federal drinking water standards and avoiding the cost to all customers of adding corrosion control chemicals to the water system indefinitely. The lead service line replacements would also avoid the cost and environmental impact of adding phosphorus to wastewater streams. Consequently, the City established a requirement for customers to replace their lead water service lines and a program whereby they would be reimbursed for half the cost of replacing those lines up to $1000 reimbursement per property.

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

The utility, for which rates are regulated by the Public Service Commission of Wisconsin (PSCW), requested that the PSCW include half the cost of replacing customer lead service lines in its rate base. The PSCW denied the request, rejecting the utility's arguments about the benefits to the utility and community and expressing the opinion that all water customers should not be burdened with any cost for replacing customer-owned service lines. Subsequently, the Common Council approved a plan to place half the cost of replacing customer lead service lines on sewer rates, for which the PSCW did not have regulatory jurisdiction. The City justified this by showing a substantial avoided cost to sewer customers by implementing a complete lead service replacement program as opposed to adding corrosion control chemicals to drinking water, which would need to be removed at the wastewater treatment plant. Madison approved a complete lead service replacement program in February 2000, with a goal of replacing all lead water service lines in the City by 2011.

On January 1, 2001, the initiation of the complete lead service line replacement program, there were approximately 6,000 existing Water Utility side services and 5,000 customer-side services. As of December 31, 2005, the Utility has replaced or cut off about 4,307 Utility-side lead services or 72%, while customers have replaced 3,633 lead services or 73%. There are 1574 utility-owned lines and 1358 customer-owned lines remaining in the distribution system. All services are now scheduled to be removed by the end of 2009, two years ahead of the original schedule (Madison Water Utility, 2006b).

COSTS OF LEAD SERVICE LINE REPLACEMENT

Madison Water Utility tracks lead service line replacement costs for those services replaced by Utility crews through the lead service replacement work order. Any replacements done by city contract during water main replacement jobs are not included in these numbers. Because of this, the total number of lead service line replacements reported here will not equal the number actually replaced. Nevertheless, the costs do reflect the unit cost to replace a lead service line. As shown in the Table B.6.1, the costs to replace the Utility-side services have averaged $2212 per service line over the past eleven years. The replacement cost per line has ranged from $1798 in 1995 to $2751 in 2005. (Madison Water Utility, 2006b)

On the Property Owner-side service, the property owner is reimbursed for 50% of the replacement costs up to $1000. The average reimbursement to property owners has been $663.88. This implies that the average property owner-side replacement cost is $1327.76. However, this number does not account for replacements that are over $2000 since amounts over $2000 are not reported to the Utility for reimbursement. Reimbursements made since December 2000 are calculated in Table B.6.1 and Table B.6.2 lists the customer side replacement costs.

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

Table B.6.1
Madison Water Utility: Utility-side Lead Service Line Replacement Costs

Year	Number of Lead Service Line Replacements	Total Cost	Unit Cost
1995	226	$406,276	$1,798
1996	202	$341,633	$1,691
1997	239	$445,960	$1,866
1998	234	$459,946	$1,966
1999	352	$679,842	$1,931
2000	309	$601,995	$1,948
2001	570	$1,128,827	$1,980
2002	528	$1,266,050	$2,398
2003	553	$1,304,975	$2,360
2004	547	$1,399,144	$2,558
2005	528	$1,452,498	$2,751
Total	4,288	$9,487,146	$2,212

Table B.6.2
Madison Water Utility: Customer-side Lead Service Line Replacement Costs

Total Dollars Reimbursed	$2,754,420.93
Number of Reimbursements	4,149
Average Reimbursement Paid	$663.88
Average Total cost for Customer-side Lead Service Line Replacement	*$1327.76

*Note: This number does not account for replacements that are over $2000 since amounts over $2000 are not reported to the Utility

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

FOLLOW-UP MONITORING ON LEAD SERVICE LINE REPLACEMENT

In 2003, Madison Water Utility initiated a special project to assess the success of the lead line replacement program in terms of achieving optimal corrosion control. The study found that total lead concentration at a residence with a lead service line in Madison is typically seen to be erratic (Figure B.6.1). After lead line replacement, the erratic behavior continues (Figure B.6.2). By comparing Figures B.6.2 and B.6.3, it is seen that the erratic lead concentration is from lead particulate matter dislodging from pipe walls and arbitrarily becoming entrained in water samples. At the same time, dissolved lead concentration, which represents uniform corrosion, is lowered with lead service line replacement. At this time in Madison, the ninetieth percentile dissolved lead sampling results are at the desired goal of 5 µg/L (Figure B.6.3). The data suggest that the lead laden particulate matter is flushed out over several years after lead materials are removed from the plumbing system and a total lead concentration of 5 µg/L is eventually achieved (Figure B.6.2). (Cantor, 2006)

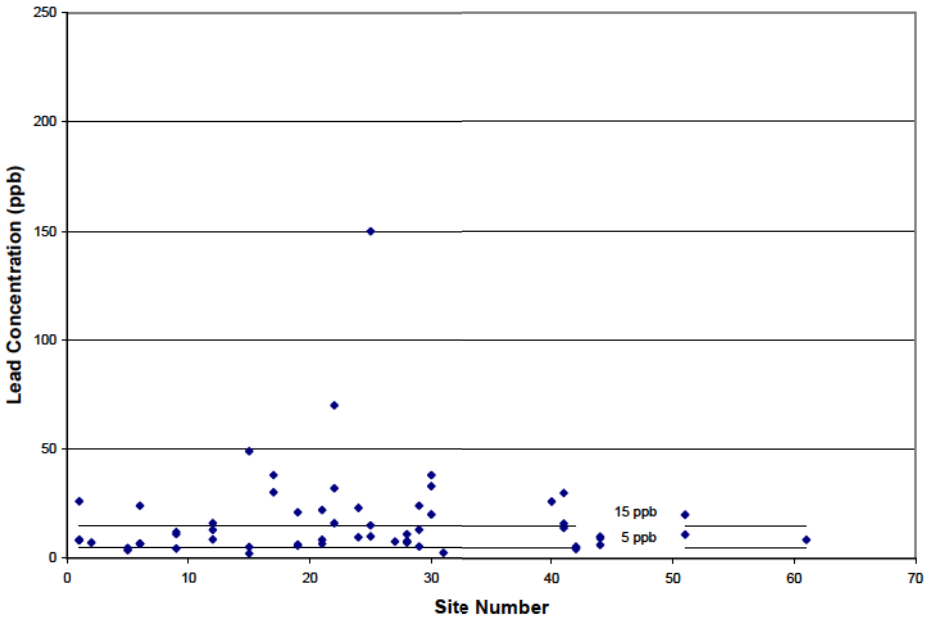

Figure B.6.1 Total (Particulate + Dissolved) Lead Concentration at Sites Before Full Lead Service Line Replacement

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

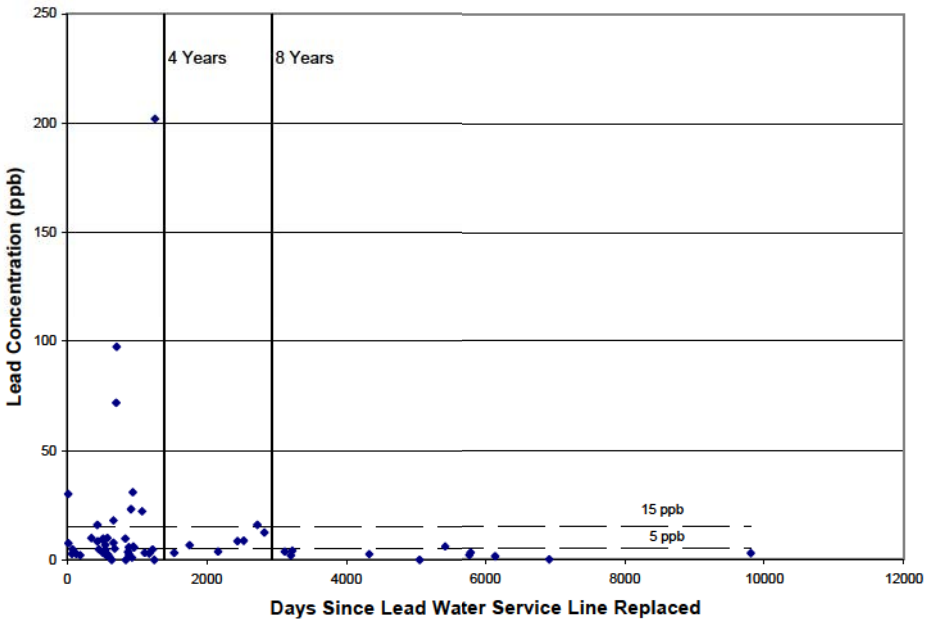

Figure B.6.2 Total (Particulate + Dissolved) Lead Concentration vs. Time Since Full Lead Service Line Replacement

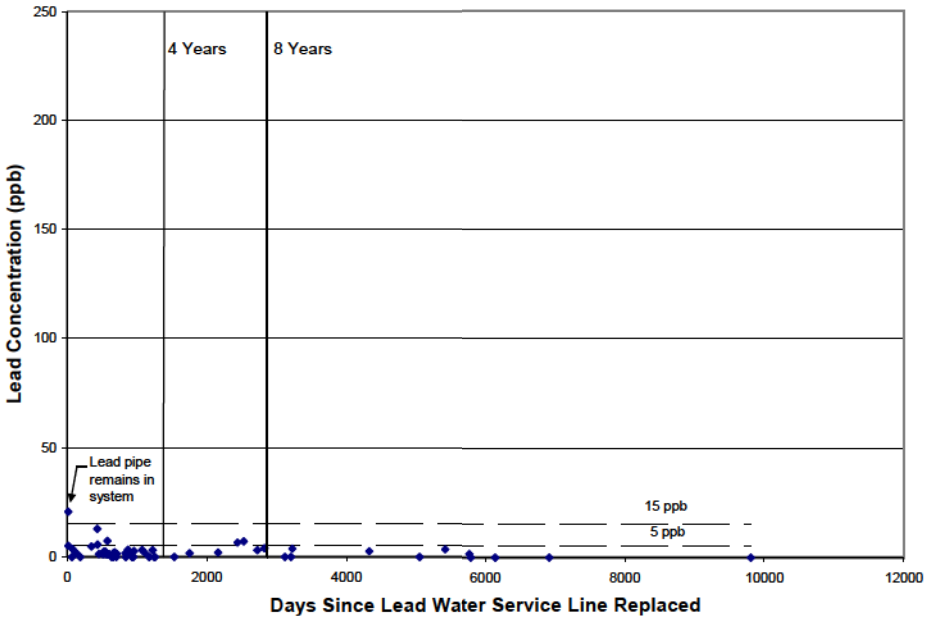

Figure B.6.3 Dissolved Lead Concentration vs. Time Since Full Lead Service Line Replacement

LEAD SERVICE PIPE SCALE EVALUATIONS

As models of lead solubility show, the DIC and pH of water determine what lead compounds will predominate, and the solubility of the predominant lead compound determines

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

the concentration of lead in the water (Schock, 1980). At a high DIC concentration such as in Madison's water, there is ambiguity in the solubility model as to how corrosive the water is. One research study reported that in high DIC water, a more soluble compound of lead (hydrocerussite) is often found where a less soluble compound (cerussite) is predicted (Sheiham and Jackson, 1981).

With that ambiguity in mind, a lead water service pipe excavated in Madison was sent to Michael Schock, US Environmental Protection Agency Research Chemist, for examination in 2001. He reported that on top of a familiar lead carbonate compound (cerussite), on the pipe wall, there was a predominance of yet another lead compound, lead dioxide (plattnerite), which was not included in the existing solubility model. He explained that this relatively insoluble lead compound would signify water with very low aggressiveness. Mr. Schock published this and similar findings noting that lead concentrations found in Madison are more than a factor of 10 below the expected lead concentrations from the DIC-based solubility model (Lytle and Schock, 2005).

Three more lead pipes were sent to Michael Schock for analysis in May and September 2005. These three pipes also had cerussite overlaid by plattnerite on the pipe wall, but there was an additional factor. A scale layer of manganese and iron compounds was observed on the pipe wall. Mr. Schock reported (Schock, et. al., 2006): "Since lead compounds are intermingled with the manganese and iron scale layers, and it is probable that lead ions are sorbed to the oxyhydroxide surfaces, destabilization of these Mn/Fe deposits could release microparticles intermittently." Indeed, past lead monitoring studies in Madison have shown lead in the drinking water to be mostly in particulate form.

FUTURE MONITORING

The results of the lead line replacement monitoring study were discussed with WDNR. Madison Water Utility proposed that more monitoring be done to substantiate the premise that particulate lead decreases over time after a complete lead service line is replaced and a concentration of 5 µg/L of total lead or below is ultimately achieved. The WDNR stated that Madison Water Utility compliance with the Lead and Copper Rule would be based on the results of the continued monitoring along with the standard Lead and Copper Rule sampling results presented at the end of the lead water service line replacement program in 2011. If the ninetieth percentile lead level for total lead concentration is over 15 µg/L at that time but the monitoring data shows that particulate lead decreases over time, then Madison Water Utility will be deemed in compliance.

SUMMARY

The Madison Water Utility has undertaken a full lead service line replacement program to meet the requirements of the Lead and Copper Rule, with a goal of replacing all lead service lines in the City by 2011. Since the customer has authority of the service line from the curb-stop to the building, the Madison Common Council approved a plan to place half the cost of replacing customer lead service lines on sewer rates. This decision was justified by showing a substantial avoided cost to sewer customers by implementing a complete lead service replacement program as opposed to adding corrosion control chemicals to drinking water, which would need to be removed at the wastewater treatment plant.

Source: *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues* by Sandvig et al.

Water quality data collected to assess the success of the lead line replacement program suggests that dissolved lead concentrations are lower after full lead service line replacement, but total lead concentration are erratic, and continue to be erratic for several years. Evaluation of the scale present on Madison lead service pipes indicates the presence of lead compounds intermingled with manganese and iron scale layers, resulting in destabilization of these Mn/Fe deposits and intermittent release of microparticles.

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