PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Nick Fish, Commissioner
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February 23, 2018

Carrie Gentry
Oregon Health Authority
Portland State Office Building
800 NE Oregon St., Suite 611
Portland, Oregon 97232

RE: Corrosion Control Treatment Pilot Study Plan – Revision 1

Dear Carrie,

Attached is a revision to the Portland Water Bureau's Corrosion Control Treatment Pilot Study Plan submitted on June 30, 2017 per our compliance schedule for improved corrosion control treatment. This plan has been revised to postpone the pilot testing phase due to the Water Bureau's decision to install treatment for *Cryptosporidium* by 2027. An Optimized Corrosion Control Treatment (OCCT) report will be submitted to OHA by July 31, 2018.

Please let us know if you have any questions.

Sincerely,

Yone Akagi
Water Quality Manager

Portland Water Bureau

Corrosion Control Treatment Pilot Study Plan

Revision 1

February 23, 2018

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Introduction

On March 9, 2017, the Portland Water Bureau (PWB) began a Corrosion Control Treatment Pilot Project (CCTP) to evaluate treatment alternatives that further minimize lead at PWB customer taps. The CCTP is being led by Confluence Engineering Group with support from Cornwell Engineering Group, HDR, Black & Veatch, and PWB. In accordance with PWB's compliance schedule for improved corrosion control treatment, the PWB submitted a Corrosion Control Treatment Pilot Study Plan to the Oregon Health Authority (OHA) on June 30, 2017. The Pilot Study Plan provided a description of the project approach, methodologies, and key findings that will be used to arrive at the recommended treatment for optimized corrosion control treatment (OCCT). The Pilot Study Plan has been revised based on the results of the bench-scale testing and the PWB's recent decision to install filtration for treatment of *Cryptosporidium* by 2027. Most notably the project methodology has been revised to postpone the pilot testing phase. Revisions to each phase of the Pilot Study Plan are described below.

Project Methodology

The CCTP consists of multiple phases and will assist PWB in finalizing OCCT selection. Figure 1 summarizes the value and purpose of each project phase. When the Pilot Study Plan was first developed, the goal of the bench-scale testing was to screen alternatives to be further evaluated in pilot testing. However, the bench-scale testing results and recent decision by PWB to implement filtration have modified the Pilot Study Plan by postponing the Pilot Testing phase. Continuation of pilot testing is not recommended at this time because future filtration will change water quality parameters relevant to corrosion control treatment. The results of the bench-scale testing, coupled with limited data from pilot testing, are sufficient to select an interim OCCT strategy that reduces lead release and maintains compatibility with a long term OCCT approach to be implemented with filtration. Additional pilot testing to determine long term OCCT is planned as part of the filtration project.

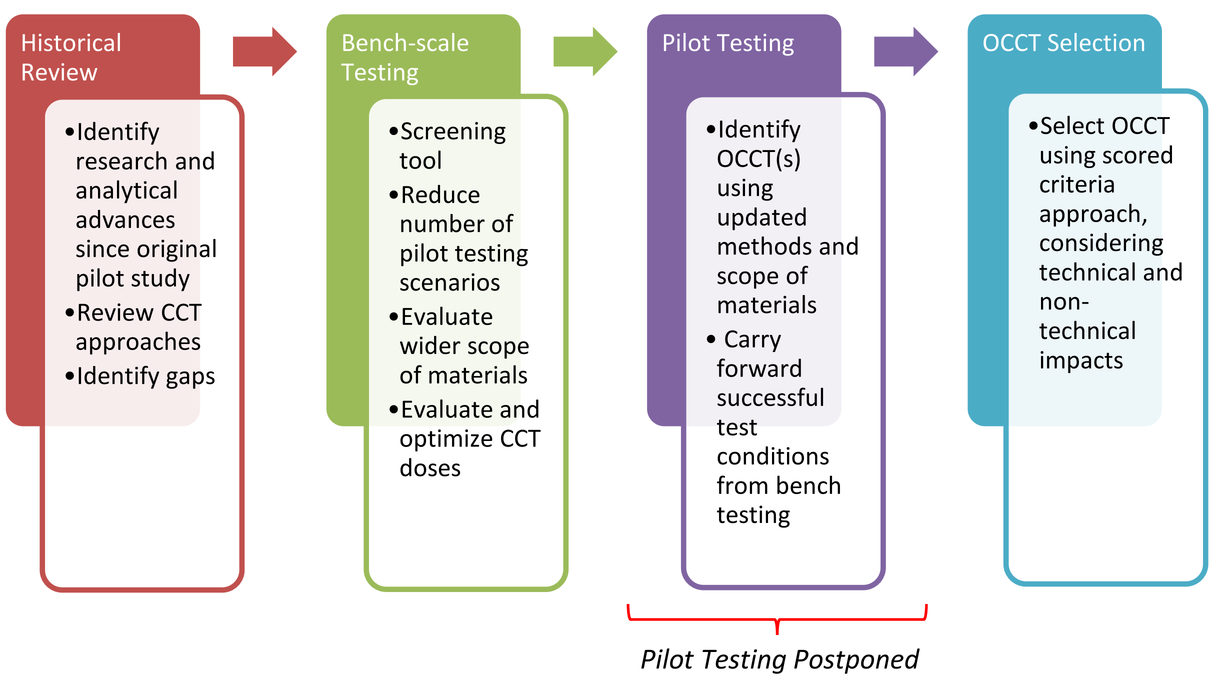

Figure 1. Lead Corrosion Control Strategy Decision Tree

Historical Review

A technical review of pertinent Lead and Copper Rule (LCR) related documentation that have been produced previous to this project was completed by the Confluence team. PWB's initial corrosion control treatment study (Montgomery Watson and Economic and Engineering Services, 1994) as well as the most recent Water Quality Corrosion Study (Black & Veatch 2017) were reviewed to evaluate the conditions studied historically compared to current water system conditions including sources of supply, sources of lead, and treatment practices.

Results from the 1994 bench-scale testing showed that all CCT conditions at pH 7.5 and above were similar in controlling corrosion. This testing did not evaluate all conditions of importance and was based on a low accuracy electrochemical stability technique for evaluating corrosion control. This testing also did not consider impacts from groundwater sources and the corresponding changes in dissolved inorganic carbon (DIC) on CCT dosing and effectiveness.

The Water Quality Corrosion Study (2017) provided a better understanding of corrosion mechanisms contributing to lead release and suggested that improvements to overall water quality, and a reduction in lead release, could be obtained through an adjustment of general chemistry entering the distribution system. Further investigation through a corrosion control treatment pilot was recommended.

The Confluence team recommended additional bench-scale and pilot-scale testing to fully evaluate CCT treatment alternatives.

Bench-Scale Testing

Bench-scale testing is complete. Bench scale testing (photo shown in Figure 2) evaluated multiple treatment alternatives for OCCT for lead control in PWB's system. Screening of alternatives was accomplished through bench-scale coupon testing, which assessed the relative effectiveness of CCT alternatives under different water quality conditions. The primary purpose of this testing was to evaluate any changes in CCT effectiveness as DIC levels change under different surface water (SW): groundwater (GW) blends.

Figure 2. PWB's bench-scale testing at Cornwell's lab

Two types of CCT were evaluated: pH/alkalinity control (pH/alk), and orthophosphate (PO_4). Table 1 summarizes all four test conditions for the pH/alk CCT evaluation.

Table 1
pH/alk CCT Test Conditions Evaluated

Test Condition	pH	Alkalinity (mg/L as CaCO3)
Baseline – SW	8.0	7
Baseline – GW	8.0	150 (varies)
Moderate pH/alk – SW	8.6*	35
High pH/alk – SW	9.3*	25

*As discussed below, the target pH was not maintained throughout the duration of the test period.

The following PO_4 doses were evaluated:

- Dose 1: 0.5 mg/L PO_4 as P
- Dose 2: 0.75 mg/L PO_4 as P
- Dose 3: 1.0 mg/L PO_4 as P

Three types of coupons were tested:

- Copper with lead solder (ASTM B88 Type L copper tube with 50 Sn/50 Pb solder)
- Brass (CDA 844 leaded semi-red brass)
- Pure lead

The bench-scale testing showed that both types of CCT reduced the release of lead compared to existing conditions. The bench-scale test data also suggested that pH/alk CCT and orthophosphate CCT performed similarly in controlling lead release from the brass coupons and copper with lead solder reactors. Orthophosphate CCT is not recommended as an interim OCCT strategy because it will be difficult to transition from orthophosphate CCT to a potentially non-orthophosphate CCT in the future without increasing the potential for lead release as the lead phosphate scales transition to lead carbonate scales. The results of the bench-scale testing will be documented in a Technical Memorandum and will be used to develop an interim OCCT strategy using pH/alk CCT to reduce lead release while maintaining compatibility with future CCT strategies to be implemented with filtration. A more detailed description of the bench-scale testing plan is provided below.

There were two phases in the initial test plan: a 5-week equilibration phase in which a fresh coupon was exposed to either 100 percent SW or GW to form scales and come to equilibrium, and a subsequent 4- to 5-week stability phase in which the coupons from the equilibration stage were exposed to blends of SW and GW to evaluate the impact of changing DIC on the stability of the lead scale. Changes in lead concentrations over time indicate CCT effectiveness.

The pH/alk testing included a baseline evaluation, consisting of coupons exposed to either 100 percent SW or 100 percent GW. In addition to the baseline evaluation, two pH/alk combinations were evaluated:

- Moderate pH/alk CCT: increase alkalinity to 35 mg/L as $CaCO_3$; adjust pH to 8.6
- High pH/alk CCT: increase alkalinity to 25 mg/L as $CaCO_3$; adjust pH to 9.3

These pH/alk combinations were tested in SW samples. Adjustment to pH and alkalinity values was accomplished using a combination of caustic soda (NaOH) and sodium bicarbonate ($NaHCO_3$) but the target pH of 8.6 and 9.3 could not be maintained throughout the duration of the test period. During the equilibration phase, duplicates of each coupon type were tested. After equilibrium was reached, the testing proceeded to the stability phase. During this phase, the duplicates tested in the preceding phase were split and each subjected to a different SW:GW blend. The focus during the stability phase testing was to evaluate if lead solubility increased following a change in DIC associated with the blended SW:GW. Due to the decline in pH during the initial testing, a third phase was added to evaluate alkalinity needed to maintain pH in the test apparatus throughout the duration of the test period and the impact of this adjustment on CCT effectiveness.

The overall test plan for the pH/alk CCT testing is shown in Figure 3.

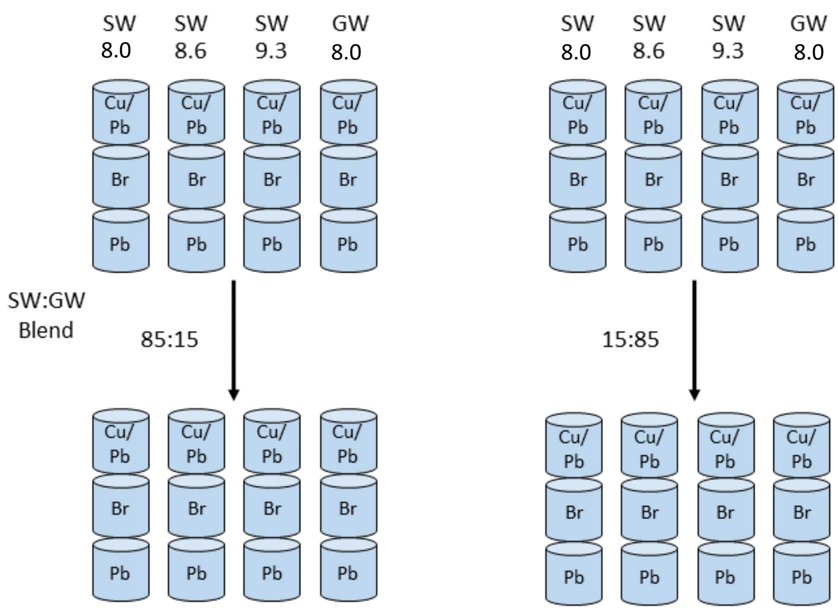

Figure 3. pH/alk bench-scale test program

PO_4 testing was evaluated similarly to the pH/alk testing, except that all test vessels contained either baseline SW or baseline GW dosed with PO_4. Phosphoric acid was used for the PO_4 dosing. After the PO_4 was added, the pH was adjusted to the initial baseline pH value (8.1 for SW, 8.0 for GW) using caustic soda.

As with the pH/alk CCT testing, duplicates of each coupon type were tested during the equilibration phase, and then the duplicates were divided and subjected to a different SW:GW blend. This test plan is shown in Figure 4.

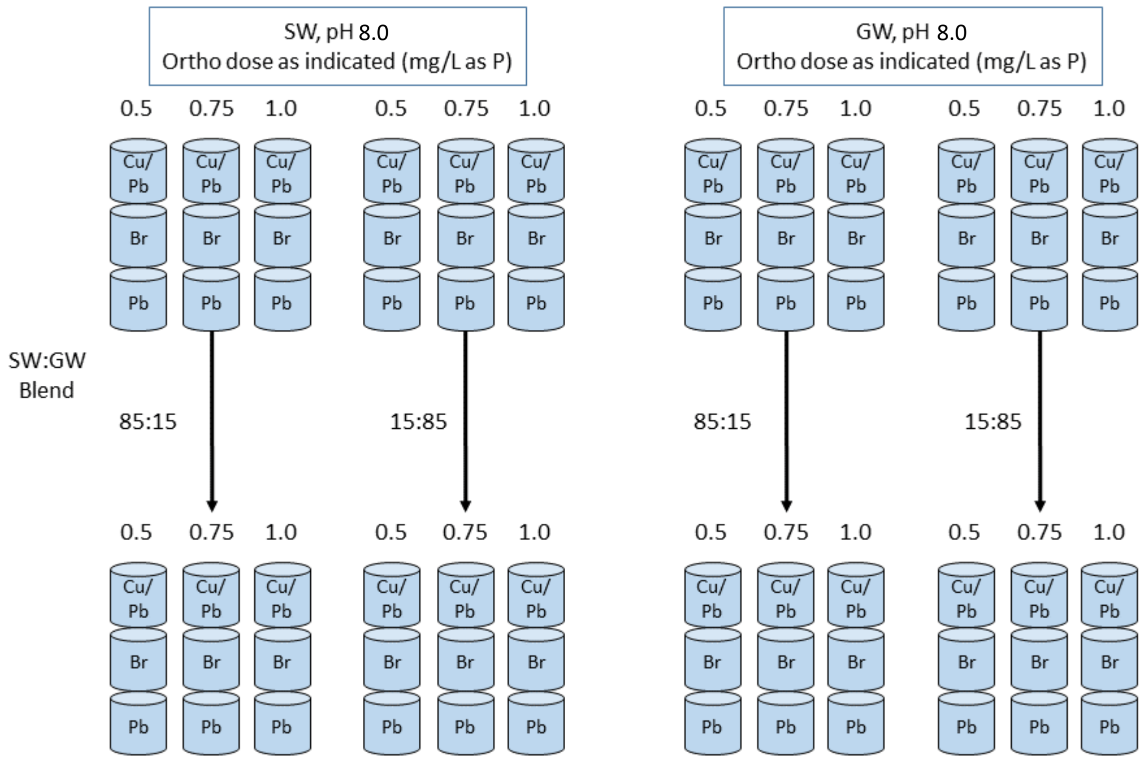

Figure 4. Orthophosphate bench-scale test program

Pilot Testing

Pilot testing was designed to expand upon results received from the bench-scale testing, and evaluate and compare selected treatment conditions against PWB's current corrosion treatment approach. Pilot testing began in July 2017 and continued through an equilibration phase. Treatment conditions were not tested at the pilot scale due to PWB's decision to postpone the pilot testing phase to the future filtration pilot. Data collected during the equilibration phase will be evaluated and used with the bench-scale data to further develop an interim OCCT strategy.

The pilot testing equipment will remain in place and continues to operate under current water quality conditions. Pilot testing equipment includes four (4) test rigs (Figure 5) and two (2) Process Research Solutions (PRS) monitoring stations. Each test rig includes two (2) different premise plumbing materials harvested from City owned facilities and a pre-1986 brass water meter harvested from PWB customer services. Harvested premise plumbing materials include copper pipe with lead soldered joints and galvanized pipe. Each PRS station is equipped with four (4) test chambers, each of which houses lead, copper with lead solder, galvanized iron, or brass plates. The test rigs were designed, fabricated, and installed by the Confluence team and operated by PWB. The test rigs are housed in a portable trailer at a PWB facility (Figure 6).

Figure 5. Test Rig

Figure 6. PWB pilot trailer

OCCT Selection

The original project methodology included a multi-criteria analysis (MCA) process to complement the results of the CCT technical analysis from the bench-scale and pilot testing and confirm the OCCT based upon multiple ranking criteria. The use of MCA analysis is particularly beneficial if there is determined to be multiple, alternative CCTs that may provide technical success based upon bench- and/or pilot-scale test results. The MCA analysis is no longer needed since orthophosphate is not a viable interim solution and pH/alk adjustment has been identified as the interim OCCT strategy. New evaluation criteria will be developed to select a treatment chemical(s) for pH/alk adjustment. The treatment chemical(s) and recommended treatment targets will be identified in the OCCT Report to be submitted to OHA by July 31, 2018 per PWB's approved compliance schedule for improved corrosion control treatment.