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Water Quality in Madison

Abigail Cantor, P.E. of Process Research Solutions, LLC

Discussion Topics

* What is water quality?
* What shapes the water quality that comes out of the consumers' taps?
* How does Madison's water compare to other systems in the state and around the country
* What directions should MWU take in the future to ensure high quality water?

What is Water Quality?

Water Quality as Defined by Regulations

* Regulations = specific contaminants entering the source water
* Regulations don't properly address the multiple factors in the distribution system that change the water quality.

Distribution systems are complex and chaotic and "one size" does not fit all.

Regulatory Definition versus New Definition

Regulatory Perspective	Comprehensive Distribution System Perspective
* Focus on one contaminant at a time typically in the source water	* Focus on quality of what the consumer drinks as the sum of all issues and aspects of the water system
* Measurements and control actions the same for all water systems	* Measurements and control actions specific to nuances of each water system
* Minimum safe requirements	* Protocol for control of water quality plus on-going optimization of water system operations

Water Research Foundation #4286: Distribution System Water Quality Control Demonstration

Regulatory Perspective	Comprehensive Distribution System Perspective
* Inorganic Chemicals	* Lead and Copper
* Arsenic	* Iron and Manganese
* Mercury, etc.	* Pathogenic and non-pathogenic microorganisms
* Synthetic Organic Chemicals	* Disinfection by-products
* Alachlor	* Biofilms in connected buildings
* Atrazine, etc.	* Effects of road salt
* Volatile Organic Chemicals	* Effects of phosphorus, nitrogen
* TCE	
* Toluene, etc.	

Examples

*What shapes the water quality that comes out of the consumers' taps?

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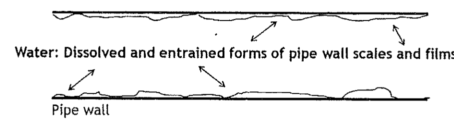
*Scales on pipe walls tell us what affects each system

- *Corrosion by-products
- *Biofilms
- *Precipitated chemicals
  - * Source water contaminants
  - * Chemical addition for water treatment



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* Most significant factors in shaping consumers' water quality

1. Biofilms
2. Precipitated chemicals
3. Distant 3rd: Corrosion by-products

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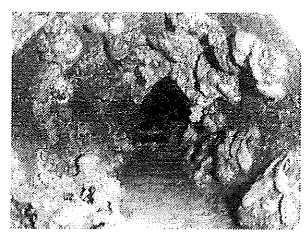
* CLEAN THE PIPES!!!!



Note: This is NOT a pipe from Madison.

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* Best Water Quality = No scales; No biofilms

- *Uni-directional flushing and pipe replacement should be the No. 1 budget priority
- *THIS IS WHAT MADISON DOES!!!

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*How Does Madison's Water Compare to Others?

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* Madison has lead the way for other utilities

*Lead control
*Uni-directional flushing

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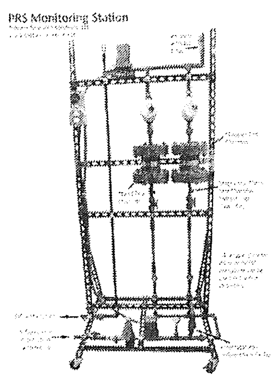
* PRS Monitoring Station

A water distribution system monitoring station that measures representative water quality that the consumer experiences.

Similar to a Water Research Foundation pipe loop; would get similar results is using a pipe loop

Many advantages to using the PRS Monitoring Station configuration:
- Cost
- Ease of use
- Lower incidence of leaks
- Uniform configuration and operation for comparisons of data
- Easy analysis of scales on internal metal plates for important insights



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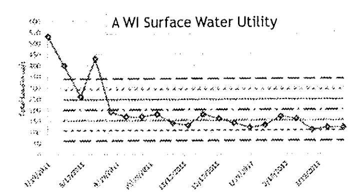
* Comparison of Lead Transfer



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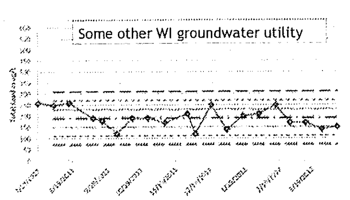
* Comparison of Lead Transfer



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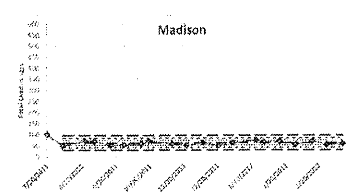
* Comparison of Lead Transfer



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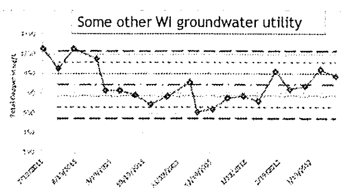
*Comparison of Copper Transfer



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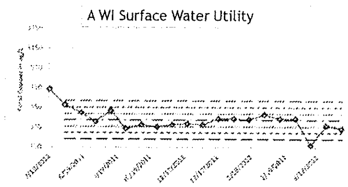
*Comparison of Copper Transfer



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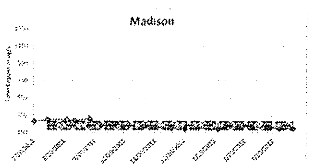
*Comparison of Copper Transfer



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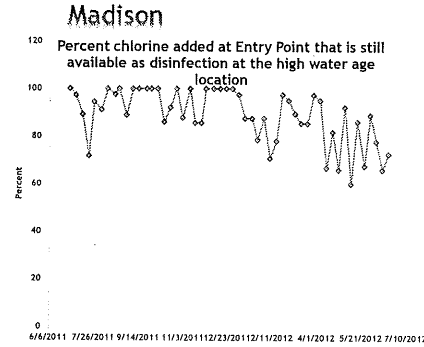
*Comparison of Pipe Cleanliness - Madison



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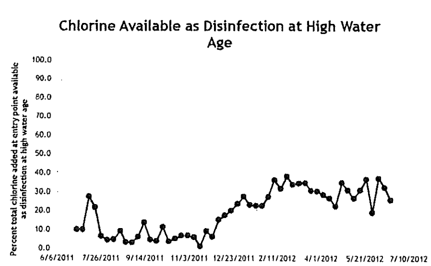
*A WI Surface Water Utility



*What Does the Future Hold for MWU Water Quality

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* Continue with:

- *Uni-directional flushing
- *Pipe replacement (unlined cast iron pipes; lead pipes are gone)
- *Keeping Fe and Mn out of distribution system
- *Wellhead protection (keep out effects of industry, agriculture, human activity)

* Add another item to the list:

- *Track "biostability" first in wells and then in distribution system
  - *Microbiological activity (use ATP tests)
  - *Nutrients (N, P, C)
  - *Disinfection (total and free chlorine tests)

* Questions?

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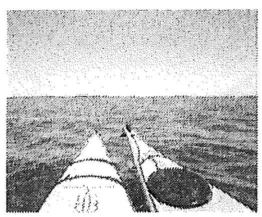

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Lead and Copper Rule Compliance Sampling

Madison Water Utility

6/24/13
Partial copy of report to show history of LEAD + COPPER RULE compliance in MADISON.
NOTE: AFTER 2012 SAMPLING, MADISON 90th % LEAD < 5 ug/L FOR 2 SUCCESSIVE 6 MONTH SAMPLING.

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May 2010

Lead and Copper Rule Compliance Sampling

Madison Water Utility

Contents

Lead and Copper Rule Compliance Sampling

Madison Water Utility

History of Lead Control in Madison

In the Madison water system, lead was commonly used for water service lines from 1882, the inception of the Madison Water Utility, through 1927. Madison Water Utility has been replacing lead water service lines in the distribution system since the 1930s. This activity was intensified in 2000 under an agreement with the Wisconsin Department of Natural Resources (WDNR) to accelerate the prevention of lead transferred from lead pipes to drinking water. (See the agreement in Appendix A.)

The effort to replace lead water service lines is close to completion. The final step in the project is to show that lead concentrations in the distribution system are below the Action Level of 15 μg/L for "regulatory compliance" and are approaching 5 μg/L for complete "optimization" of controlling lead levels in the drinking water. The sampling protocol prescribed by the Federal Lead and Copper Rule (Code of Federal Regulations) must be used for this step.

This report summarizes the history of lead control in Madison, describes a successful approach to a similar problem in another water system, and recommends the next steps for Madison in planning and carrying out the Lead and Copper Rule sampling.

Lead in Madison's Distribution System

As stated, lead was commonly used for water service lines from 1882 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, replacing them 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. (PRS, 2006a)

Lead can also be found in other components of the distribution system. For example, Hersey water meters, some of which used lead weights, were used in the Madison water system 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. (PRS, 2006a)

Brass Mueller corps and curb stops used in the Madison Water Utility distribution system contain about 5% lead (PRS, 2006a).

In addition, brass faucets and fittings that are purchased and installed by property owners in residential and commercial plumbing systems can contain lead.

Initial Water Testing

The federal Lead and Copper Rule regulation was enacted in 1991. The regulation describes a protocol for sampling the water distribution system for lead and copper concentrations. If ten percent or more of the water samples have lead concentrations above the "Action Level" of 15 µg/L, then a water utility must alter the chemical composition of the water to make the water "less corrosive". The lowest concentration in the top ten percent of the samples is called the "ninetieth percentile lead concentration". (Code of Federal Regulations)

Just after the first Lead and Copper Rule sampling in Madison where the ninetieth percentile lead concentration was found to be 16 µg/L, a corrosion control investigation was initiated. That was in 1992. The true nature of Madison's water would not be discovered until 2006. In the meantime, the water utility management made logical decisions based on investigation results regardless of popular anecdotal opinion concerning corrosion control.

The first tests on corrosion control in Madison were jar tests. In these tests, coupons of lead were suspended in jars of water. Using a statistical design to compare various treatments, the water in each jar used a different corrosion control chemical treatment. In this way, the transfer of lead into raw water was compared to water with sodium silicate addition, pH adjustment with sodium hydroxide, and a polyphosphate/orthophosphate blend addition. There was no change in lead levels with the sodium silicate addition; the increase of pH lowered the lead levels a little; the lead levels increased with the polyphosphate blend.

This information was used to set up an off-line pipe loop experiment using both old and new lead pipes. Three systems were set up in order to compare no treatment to two chemical treatments. Even though polyphosphate blend addition was shown to increase lead concentrations in the jar tests, the chemical was tested further in the pipe loop tests. This was because popular opinion at the time was to add a polyphosphate blend for corrosion control. Case studies were published in the technical literature, but many reports were contradictory. Chemical companies encouraged the use of polyphosphate blends, but the data they presented on the efficacy of the products were ambiguous. Plus, the chemical companies claimed that the jar tests did not represent an actual piping system. In addition, many smaller communities around Wisconsin were adding polyphosphate blends directly to the water system without previous off-line testing and with no distribution system monitoring. Based on the technical literature at the time, the Lead and Copper Rule and the federal and state regulatory agencies condoned and encouraged the use of polyphosphates for corrosion control. Finally, the use of orthophosphates was discouraged by chemical companies. It was rumored that pure orthophosphate would form a precipitate with calcium in the water that would obstruct pipelines. All of these factors led to the additional testing of polyphosphate blends in the Madison corrosion control investigation. A second treatment chosen was pH adjustment using sodium hydroxide. Here again, it was known that there were potential problems. Given the high hardness concentration of the Madison water, an increase in pH could easily set off the precipitation of calcium and magnesium into the pipe causing hydraulic problems. There were no other chemical corrosion control techniques available to test. The results of the tests showed that the pipeline and appurtenances plugged up with calcium and magnesium precipitate when the pH of the water was increased. The results also showed that lead increased four times the concentration in untreated water when a polyphosphate blend was added. (Cantor, et. al., 2000)

Subsequent Discussions

The results of the corrosion control investigation were presented to the WDNR. Madison Water Utility requested that the water system be allowed 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 is not chemically viable.
- Because the water comes from twenty-three distinct sources with no common treatment or storage facilities, alkalinity adjustment is not economically viable.
- Sodium silicate did not show any benefit in jar tests. Plus, there is little information on the use of sodium silicates.
- Polyphosphates increased the lead concentration in the water. In addition, there was concern about adding phosphorus to water that will run off into the surrounding lakes where nutrients were already a problem. The wastewater treatment plant would also be responsible for removing the phosphorus for water that went through the wastewater system so that the Clean Water Act regulations would not be compromised.
- Orthophosphate usage was discouraged because of a possible precipitate even though the technical literature indicated that the chemical may be effective in lowering the lead levels. Nevertheless, the phosphorus discharge to the environment was a problem as described previously.
- There are no other chemical corrosion control techniques available.

Because of the emphasis that the Lead and Copper Rule has on chemical alteration of water for corrosion control, the WDNR requested that pipe loop tests be run using orthophosphate for corrosion control.

Continued Testing

In 1998, the pipe loop tests with orthophosphate were run. Both old and new lead pipes were used. The orthophosphate 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. There was already discussion in the city council about banning phosphorus lawn fertilizers in Madison to prevent nutrient-laden runoff.

The WDNR then agreed that removing lead water service lines as a means of corrosion control was the only reasonable option available.

Complete Lead Service Line Replacement

The WDNR also stated that, in accordance with the Lead and Copper Rule, a large system like Madison must achieve a 90th Percentile lead concentration of 5 µg/L in order for the water system to be deemed "optimized" for lead corrosion control. In order to achieve this low 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 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.

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. This would set a precedent for other customer-owned systems, such as electrical wiring, which must be kept up to code at the customers' expense.

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. Customers replacing lead service lines were to be reimbursed for half the cost of replacing those lines up to $1000 reimbursement per property

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. (PRS, 2006a)

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 <u>with</u> a lead service line in Madison is typically seen to be erratic. Figure 1 shows that an individual site can have high lead at times and low lead at other times. <u>After</u> lead line replacement, the erratic behavior of total lead concentration continues for three or four years (Figure 2) and then appears to subside.

This was a surprising finding to see that lead can persist in a plumbing system several years after the source of lead has been removed.

This happens because lead is found in two forms in the water. The total lead concentration is actually a summation of lead dissolved in the water and lead entrained in the water as particulate matter. Figure 3 shows the dissolved fraction of lead in the 2003 water samples. By comparing Figures 2 and 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 is lowered with lead service line replacement. The 2003 water sampling showed that the dissolved lead sampling results are at the desired goal of 5 µg/L (Figure 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 2). (Cantor, 2006)

The results of the lead line replacement monitoring study were discussed with WDNR. Essentially, Madison's compliance with The Lead and Copper Rule hangs on the random release of lead particulates into the water. This mechanism of the transfer of lead into water was not considered in The Lead and Copper Rule. In addition, until the Madison study was reported, the technical literature did not acknowledge this mechanism as a significant contributor to lead in drinking water.

Pipe Film Analyses

In 2001, a lead water service pipe excavated in Madison was sent to Michael Schock, US Environmental Protection Agency Research Chemist, for examination. Around 2003, 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 had not been expected or included in the existing theoretical model of lead corrosion. 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 theoretical 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 manganese/iron deposits could release microparticles intermittently."

The role of manganese scale in Madison was confirmed in further pipe film analysis by Dr. Barry Maynard and Dr. David Mast, professors at University of Cincinnati, in a 2006 AWWA Research Foundation study (Maynard & Mast, 2006).

Indeed, the 2003 lead monitoring studies in Madison had shown lead in the drinking water to be mostly in particulate form. Only in 2006 was it understood that manganese scale played a major role in holding and randomly releasing lead measured as particulates into the drinking water.

Figure 1. Madison Water Utility: Total Lead Concentrations at Residences with Lead Water Service Lines (Cantor, 2006)

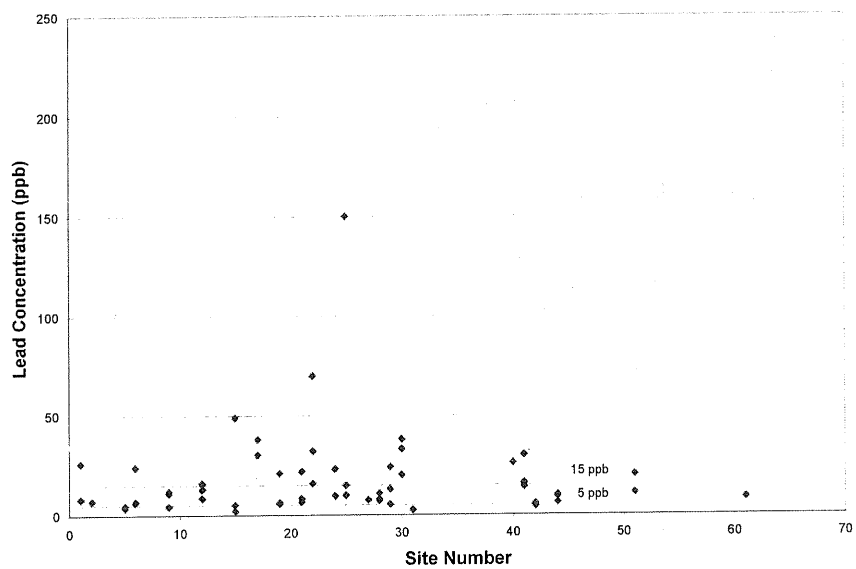


Figure 2. Madison Water Utlity: Total Lead Concentrations at Residences After Lead Water Service Line Replacement (Cantor, 2006)

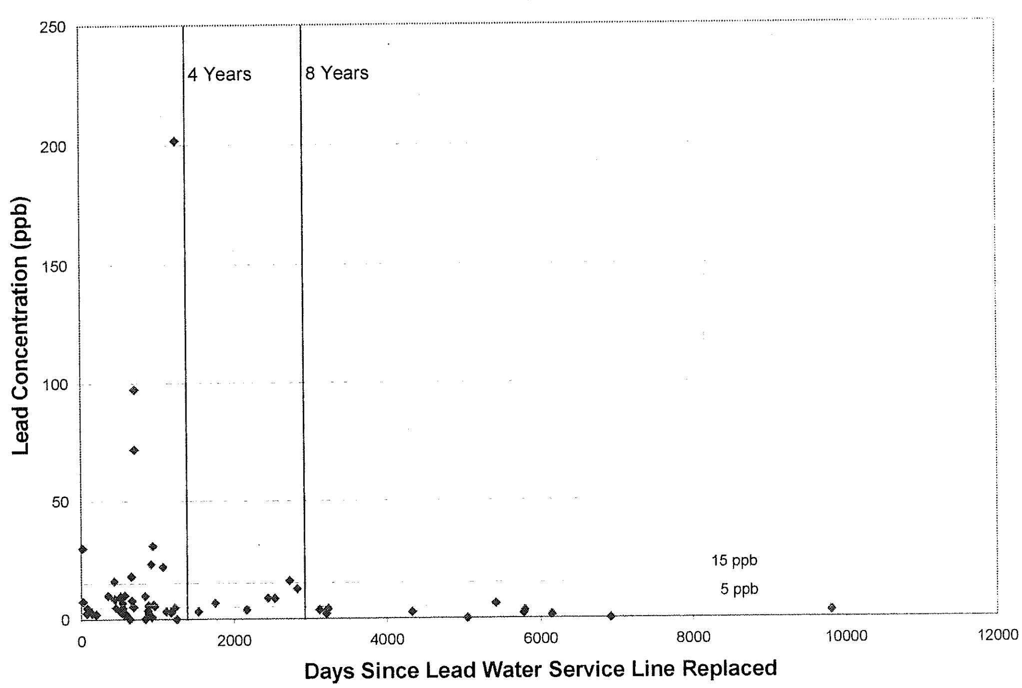
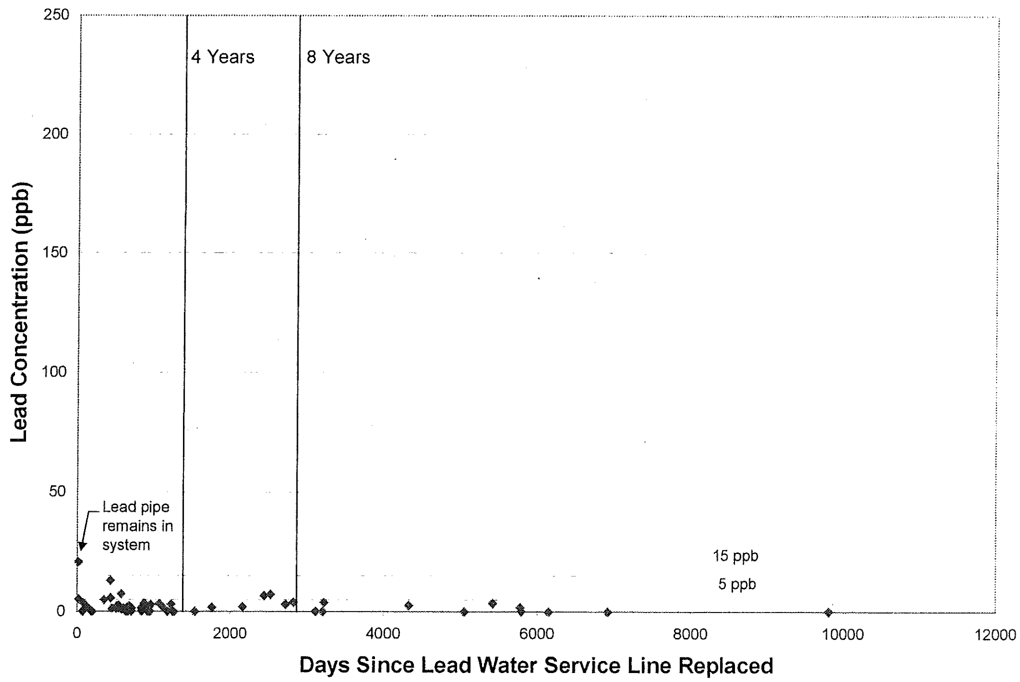


Figure 3. Madison Water Utility: Dissolved Lead Concentrations at Residences After Lead Water Service Line Replacement (Cantor, 2006)



Summary

In hindsight, the decision to replace lead service lines rather than alter the water chemistry still stands as a good one. As discussed previously, it is now known that Madison water already offers minimum aggressiveness toward lead. It is the presence of manganese scale on the pipe wall that captures, stores, and randomly releases lead particulates into the drinking water.

Publications about the Madison Experience

The investigations in Madison have served as an example to the national drinking water community. Discoveries in Madison contradicted assumptions about lead release into drinking water that have been stated in The Lead and Copper Rule and in technical literature. Therefore, the investigators, Abigail Cantor of Process Research Solutions, LLC, Michael Schock of US Environmental Protection Agency, and Barry Maynard and David Mast of University of Cincinnati, have felt it important to publish the findings from Madison data. The important discoveries have been:

- Polyphosphate corrosion control products are not necessarily successful at controlling lead or copper concentrations in drinking water. Ironically, the chemical can, in some cases, increase the lead or copper concentrations instead of decreasing them. Madison Water Utility tested a polyphosphate product to lower lead concentrations in the drinking water; the off-line tests showed that the lead concentration increased four times over that in untreated water.

- In some cases, a very protective pipe film can form naturally in the water practically stopping uniform corrosion in a water system. Madison's water was found to form this highly protective film.

- Manganese scale which precipitates and builds up in water distribution systems when found in source water has a tendency to capture dissolved and particulate lead (and other metals) from the water that flows past. In this way, lead is stored in the distribution system until it is released randomly to the consumers' taps where it is measured as lead particulates.

- Not all increases in lead and copper in drinking water are caused by uniform corrosion as the primary drinking water regulation, The Lead and Copper Rule, assumes. Madison has been shown to have minimal uniform corrosion.

The following international publications use Madison as an example to alert other water utilities to contradictions and discoveries for lead control in drinking water:

Cantor, A.F., D. Denig-Chakroff, R.R. Vela, M.G. Oleinik, D.L. Lynch (2000). "Use of Polyphosphate in Corrosion Control," *Journal of the American Water Works Association* (92:2:95).

Cantor, A.F. (2006). "Diagnosing Corrosion Problems Through Differentiation of Metal Fractions," *Journal of the American Water Works Association* (98:1:117).

Cantor, A.F. & S. Estes-Smargiasi (2006). "Report on Lead Service Line Replacement AwwaRF Study", Proceedings of the American Water Works Association 2006 Water Quality and Technology Conference Nov. 5-9, 2006 (Denver, CO).

Lytle, D.A. and M.R. Schock (2005). "Formation of Pb(IV) Oxides in Chlorinated Water," *Journal of the American Water Works Association* (97:11:102).

Maynard, B. & D. Mast (2006). Composition of Interior Scales on Lead Source Materials. Proceedings of the American Water Works Association 2006 Water Quality and Technology Conference Nov. 5-9, 2006 (Denver, CO).

Sandvig, A., P.Kwan, G. Kirmeyer, B. Maynard, D. Mast, R.R. Trussell, S. Trussell, A. Cantor, & A. Prescott (2008). *Contribution of Service Line and Plumbing Fixtures to Lead and Copper Rule Compliance Issues.* AWWA Research Foundation (Denver).

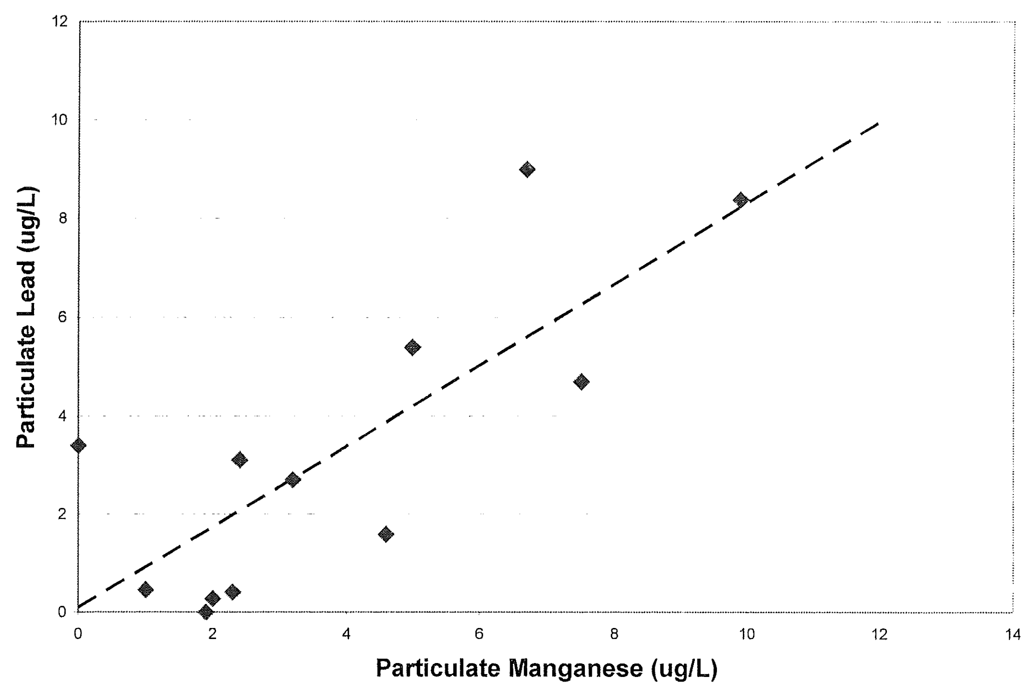
Cantor, A.F (2009). *Water Distribution System Monitoring: A Practical Approach for Evaluating Drinking Water Quality.* CRC Press (Boca Raton).

Lead and Copper Rule Sampling Results from Other Utilities After Uni-directional Flushing

The discoveries from Madison Water Utility investigations have been carried forward to subsequent water quality investigations by Process Research Solutions. Many groundwater systems in Wisconsin and around the country have iron and manganese dissolved in well water from the aquifer. These metals oxidize in the distribution system and precipitate as a solid on the distribution system pipe walls. Both iron and manganese have a tendency to form chemical bonds with other metals passing by the surface of the scales. Manganese, especially, has a tendency to "sorb" lead in this way. When pieces of the manganese scale inevitably break off, the lead "piggybacks" with the manganese and can end up at the consumers' tap.

Marshfield Utilities in western Wisconsin showed the same pattern of particulate lead randomly occurring at consumers' taps as was seen in Madison. Marshfield has a presence of iron and manganese varying from well to well just as Madison does. A moderate relationship was found between particulate manganese and particulate lead at consumers' taps as shown in Figure 4 (PRS, 2006b).

Figure 4. Marshfield Utilities: Manganese versus Lead Particulates in Drinking Water



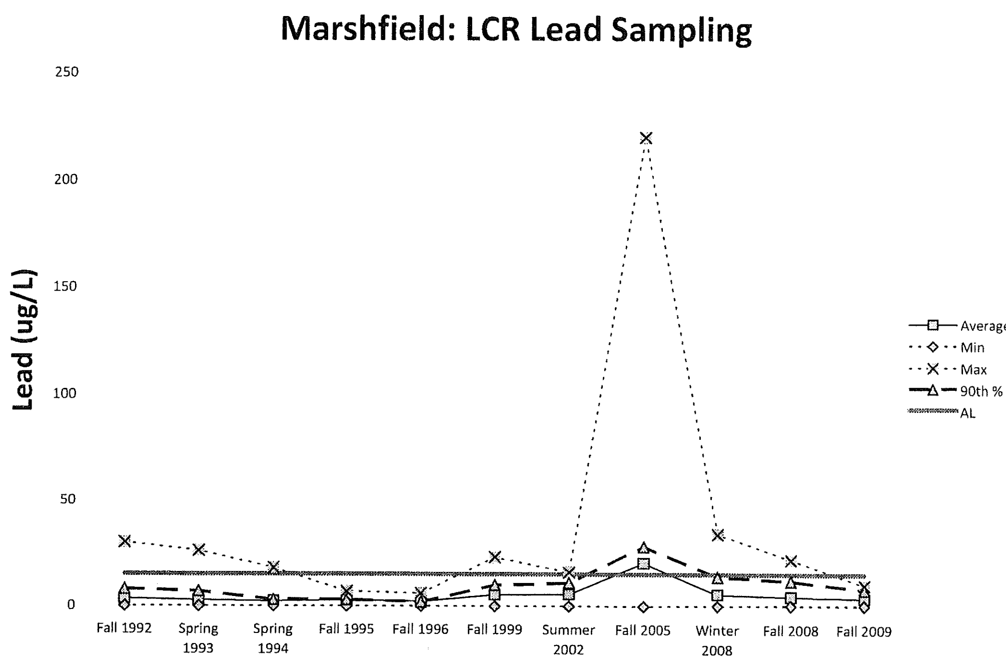
It was recommended that Marshfield perform uni-directional flushing of water mains to efficiently clean out manganese scales (PRS, 2006b). The utility performed this flushing in the summer of 2007 as well as flushed critical water service lines and has completed follow-up Lead and Copper Rule sampling. The utility is now in compliance with The Lead and Copper Rule and maximum lead levels have dropped from 220 µg/L to 10 µg/L, ninetieth percentile lead levels have dropped from 32 µg/L to 8 µg/L (PRS, 2008). Table 1 and Figure 5 illustrate the improvements made in controlling lead by cleaning out the manganese scales in Marshfield.

Madison Water Utility has also been efficiently cleaning water mains with uni-directional flushing since 2006. The motivation to do so was from customer complaints about excessive manganese particulates in the water. The first pipe film analysis report that found manganese to be a significant mechanism to holding and releasing lead into the water (described above) was received a few weeks before the flushing program began. It was realized at that point that the flushing program not only benefits the issue with water discolored by manganese but also addresses the lead particulate issue as well. Now that data from Marshfield Utilities' experience shows success of uni-directional flushing with lowering lead levels, it is expected that Madison's Lead and Copper Rule sampling will show the system in compliance.

Table 1. Marshfield Utilities: Lead and Copper Rule Sampling Statistics

Year	Average Value	Standard Deviation	Max Value	90th Percentile
1992	2.5	6.3	30	8
1993	1.8	4.1	26	7
1994	1.4	3.3	18	4
1995	2.1	1.6	7	4
1996	1.3	1.6	6	3
1999	4.7	4.9	23	12
2002	4.9	4.3	16	13
2005	20	48.7	220	32
2008, winter	5.7	6.3	34	14
2008, fall	4.6	4.9	22	12
2009, fall	3.9	2.5	10	8

Figure 5. Marshfield Utilities: Lead and Copper Rule Sampling Statistics



Marshfield's experience also suggests that perhaps the lead water service lines did not need to be replaced in Madison; uni-directional flushing alone may have solved the problem. That may be so. However, that could not have been known in 1991 or even 2003. It was the Madison experience that paved the way into understanding the lead issue for the drinking water industry. In addition, lead water service lines should be replaced anyway because lead can be transferred to water by a number of mechanisms (Cantor, 2009). As long as major sources of lead exist in a system, it poses a threat to water quality. It is also known now that replacing both the utility's side and the property owner's side of the lead water service line is imperative as the human exposure to lead is greatly increased if only part of the line is replaced (Sandvig, et. al., 2008). Other water utilities should follow Madison both in removing lead from the distribution system over time and in efficiently cleaning water mains and water service lines routinely.

Sampling Plans

Lead and Copper Rule Sampling

Monitoring Period

At the completion of the lead service line replacement program in 2010, Madison Water Utility must perform Lead and Copper Rule sampling at one hundred residences and prove compliance in two successive six month periods (January to June 2011 and July to December 2011).

If the Action Levels for lead and copper (15 and 1300 ug/L, respectively) are not exceeded for the two monitoring periods, sampling is expected at fifty sites annually for two more years (2012 and 2013). If compliance is again proven during those sampling events, sampling frequency moves to every three years where the cycle would begin in July 2014.

If, during the two six month sampling periods in 2011, the lead ninetieth percentile concentration is 5 µg/L, then the water system is exempt from the annual sampling requirements in 2012 and 2013 and the sampling frequency moves to every three years, where the cycle would begin in July 2014 for fifty sites. Table 2 summarizes the monitoring requirements.

Table 2. Madison Water Utility: Lead and Copper Rule Sampling Schedule

<table>
<tr><th>Item</th><th>Year</th><th>Months</th><th>Number of Sites</th><th>Comments</th></tr>
<tr><td>A</td><td>2011</td><td>January to June</td><td>100</td><td rowspan="2">If 90th percentile lead is 15 ug/L, then in compliance; continue to Item C. If 90th percentile lead is 5 ug/L, then optimized; jump to Item E.</td></tr>
<tr><td>B</td><td>2011</td><td>July to December</td><td>100</td></tr>
<tr><td>C</td><td>2012</td><td>July to December</td><td>50</td><td></td></tr>
<tr><td>D</td><td>2013</td><td>July to December</td><td>50</td><td></td></tr>
<tr><td>E</td><td>2014</td><td>July to December</td><td>50</td><td></td></tr>
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