APPENDIX B

Study of Corrosion Control in Small Public Water Systems

Sponsored by the Midwest Technical Assistance Center for Small Public Water Supplies

July 20, 2000

Objective

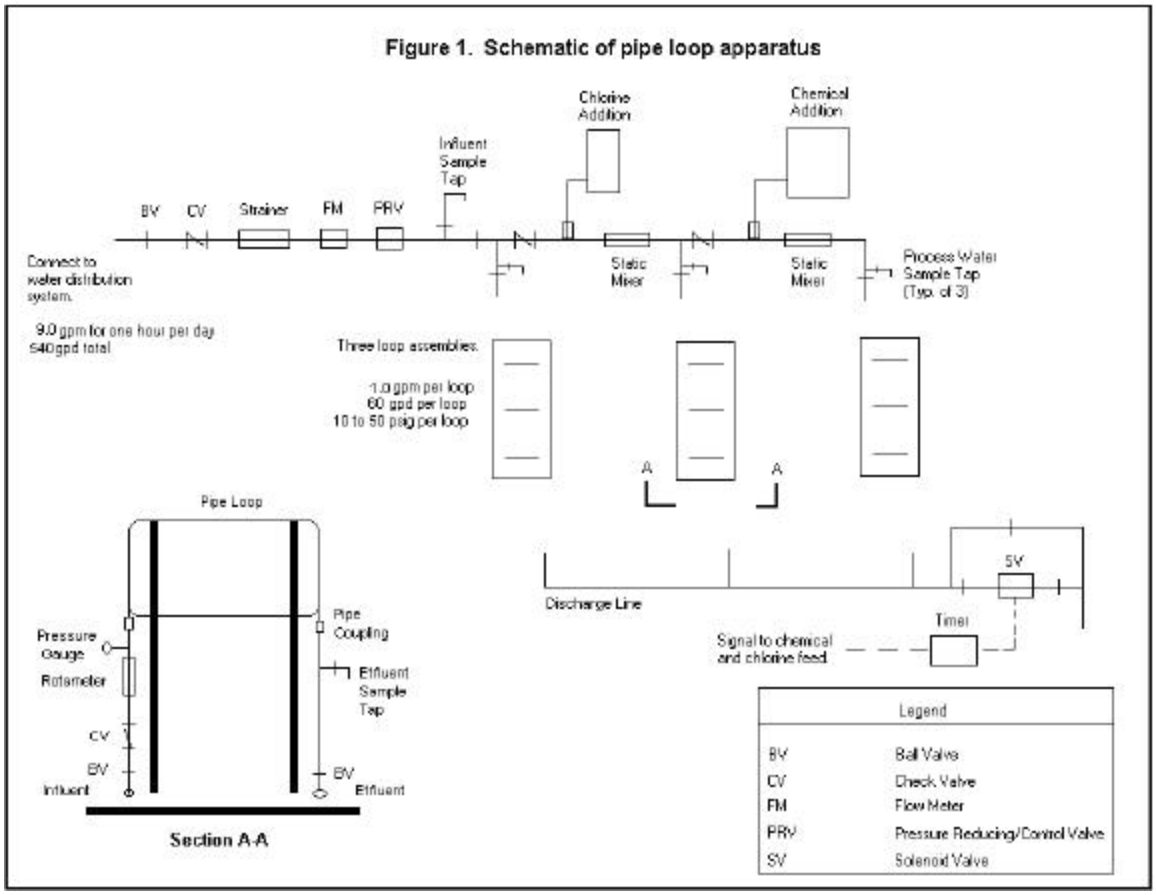
The goal of this project is to identify the effect of chlorine on small drinking water systems that have not previously used chlorination for disinfection. The interaction of chlorination and corrosion control techniques is also examined.

Project Team

The project team includes:

- Professor Jae K. Park of the University of Wisconsin Department of Environmental Engineering
- Abigail Cantor, P.E. of Process Research, an engineering consulting firm
- Prasit Vaiyavatjamai, a student assistant

Description of Project



The project was described in detail in the six month interim report issued in September, 1999. In review, two small water utilities in Wisconsin are hosting the experimental

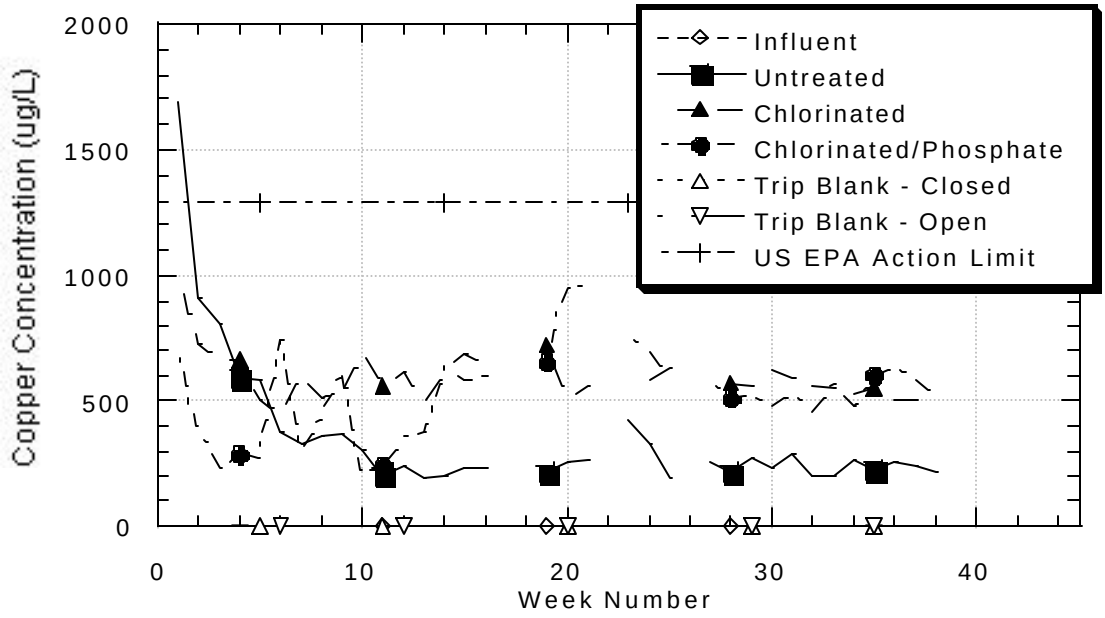
apparatuses. One utility in the Village of Dane has high alkalinity water and the other in the Village of Lone Rock has lower alkalinity water. An apparatus consisting of three groups of three pipe loops each (nine loops) have been installed at each site. In each group, one loop is copper, another lead, and the other iron. One group of loops receives untreated water, a second receives chlorinated water, and a third receives water where chlorine and a corrosion control chemical have been added. A schematic of the apparatus is shown in Figure 1. Each pipe loop simulates a residential plumbing system and is similar to the AWWARF Pipe Loop Model. This model was introduced in the book, Lead Control Strategies (1991) published by the American Water Works Association Research Foundation. The loops are sampled every week to check the effluent metals concentrations. The loops will be compared in their response to corrosive factors. A number of other samples are taken for process control and to define the water quality at the sites.

Status

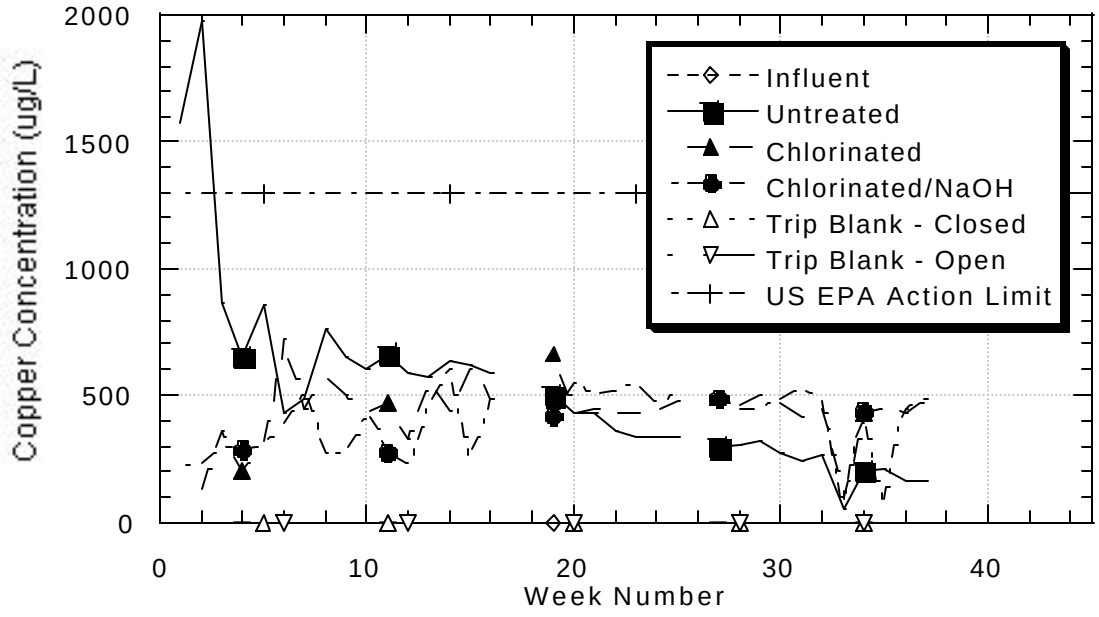
The loops have operated as planned since they were started in September, 1999 to June, 2000. A leak in a cracked plastic coupling was discovered at the Lone Rock chlorinated copper loop during the week of June 12 and was repaired on June 19. A special sampling event to gather data for stagnation curves began later that week and was completed the week of July 3. On July 4, multiple small leaks were discovered in the Lone Rock chlorinated lead loop. This probably occurred because of disruption to the apparatus while repairing the previous leak. The lead loop was isolated and taken out of service for the remainder of the study.

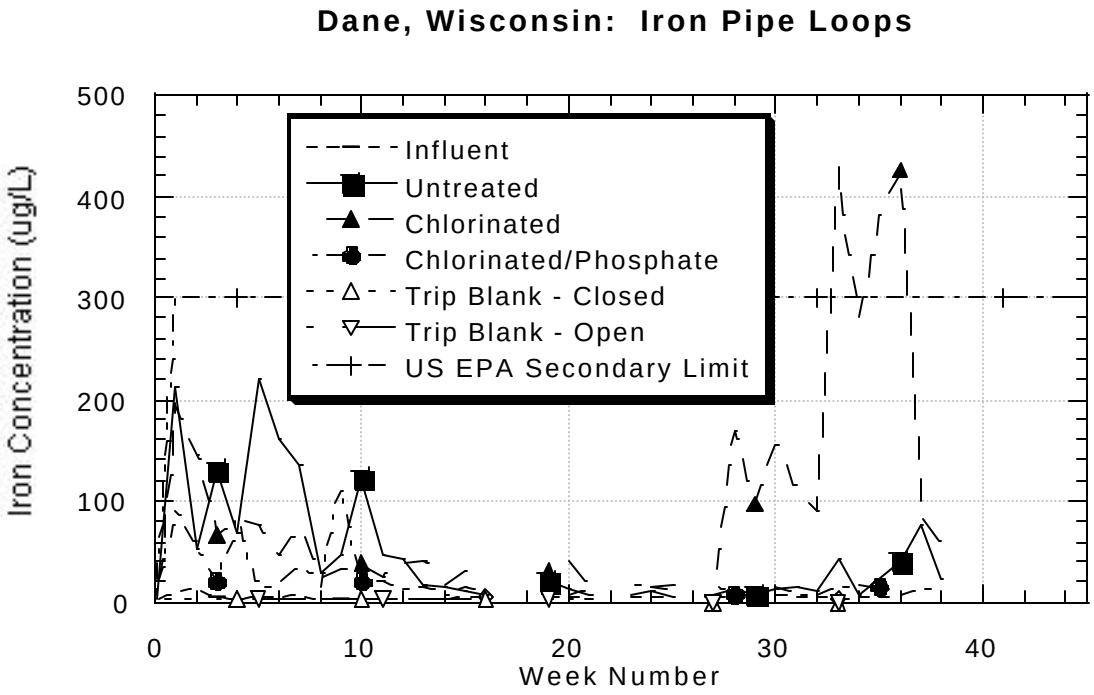
Metals data that have been obtained over the forty-five weeks of the study are shown below.

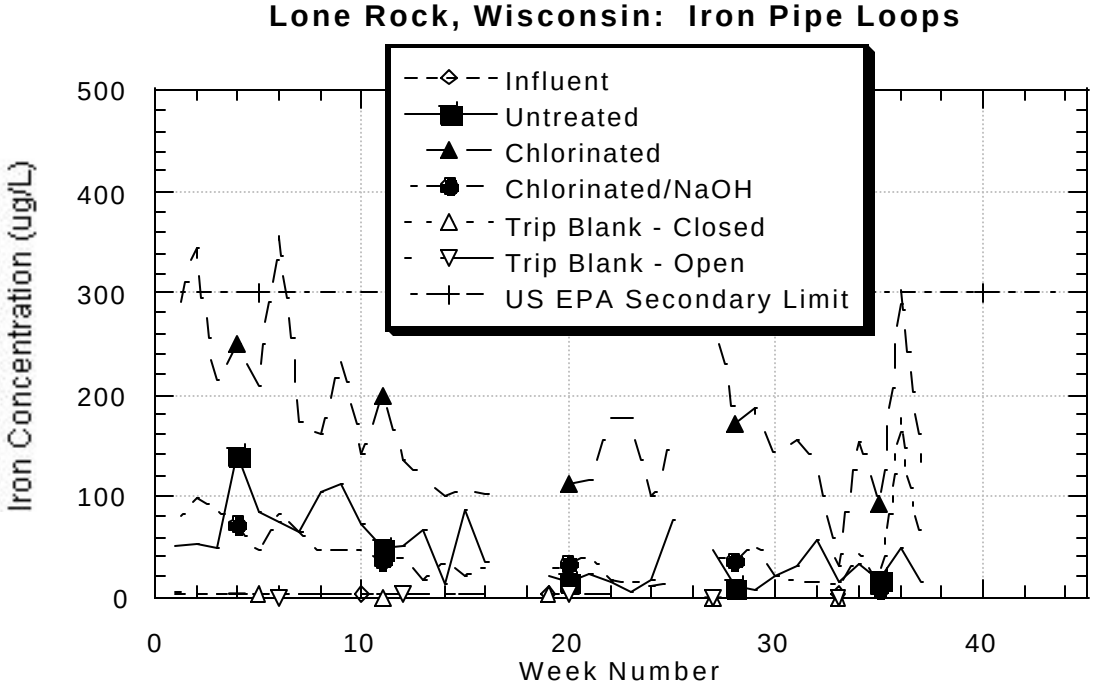
Dane, Wisconsin: Copper Pipe Loops



Lone Rock, Wisconsin: Copper Pipe Loops







Conclusions drawn from the data are subject to change after statistical analysis of the influence of many factors recorded in the study is performed in September. Tentative conclusions are shown in the tables below.

Lead Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to lead	Corrosive (over the action limit)	Corrosive (over the action limit)
Effect of adding chlorine	Lowers lead a little at first, but as the pipe ages, there is no difference with the raw water	Lowers the lead levels
Effect of corrosion control chemicals added to the chlorinated water	Adding orthophosphate does not change the chlorinated water's corrosivity at first but possibly lowers the lead in the long term	Increasing pH does not change the chlorinated water's corrosivity
Background "noise" as shown in the influent sample and two trip blanks	Insignificant	Insignificant

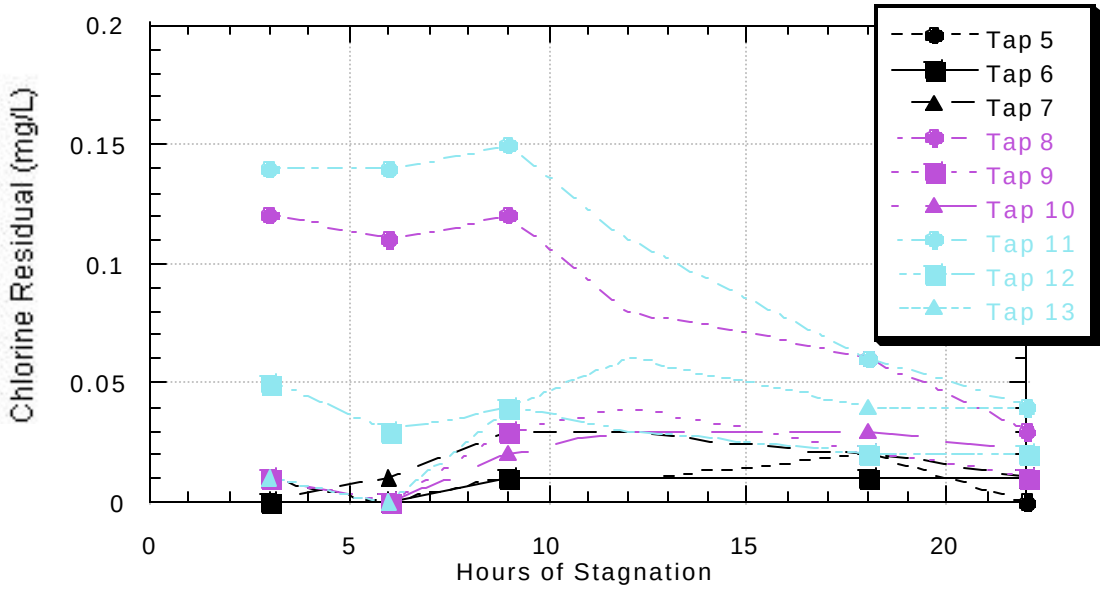
Copper Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to copper	Not over the action limit	Not over the action limit
Effect of adding chlorine	Water is more corrosive than raw water but still not over the action limit	Water is not different than raw water at first, but later on, copper is elevated
Effect of corrosion control chemicals added to the chlorinated water	Adding orthophosphate does not change the chlorinated water's corrosivity	Increasing pH does not change the chlorinated water's corrosivity
Background "noise" as shown in the influent sample and two trip blanks	Insignificant	Insignificant

Iron Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to iron	Not over the secondary limit	Not over the secondary limit
Effect of adding chlorine	Chlorine has no effect at first but elevates the iron greatly later on; could be because of temperature influence instead of time	Chlorine elevates the iron levels
Effect of corrosion control chemicals added to the chlorinated water	Adding orthophosphate is effective in counteracting the influence of chlorine	Increasing pH is effective in counteracting the influence of chlorine
Background "noise" as shown in the influent sample and two trip blanks	Insignificant	Insignificant

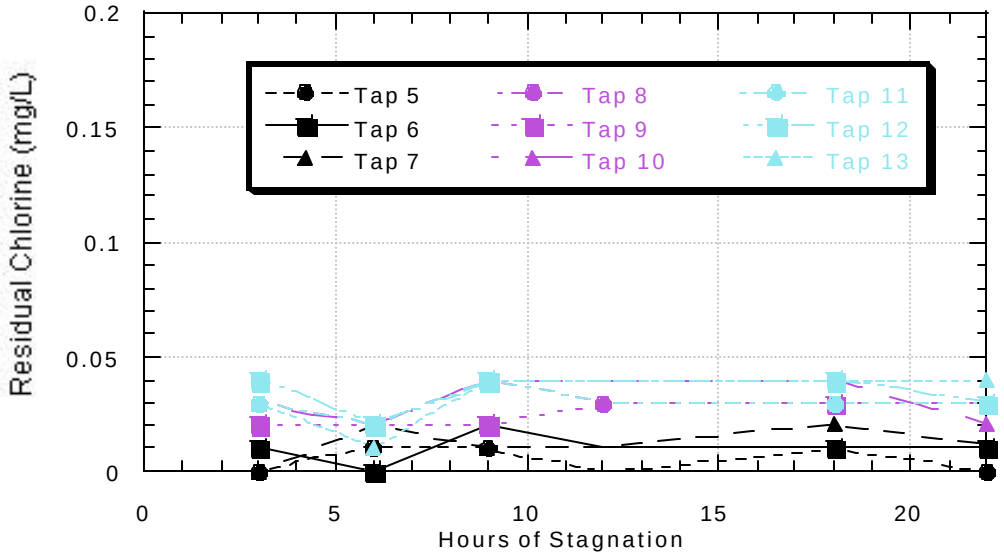
The above data and conclusions must also be tempered by information gleaned from stagnation curves. Stagnation curves are measures of metals concentrations and oxidants (dissolved oxygen, chlorine residual) over various times that the water is in contact with the pipe loop metal. The curves show that maximum metals concentrations can occur sooner or later than expected. This critical information may not be captured during routine sampling and conclusions may be different. It should be noted that stagnation curves change with pipe age typically. The curves developed in this study are applicable to the loop conditions around weeks 41 to 45. In addition to metals concentrations, chlorine residual and dissolved oxygen data were also obtained as well as pH and temperature. The results are shown below except for temperature which remained constant over time.

Explanation of Legend for Stagnation Curves	
Tap Number	**Description**
5	Lead Loop, Untreated
6	Copper Loop, Untreated
7	Iron Loop, Untreated
8	Lead Loop, Chlorinated
9	Copper Loop, Chlorinated
10	Iron Loop, Chlorinated
11	Lead Loop, Chlorinated/Phosphate or Chlorinated/NaOH
12	Copper Loop, Chlorinated/Phosphate or Chlorinated/NaOH
13	Iron Loop, Chlorinated/Phosphate or Chlorinated/NaOH

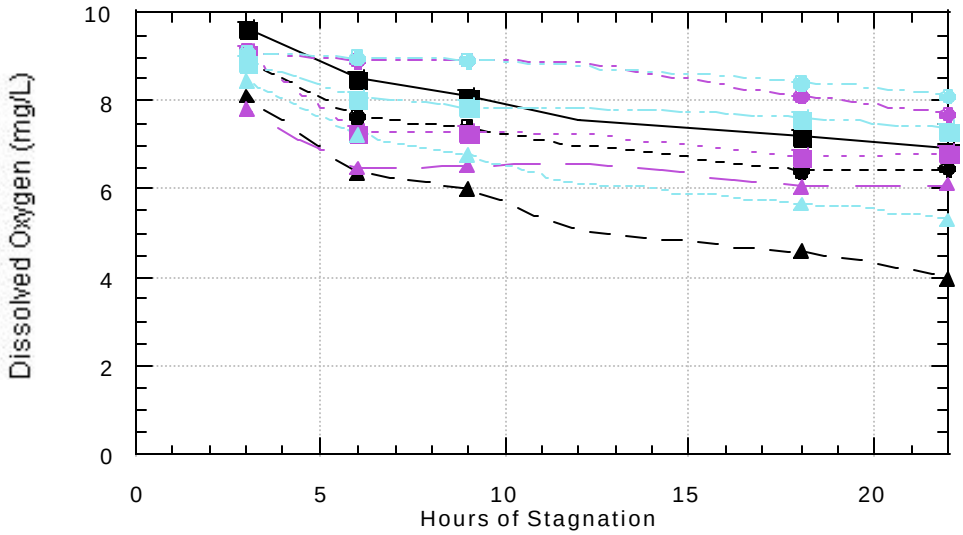
Dane, Wisconsin: Stagnation Curves for Chlorine Residual



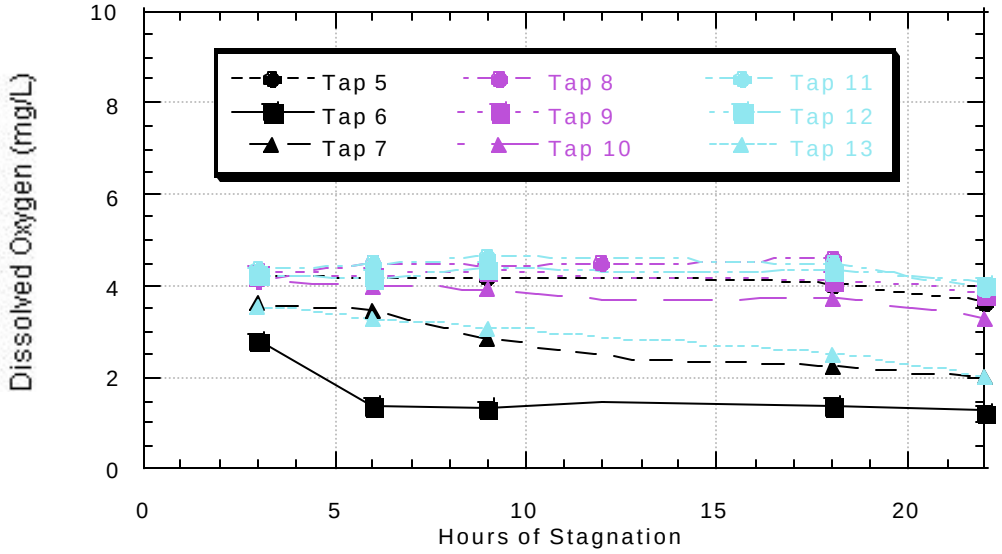
Lone Rock, Wisconsin: Stagnation Curves for Residual Chlorine



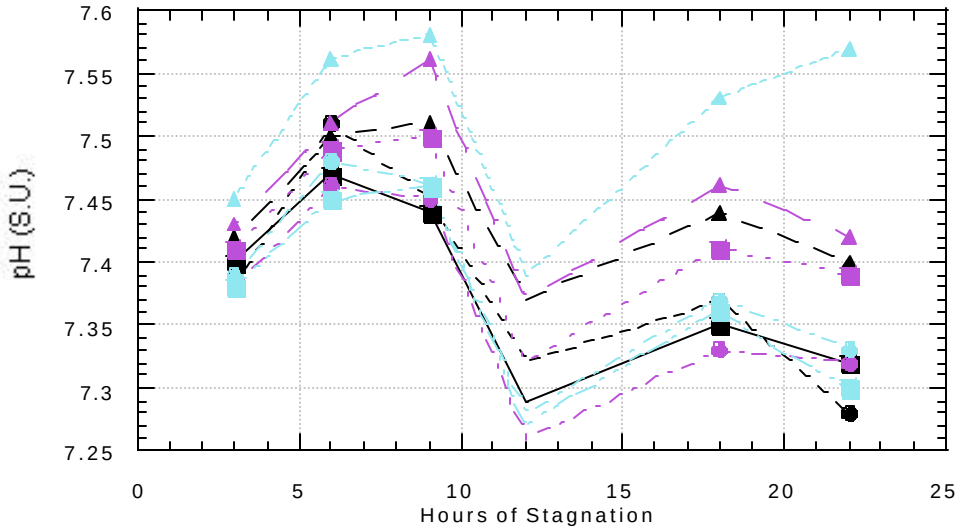
Dane, Wisconsin: Stagnation Curves for Dissolved Oxygen



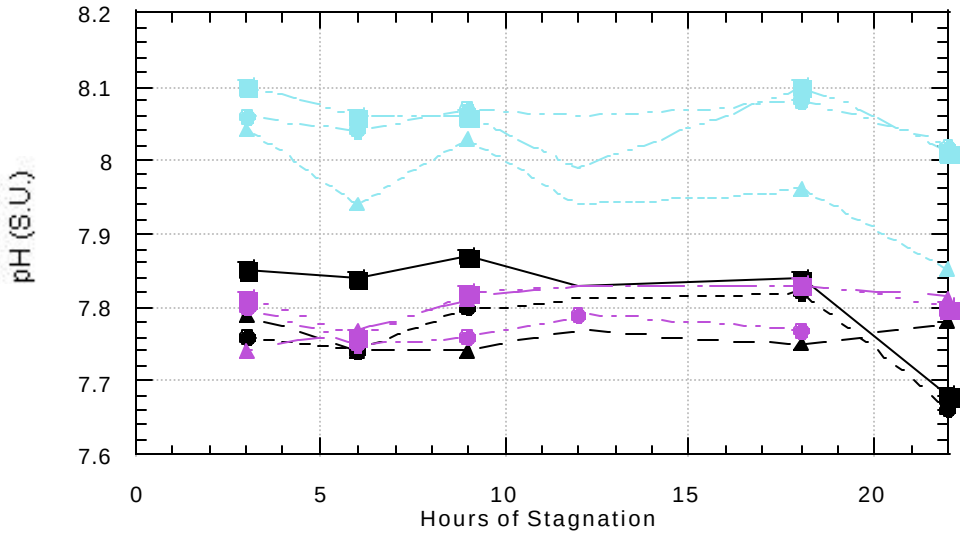
Lone Rock, Wisconsin: Stagnation Curves for Dissolved Oxygen



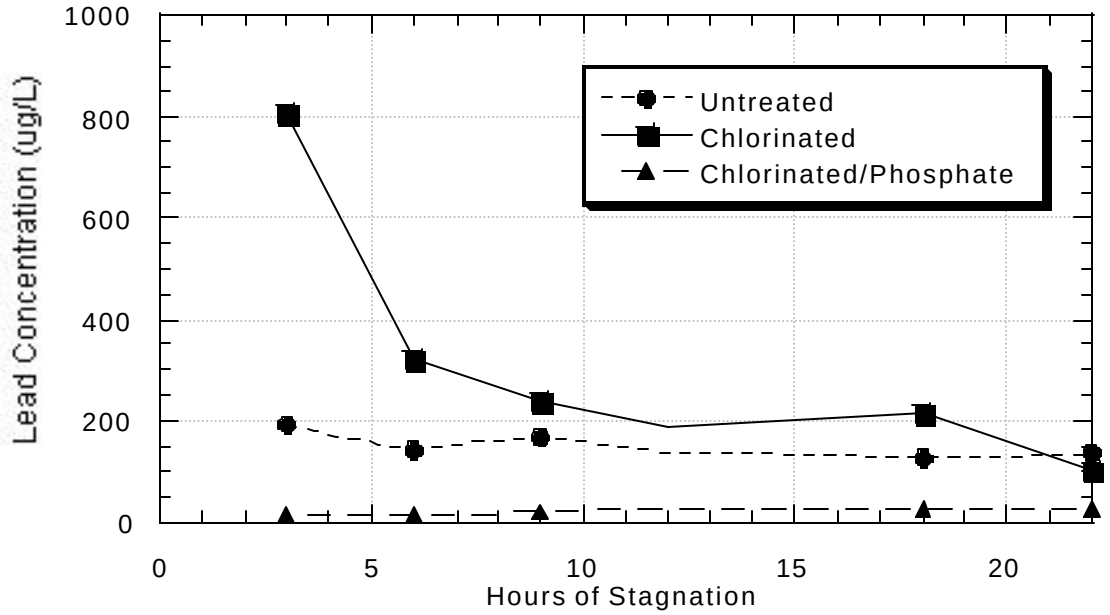
Dane Wisconsin: Stagnation Curves for pH



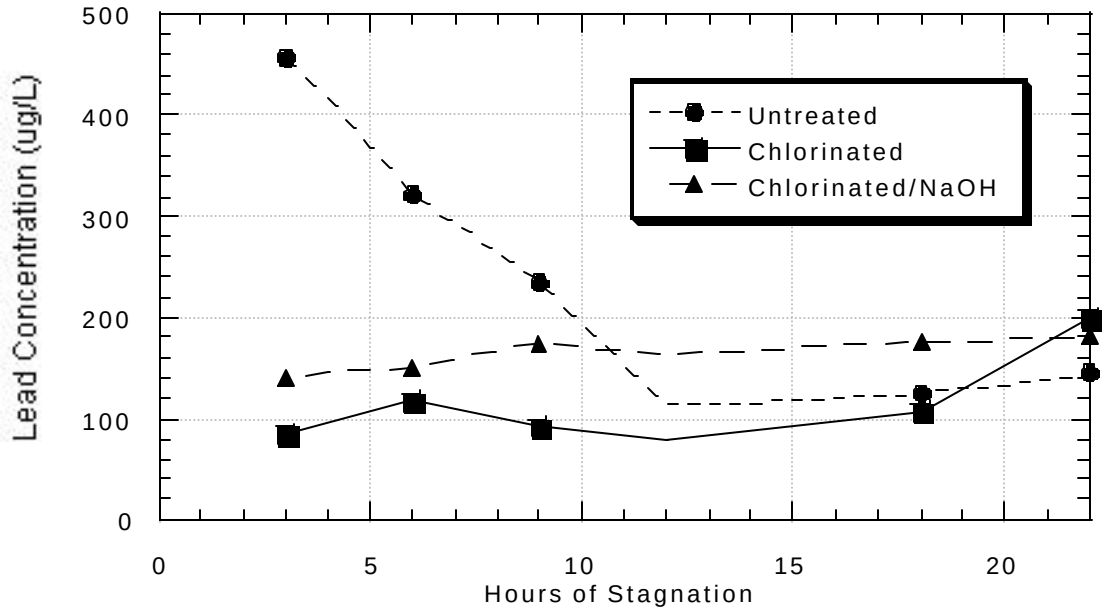
Lone Rock, Wisconsin: Stagnation Curves for pH



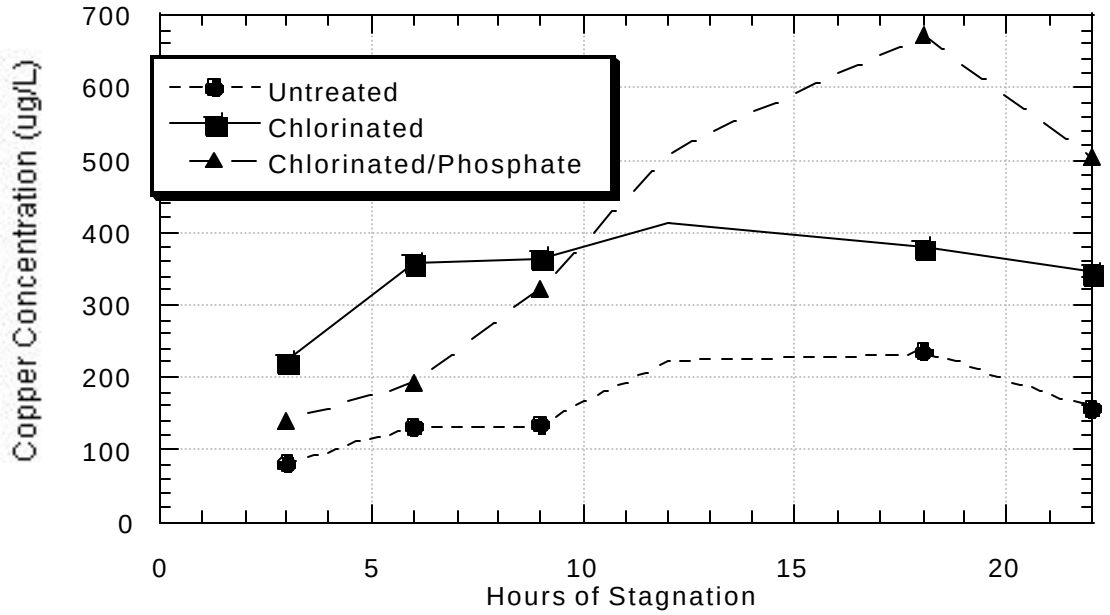
Dane, Wisconsin: Stagnation Curves for Lead



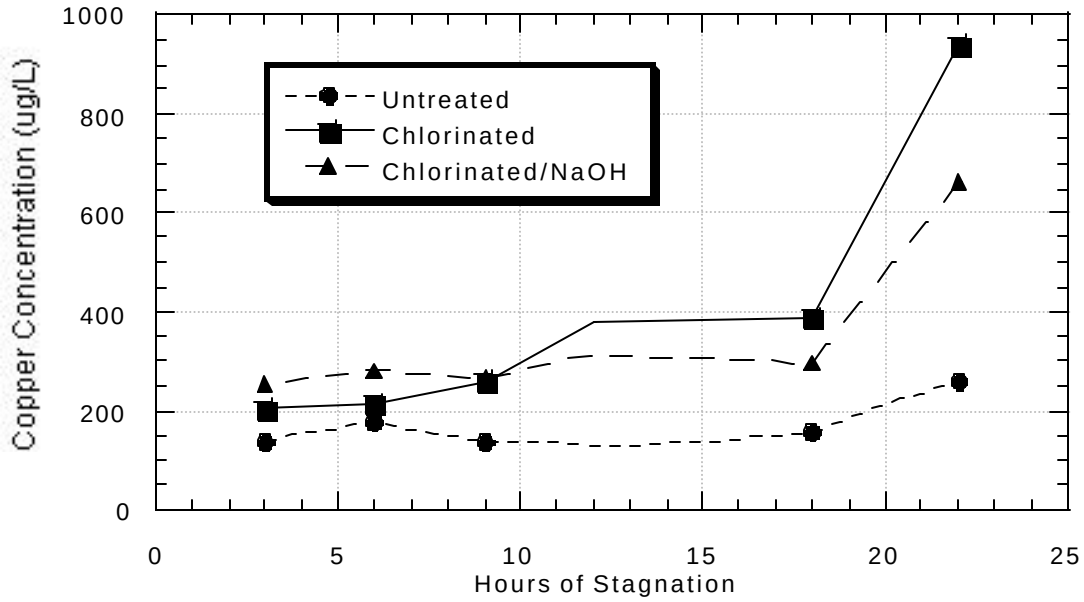
Lone Rock, Wisconsin: Stagnation Curves for Lead



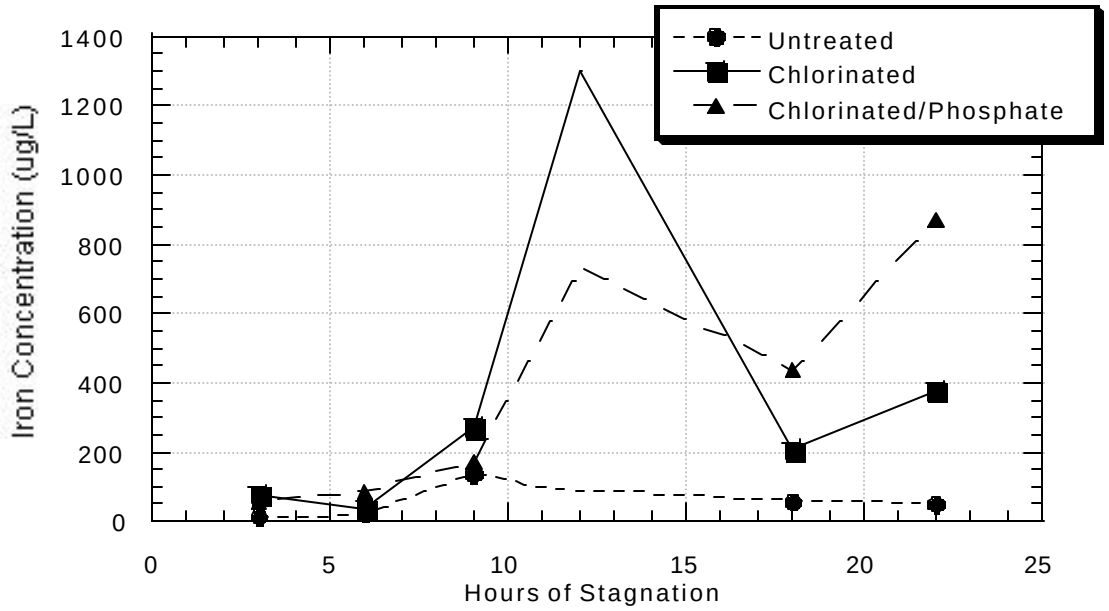
Dane, Wisconsin: Stagnation Curves for Copper



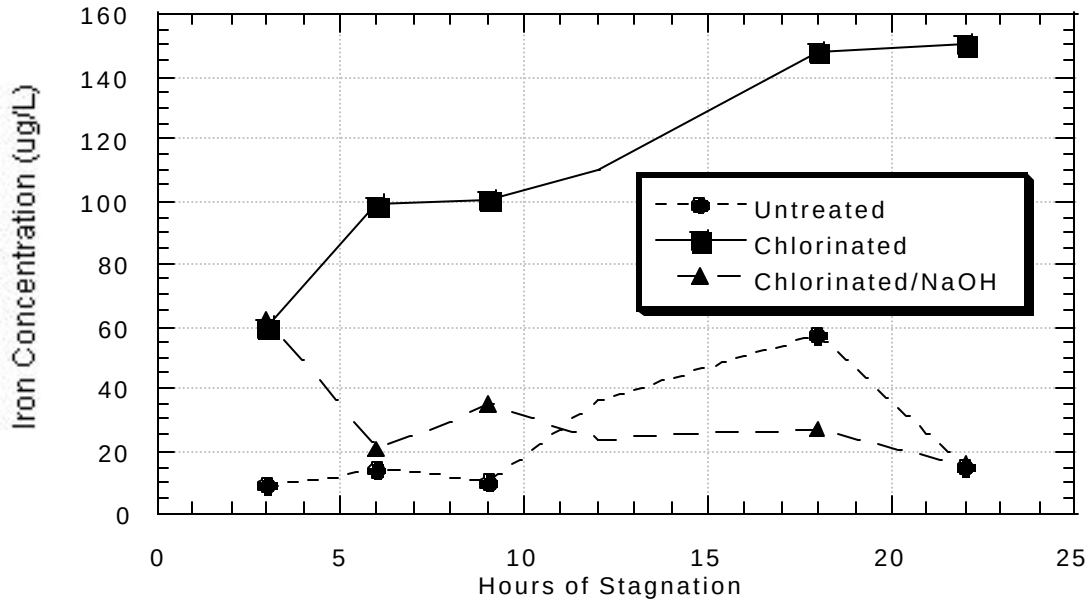
Lone Rock, Wisconsin: Stagnation Curves for Copper



Dane, Wisconsin: Stagnation Curves for Iron



Lone Rock, Wisconsin: Stagnation Curves for Iron



Conclusions from the stagnation curves are summarized below. Items in bold type show different conclusions from the previous routine sampling data.

Lead Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to lead	Corrosive (over the action limit)	Corrosive (over the action limit)
Effect of adding chlorine	**Increases the lead levels**	Lowers the lead levels
Effect of corrosion control chemicals added to the chlorinated water	Adding orthophosphate lowers the chlorinated water's corrosivity	Increasing pH does not change the chlorinated water's corrosivity

Copper Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to copper	Not over the action limit	Not over the action limit
Effect of adding chlorine	Water is more corrosive than raw water but still not over the action limit	Water is more corrosive than raw water but still not over the action limit
Effect of corrosion control chemicals added to the chlorinated water	**Adding orthophosphate increases the chlorinated water's corrosivity**	Increasing pH slightly counteracts the effect of chlorine

Iron Pipe Loops		
Issue	**Dane (High Alkalinity)**	**Lone Rock (Lower Alkalinity)**
Corrosivity of the raw water with respect to copper	Not over the secondary limit	Not over the secondary limit
Effect of adding chlorine	Chlorine elevates the iron levels	Chlorine elevates the iron levels
Effect of corrosion control chemicals added to the chlorinated water	Adding orthophosphate is effective in counteracting the influence of chlorine	Increasing pH is effective in counteracting the influence of chlorine, however the effect is at first the same as the chlorinated water

Schedule
August 29, 2000 Final week of sampling
October/November, 2000 Final Report