Proposed Flow-Through, Lead Pipe Loop Test Plan

Prepared for

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This document describes the flow-through, lead pipe loop test plan proposed for the Washington Aqueduct Dalecarlia Water Treatment Plant (WTP). The proposed flow-through pipe loop testing complements the ongoing lead research work being performed by DC WASA, EPA, and associated members of the Technical Expert Working Group (TEWG) formed earlier this year in response to elevated drinking water lead concentrations being measured in select Washington D.C. drinking water samples. Among other objectives, the TEWG is tasked with defining the most effective method to reduce lead concentrations below EPA's Lead and Copper Rule (LCR) Action Level of 15 ppb. The LCR requires a water system to optimize its corrosion control treatment so that no more than 10 percent of all collected samples (samples are collected in homes following a minimum six-hour stagnation period) have lead concentrations greater than 15 ppb.

The flow-through, lead pipe loop testing being proposed by Washington Aqueduct differs from the ongoing recirculation and electrochemical pipe loop testing being performed under DC WASA's direction at the Fort Reno Pumping Station. The Washington Aqueduct flow-through pipe loop testing will provide results that simulate actual homeowner plumbing conditions and evaluation of treatment scenarios to reduce lead leaching. The Washington Aqueduct testing program is capable of being utilized as a predictive treatment model whereas, the DC WASA testing program is a rapid evaluation of potential treatment scenarios to evaluate corrosion trends.

Flow-Through, Lead Pipe Loop Testing Purpose and Key Assumptions

The primary purpose of the proposed flow-through, lead pipe loop testing is to evaluate the effectiveness of alternate corrosion control strategies on reducing lead concentrations in District of Columbia drinking water. Secondarily, the results obtained during the testing period will be disseminated to the water industry at large as a good will offering. It is important to recognize that, although the research needs of the water industry pertaining to lead corrosion may be significant, the purpose of this program is to provide a treatment strategy that mitigates lead corrosion and protects public health within the areas served by the Washington Aqueduct.

Based on the results and recommendations of Washington Aqueduct's 2004 Desktop Evaluation, a comparison of the effectiveness of two alternate corrosion inhibitors (phosphoric acid and zinc orthophosphate) will be conducted.

Filtered and finished (i.e., potable) water produced at Washington Aqueduct's Dalecarlia WTP will be used as source water for the testing. Additional treatment chemicals will be added to the filtered water flow stream to "simulate " finished water quality under a variety of conditions.

Samples of lead service lines excavated from the Washington D. C. water distribution system will be used to construct the proposed pipe loops to ensure that the test results replicate actual full scale conditions to the greatest degree possible.

Based on historical distribution system disinfection by-product concentrations, it is assumed that the Washington Aqueduct WTP's (Dalecarlia and McMillan) will be required to continue to use chloramines as a secondary disinfectant in the future to ensure compliance with the Disinfectants and Disinfection By-Products (D/DBP) Rule. As a result, all pipe loops will be operated on chloramines or a combination of free chlorine and chloramines (i.e., no free chlorine pipe loops are proposed).

Questions to be Addressed by the Proposed Pipe Loop Testing

The pipe loops described below will allow the Washington Aqueduct to address several important questions related to water treatment operations and answer select questions of interest to the water treatment industry at large. These questions include:

Questions of Direct Interest to Washington Aqueduct

1. Does zinc orthophosphate control lead concentrations more effectively than phosphoric acid?
2. What is the optimum long-term dose of phosphoric acid for the Washington, D. C. distribution system?
3. What is the approximate timeframe for reducing lead concentrations in the Washington, D. C. distribution system?
4. Does periodically switching from chloramines to free chlorine have any impact on lead concentrations? If so, what is the impact and approximately how long does this effect last?

Questions of Interest to the Water Treatment Industry

1. Do lower chloramine concentrations reduce lead levels under conditions where a corrosion inhibitor is fed?
2. What is the relative impact of feeding a corrosion inhibitor on lead concentrations in a system that uses chloramines?
3. What is the relative effectiveness of zinc orthophosphate versus phosphoric acid as a lead corrosion inhibitor?
4. Does periodically switching from chloramines to free chlorine impact lead concentrations?

Test Conditions to be Studied During the Flow Through, Lead Pipe Loop Testing

The proposed flow-through lead pipe loops will be tested under a total of seven different operating conditions (i.e., racks), as defined in Table 1. Three pipe loops will be provided in each of the seven racks to ensure that the test results are statistically significant and reproducible. Twenty-one lead pipe loops will be provided in total.

The proposed flow-through testing will initially focus on confirming that a conservative dose of each corrosion inhibitor (currently assumed to be 3.5 mg/L as phosphate) will be effective in reducing distribution system lead concentrations following pipe loop passivation. Following successful confirmation of this goal, the testing will focus on defining the optimum long-term corrosion inhibitor dose recommended for implementation by the Washington Aqueduct.

The proposed flow-through, lead pipe loop testing will also examine the impact of operational variations (such as periodically switching back and forth from chloramines to free chlorine) on corrosion inhibitor effectiveness and associated lead concentrations. Historical Total Coliform Rule (TCR) testing results have indicated that periodic switching from chloramines to free chlorine helps minimize biological activity in the distribution system. This is a significant finding since biologically induced nitrification has been shown to reduce pH in distribution systems resulting in exacerbated lead corrosion rates. Based on these assumptions, it is proposed that one set of the pipe loops be dedicated to defining the short-term impact of periodically switching from chloramines to free chlorine on distribution system lead concentrations.

Two sets of pipe loops will be dedicated to evaluating the impact of high and low chloramine concentrations on lead corrosion in the presence of a corrosion inhibitor. A reduced chloramine concentration of between 1.0 and 2.0 mg/l will be studied in one set of loops. All of other pipe loops will be operated at a chloramine concentration of 3.5 mg/l. A comparison of the lead concentrations measured in the high chloramine pipe loop with corrosion inhibitor with the results from the high chloramine pipe loop without corrosion inhibitor will allow Washington Aqueduct to define the relative benefit of feeding a corrosion inhibitor. A comparison of the lead concentrations measured in the high and low chloramine concentration loops with a corrosion inhibitor, will allow Washington Aqueduct to define the relative impact of lowering the concentration of chloramines on lead levels.

Finally, one set of loops will evaluate lead concentrations associated with the finished water produced at the Dalecarlia WTP. No additional chemical conditioning of the finished water will be performed prior to testing this flow stream. This set of loops will serve as a control for the study. This loop set will be similar to the loops listed above with the following exceptions:

- Lime will be used for pH control in the full-scale plant. However, sodium hydroxide is proposed for controlling the pH of the pipe loops. Sodium hydroxide is recommended for the pipe loops because it is easier to control and more suitable for pilot scale facilities. Calcium will not be added to the loops. Lime is only adding approximately 4 mg/l of Ca, approximately the same difference between raw and finished water, which remains relatively constant.
- Fluoride is fed in the full-scale plant and will be fed at the same dose to the "chemically conditioned" filtered water pipe loops

All of the pipe loops will be conditioned with finished water for a period of one month after startup to allow for the scale on the pipes to reach a common baseline. After the 1-month conditioning period, all of the pipe loops except the one finished water loop will be fed " filtered water with chemicals added according to the Pipe Loop Test Plan. The filtered water fed to these loops will have received a low dose of free chlorine (between 1.0 and 2.0 mg/l) prior to filtration, but will not have received any other finished water chemicals (such as lime, ammonia, or fluoride). Select chemicals will be fed to each of the filtered water loops under controlled conditions to achieve the desired pH, chorine species and concentration, and corrosion inhibitor dose.

Copper Piping, Lead Solder, and Brass Faucet Issues

As currently envisioned, the proposed flow-through lead pipe loop testing will focus on lead pipe corrosion. Copper pipe, lead solder, and faucet corrosion will not be studied. This focus was selected because lead pipe corrosion represents the primary issue of concern in the District of Columbia distribution system.

Flow-Through Pipe Loop System Operation

It is anticipated that the flow-through pipe loops will be operated automatically with the exception of sampling, which will be accomplished by hand. A dedicated PLC control system will be provided to control the chemical feed pumps and maintain the desired chlorine and corrosion inhibitor concentration and pH in each of the proposed pipe loops. Separate flow meters will be provided on all flow streams receiving chemicals to allow automatic flow pacing of chemical feeds. The pH will be controlled automatically based on feedback from dedicated pH meters installed in each flow stream. A multiple-head, positive displacement pump will be used to control the flow through each individual pipe loop.

Pipe loop flow and stagnation cycle duration times will also be automatically controlled by the PLC control system. The LCR requires a minimum of 6-hour stagnation time, but the proposed testing protocol will require a longer stagnation period to facilitate sampling.

Data Collection and Distribution

The flow-through pipe loop test facilities will be operated 7 days per week. Periodic water quality samples will be collected Monday through Friday and delivered to the Washington Aqueduct Laboratory for analyses. The pipe loops will include two or three sections, for a total length of 13', of ¾-inch I.D. pipe, which will yield a sample volume of 1.1 liters per pipe loop. The samples will be analyzed to determine the following parameters:

- Total and dissolved lead;
- pH;
- Alkalinity (as $CaCO_3$)
- Calcium (as Ca);
- TDS;
- CCPP;
- Turbidity;
- DIC (as C);

- Periodic HPC's;
- NH_3 (as N); and
- Nitrite and Nitrate (as N).

The resultant data will be evaluated weekly and distributed to the TEWG on a monthly basis.

Schedule

It is anticipated that the pipe loops will be operational in late Fall 2004 and will operate for approximately 12 months. This duration may vary depending on the amount of time required to passivate the lead service lines and reduce and stabilize lead concentrations. It is anticipated that it may take up to 6 months before the lead concentrations stabilize and are considered representative of what will be observed at homeowners' taps.

The proposed schedule for the flow-through pipe loop testing will overlap with the full-scale application of phosphoric acid to the distribution system. This concurrent conditioning schedule will allow Washington Aqueduct to determine when the flow-through pipe loops lead levels are representative of full scale results.

Table 1: Washington Aqueduct Flow-Through Lead Pipe Loop Study Summary

Pipe Rack Number	Rack Name	Water Source	Chemicals to be Added to Water	Chemical Dose (mg/l)	Pipe Loop pH	Question to be Addressed by this Rack
1	High Chloramines with Zinc Ortho, Decrease Zinc Ortho Dose Over Time	filtered water	zinc ortho	3.5 mg/l as phosphate, ramp down once lead levels drop below action level	7.7	1. What dose of zinc orthophosphate should be used to control lead levels in the distribution system once the system has been passivated? What is the lowest effective dose that will still ensure compliance with the LCR lead action levels? 2.How does zinc orthophosphate performance compare with phosphoric acid (i.e., compare rack 1 and 2 results).
			sodium hydroxide	as needed for pH control		
			sodium hypochlorite	as needed to maintain 3.5 mg/l chloramine concentration		
			ammonia	as needed to maintain 3.5 mg/l chloramine concentration		
			fluoride	1.0 mg/l		
2	High Chloramines with Phosphoric Acid, Decrease Phosphoric Acid Dose Over Time	filtered water	phosphoric acid	3.5 mg/l as phosphate, ramp down once lead levels drop below action level	7.7	1. What dose of phosphoric acid should be used to control lead levels in the distribution system once the system has been passivated? What is the lowest effective dose that will still ensure compliance with the LCR lead action levels? 2.How does zinc orthophosphate performance compare with phosphoric acid (i.e., compare rack 1 and 2 results).
			sodium hydroxide	as needed for pH control		
			sodium hypochlorite	as needed to maintain 3.5 mg/l chloramine concentration		
			ammonia	as needed to maintain 3.5 mg/l chloramine concentration		
			fluoride	1.0 mg/l		
3	Switch Between Free Chlorine and Chloramines with Constant Phosphoric Acid Dose	filtered water	phosphoric acid	3.5 mg/l as phosphate, no change over time	7.7	1. How are lead levels impacted by periodically swinging back and forth from free chlorine to chloramines in the presence of a corrosion inhibitor? 2. Does switching disinfectants inhibit the effectiveness of phosphoric acid for some period of time? An item to be resolved here involves whether to initially condition this loop with free chlorine or chloramines???
			sodium hydroxide	as needed for pH control		
			sodium hypochlorite	3.5 mg/l +/-, or as needed to achieve distribution system microbial goals.		

			ammonia	as needed to maintain 3.5 mg/l chloramine concentration		
			fluoride	1.0 mg/l		
4	High Chloramines, No Corrosion Inhibitor	filtered water	sodium hydroxide	as needed for pH control	7.7	1. What lead levels can be expected with chloramines in the absence of a corrosion inhibitor? 2. How do chloramine lead levels compare with and without orthophosphate (i.e., compare racks 1, 2, and 4)?
			sodium hypochlorite	as needed to maintain 3.5 mg/l chloramine concentration		
			ammonia	as needed to maintain 3.5 mg/l chloramine concentration		
			fluoride	1.0 mg/l		
5	Low Chloramines with Constant Phospohoric Acid Dose	filtered water	phosphoric acid	3.5 mg/l as phosphate, no change over time	7.7	1. How do lower chloramine concentrations impact lead concentrations in the presence of a corrosion inhibitor (I.e., compare racks 5 and 6)?
			sodium hydroxide	as needed for pH control		
			sodium hypochlorite	as needed to maintain 1.0-2.0 mg/l chloramine concentration		
			ammonia	as needed to maintain 1.0-2.0mg/l chloramine concentration		
			fluoride	1.0 mg/l		
6	High Chloramines with Constant Phosphoric Acid Dose	filtered water	phosphoric acid	3.5 mg/l as phosphate, no change over time	7.7	1. How do lead levels compare if phosphoric acid concentrations are lowered over time after passivation versus maintained at a constant concentration after passivation (I.e., compare racks 2 and 6)?
			sodium hydroxide	as needed for pH control		
			sodium hypochlorite	as needed to maintain 3.5 mg/l chloramine concentration		
			ammonia	as needed to maintain 3.5 mg/l chloramine concentration		
			fluoride	1.0 mg/l		
7	Finished Water Control Loop	finished water	phosphoric acid	full scale plant dose during test period (3.5 mg/l dose anticipated)	7.7	1. Control loop - finished water conditions during the pipe loop test period.2. Lead containing faucets will be installed in a separate pipe loop on this rack.
			lime	full scale plant dose as needed for pH control during test period		
			sodium hypochlorite	full scale plant dose during test period (3.5 mg/l chloramine concentration anticipated)		
			ammonia	full scale plant dose during test period (3.5 mg/l chloramine concentration anticipated)		
			fluoride	full scale plant dose during test period (1.0 mg/l dose anticipated)		