Review of the Interim Optimal Corrosion Control Treatment for Washington, D.C.

Final Report

March 30, 2007

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Work Assignment Number 47

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Acknowledgements

This report was completed for US EPA, Region III, with direction from Rick Rogers, George Rizzo, and Jennie Saxe. Special thanks is given to Jennie Saxe for compiling and providing compliance data for analysis and to Rich Giani, Maureen Donnelly, and Will Keefer of the D.C. Water and Sewer Authority (DCWASA) for providing additional data.

This report was prepared by The Cadmus Group, Inc., with assistance from its subcontractor, Dr. Steve Reiber of HDR Engineering.

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Acronyms

AL	Action Level
AWWA	American Water Works Association
CCPP	Calcium Carbonate Precipitation Potential
CDCP	Centers for Disease Control and Prevention
CFU/mL	Colony-forming units per milliliter
DBP	Disinfection Byproduct
D.C.	Washington, D.C.
DCWASA	D.C. Water and Sewer Authority
DOH	D.C. Department of Health
EC	Electrochemical
EPA	U.S. Environmental Protection Agency
HPC	Heterotrophic Plate Count
IOCCT	Interim Optimal Corrosion Control Treatment
LCR	Lead and Copper Rule
LSL	Lead Service Line
MCL	Maximum Contaminant Level
MPY	Mils per year
mg/L	Milligrams per liter
NE	Northeast Quadrant of D.C.
NW	Northwest Quadrant of D.C.
OCCT	Optimal Corrosion Control Treatment
ORD	U.S. EPA Office of Research and Development
ORP	Oxidation Reduction Potential
PLSLR	Partial lead service line replacement
ppb	Parts per billion
ppm	Parts per million
SDWA	Safe Drinking Water Act
SE	Southeast Quadrant of D.C.
SW	Southwest Quadrant of D.C.
TCR	Total Coliform Rule
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TTHM	Total Trihalomethanes
TEWG	Technical Expert Working Group
U.S. EPA	U.S. Environmental Protection Agency
WA	Washington Aqueduct
WQP	Water Quality Parameter
WQTC	Water Quality Technology Conference
WTP	Water Treatment Plant

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1. Introduction and Background

1.1 Purpose and Scope

The purpose of this document is to provide a technical review of the effectiveness of the Interim Optimal Corrosion Control Treatment (IOCCT) for Washington D.C. Specifically, we reviewed findings from various research studies as they relate to corrosion control treatment. A significant part of this report is a review of water quality data collected from the distribution system from January 2003 through December 2005.

Reduction of lead concentrations in drinking water is the primary measure of corrosion control treatment success. Reduced microbial activity in the distribution system is a second potential benefit of the orthophosphate treatment implemented in August 2004 and is assessed in this report.

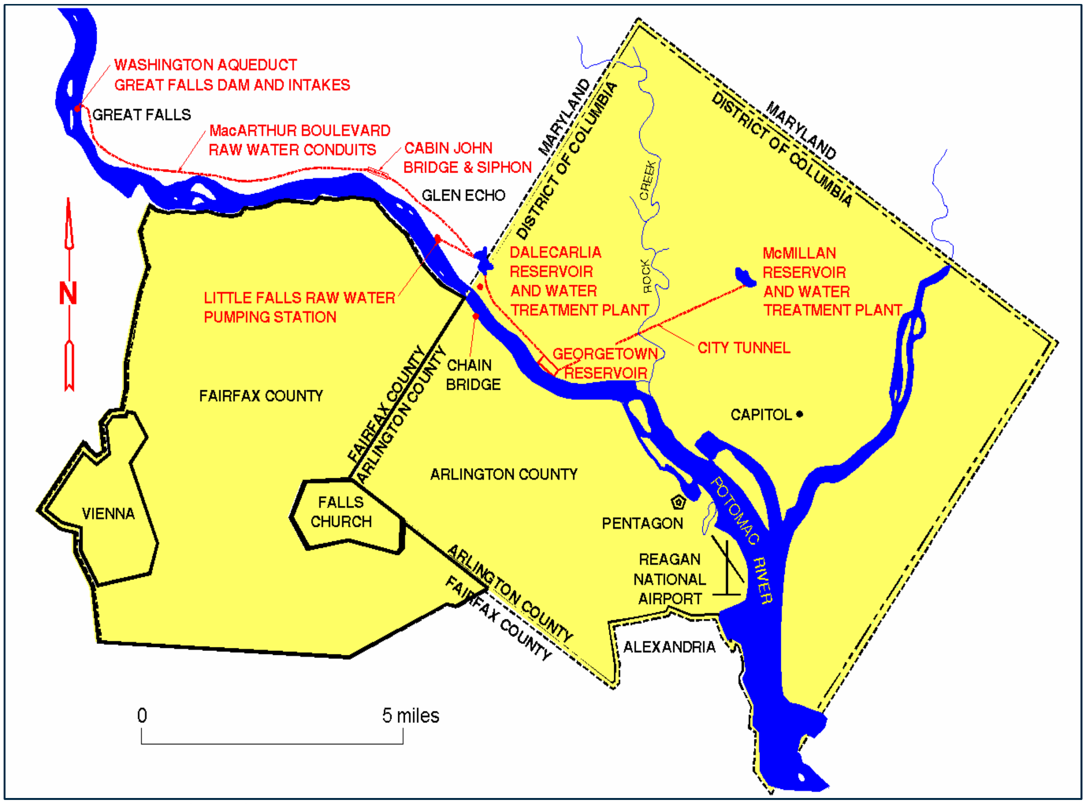
It is important to note that this report evaluates all water quality data available, including data not used to calculate compliance with drinking water standards. Therefore, analyses are not meant to evaluate compliance with Safe Drinking Water Act (SDWA) regulations.

1.2 Description of the DC Water System

The Washington Aqueduct (WA), the D.C. Water and Sewer Authority (DCWASA), and U.S. EPA Region III are responsible for providing safe drinking water to D.C. residents. Owned and managed by the U.S. Army Corps of Engineers, WA draws water from the Potomac River, treats the water, and sells it to three consecutive systems: DCWASA, the City of Falls Church, VA, and Arlington County, VA. WA provides all water treatment; no additional treatment is provided by DCWASA, Falls Church, or Arlington. DCWASA, a private, semi-autonomous municipal utility, distributes drinking water throughout all of D.C. EPA Region III in Philadelphia, PA is the primacy agency for D.C.'s water system and thus provides regulatory oversight and system supervision for both WA and DCWASA. A service map of the D.C. water distribution system is provided in Exhibit 1.2.1.

WA treats Potomac River water at two plants, Dalecarlia and McMillan. Dalecarlia and McMillan perform pre-sedimentation, coagulation/flocculation, primary disinfection with free chlorine, and secondary disinfection with chloramines. The plants use alum for coagulation and add polyaluminum chloride as a filtration aid. Since August 23, 2004, WA has added orthophosphate as a corrosion inhibitor at doses generally above 3.5 mg/L. WA continues to use lime for pH control as part of its corrosion control treatment regime. Exhibit 1.2.2 shows finished water quality parameters (WQPs) for 2005 as reported by WA in their Report of Water Analysis for 2005.

Exhibit 1.2.1 Service Map of DCWASA and its Consecutive Systems



Source: DCWASA (2005).

Exhibit 1.2.2 Water Quality Parameters for Washington Aqueduct Finished Water (2005) for McMillan and Dalecarlia

Parameter	Units	Treatment Plant	Average	Maximum	Minimum
Total Organic Carbon (TOC)	ppm	McMillan	1.8	2.3	1.3
		Dalecarlia	1.7	2.5	1.2
Alkalinity	ppm	McMillan	74	100	43
		Dalecarlia	86	112	60
pH	pH	McMillan	7.7	7.7	7.7
		Dalecarlia	7.7	7.7	7.7
Total Chlorine	mg/L	McMillan	3.7	3.8	3.7
		Dalecarlia	3.7	3.8	3.7
Orthophosphate	mg/L	McMillan	3.20	3.34	3.08
		Dalecarlia	3.18	3.51	2.92

Source: WA Water Quality Analysis Report for 2005.
(http://washingtonaqueduct.nab.usace.army.mil/AnnualReports/2005WaterAnalysisReport.pdf)

The distribution system under DCWASA's management consists of four pumping stations, five reservoirs, four elevated storage tanks, 1,300 miles of pipes, 36,000 valves, and 8,700 hydrants. WA also owns and operates three finished water storage facilities and one finished water pumping station in D.C. In all, these facilities deliver water to DCWASA's more than 550,000 customers,[1] who consume an average of 120 million gallons a day.

DCWASA's distribution system is separated by valves into seven major pressure zones, which vary by elevation and are served by different storage and pumping facilities. Exhibit 1.2.3 summarizes these pressure zones, the ground elevation served, and overflow elevation accommodated by each zone.

Exhibit 1.2.3 DCWASA Service Area Information

Service Zone	***Ground Elevation Served (ft)***	***Overflow Elevation (ft)***
West of Anacostia River		
Low	0-(50) 70	172
1st High	(50) 70-140	250
2nd High	140-210	335
3rd High	210-(330) 350	424
4th High (East and West)	(330) 350 +	485
East of Anacostia River		
Anacostia—Low	0-(50) 70	172
Anacostia—1st High	(50) 70-170	258
Anacostia—2nd High	170 +	382

Source: DCWASA distribution system map

At 150 years old, the D.C. water distribution system is comprised of pipelines of widely varying age and composition. While pipelines range in age from 30 years to over a century, most transmission and distribution lines date to the first half of the twentieth century. Distribution mains and lines range in size from 4 to 54 inches in diameter. Most of DCWASA's distribution system is constructed from cast iron pipe (87%), ductile iron pipe (8%), steel pipe (2.5%), and pre-stressed concrete pipe (2.5%). The predominance of iron pipe in the distribution system is an important factor to be considered in reviewing D.C.'s corrosion control treatment. Iron pipe has been associated with bacteriological growth, and high bacterial counts have been a frequent problem for the D.C.

While most of D.C.'s large water mains consist of iron, service pipes to customers are composed primarily of lead, copper, and brass. Following the Lead and Copper Rule (LCR) lead action level (AL) exceedance reported in 2002, DCWASA was required by EPA to replace 7% of its lead service line (LSL) inventory and to revise its inventory of lines of unknown composition each year, at least until it is at or below the LCR lead AL. In 2004, DCWASA committed to replacing all LSLs under its control by the year 2015. In many cases, DCWASA is limited to replacing the portion of the service line that it in the public space between the water main and the property line. The portion of the line

[1] Based on the 2005 U.S. Census estimate of D.C.'s population. Does not include Virginia customers.

from the property line to the building is in private space and owned by the customer. Although DCWASA initiated an aggressive customer participation program, the proportion of residents that are simultaneously paying to have their portion of the LSL replaced is low.

1.3 History of OCCT Designation

In 1991, EPA promulgated the LCR to reduce lead exposure via tap water, setting an AL for lead of 15 parts per billion (ppb) based on the 90^{th} percentile of all tap water samples taken by a water system. In other words, the Federal AL is exceeded if more than 10 percent of tap water samples contain more than 15 ppb of lead. An exceedance of the lead AL triggers requirements for additional monitoring, public education, LSL replacement, and corrosion control treatment until lead levels return to below the AL.

Corrosion control treatment embodies the method or group of methods used by a water system to prevent tap water from corroding metals such as lead and copper from distribution pipes. Because each system differs in water chemistry, treatment regime, and pipe makeup, its “optimal” corrosion control treatment (OCCT) is unique and can be determined by assessing several WQPs such as pH and alkalinity.

Upon promulgation of the LCR, all large water systems—including D.C.’s—were required to conduct corrosion control studies regardless of their LCR compliance status. (In contrast, small and medium systems were typically only required to initiate CCT research if they exceeded the AL). Based on these studies, the primacy agency would then approve OCCT for a system, and that system was required to operate within a specified range of WQPs to maintain optimized corrosion control. If a system, after implementing OCCT, again exceeds the AL, it may have to revisit its corrosion control strategy and implement new treatment. This was the case for D.C.

Since the promulgation of the LCR, WA and DCWASA have used pH adjustment to control the corrosion of lead. EPA Region III first submitted official approval for interim OCCT in 1997, on condition that WA and DCWASA conduct further study of potential corrosion control treatment methods for the D.C. system. High pH levels can result in the formation of less soluble lead compounds, meaning that they will not dissolve into the drinking water. Historically, WA has added small amounts of lime (calcium oxide) to the water to maintain a high pH and thereby control lead corrosion. Corrosion control studies conducted by WA and its contractor recommended that lime be used to maintain a pH range of 7.4 to 8.5. While one EPA contractor recommended that WA try to achieve the highest pH possible, excessive application of lime results in the accumulation of calcium carbonate.

EPA’s original IOCCT approval depended on WA and DCWASA’s commitment to further investigate sodium hydroxide (caustic soda) for pH adjustment as a corrosion control option. The use of caustic soda would allow them more leeway in raising water pH without exceeding the Total Trihalomethane Maximum Contaminant Level (TTHM

MCL)[2] and without causing excessive precipitation of calcium carbonate. As part of this investigation, WA was required to evaluate the costs as well as economic impacts of pH adjustment strategies, as well as the feasibility and costs of introducing a non-zinc orthophosphate corrosion inhibitor. After two studies were submitted reviewing caustic soda application as well as corrosion inhibitors, it was recommended that D.C. continue using pH adjustment with lime as its OCCT. In 2000, EPA granted OCCT approval for pH maintenance using lime, later modifying pH goals for OCCT in 2002. Exhibit 1.3.1 summarizes the corrosion control studies and actions undertaken by DCWASA, WA, and EPA Region III from 1994 to 2002 to determine the optimal treatment strategy.

Exhibit 1.3.1 Corrosion Control Treatment History for D.C. (1994-2002)

Action	**Date**
Corrosion Control Study (DCWASA) recommends pH adjustment using lime for OCCT	June 1994
EPA Region III Approves interim OCCT of pH adjustment w/ lime	December 1996
Caustic Soda Feasibility Study	January 1998
Corrosion Inhibitor Study for Dalecarlia and McMillan Treatment Plants	May 1998
EPA Grants OCCT for pH adjustment	February 2000
WA switches to chloramines	November 2000
EPA Adjusts Approved OCCT pH Range	May 2002

1.4 Response to Elevated Lead Levels and Change in OCCT

Lead levels in D.C. tap water remained low through 2001 until DCWASA reported an exceedance for the monitoring period of July 2001 to June 2002. The 90th percentile level of lead went from 8 ppb the previous monitoring period to 75 ppb, with more than half the samples exceeding the AL. The following monitoring period, ending June 30, 2003, DCWASA again exceeded the AL (40 ppb), suggesting that the elevated lead levels represented a trend in the D.C. distribution system. To evaluate potential causes of the elevated lead levels and identify potentially useful research approaches, EPA commissioned an evaluation by Virginia Tech professor Marc Edwards. Professor Edwards is a national expert on corrosion of drinking water system materials.

Professor Edwards reviewed the available research on lead corrosion, analyzed DCWASA and WA's historical water quality data, and evaluated sampling protocols. Based on this work, he identified the switch to chloramines as the probable cause of corroded lead in the distribution system, noting that samples taken during the July 2000-June 2001 monitoring period may have possibly under-represented the effect of chloramine on lead levels during the time the switch took place. Dr. Edwards also found that elevated nitrates in chloraminated water may exacerbate lead corrosion, while greater turbidity may affect particulate lead release.

[2] A type of DBP, TTHMs form in highly basic conditions or when lime exists in the system.

Dr. Edwards issued several recommendations:

1. Compare sampling protocols for the seven utilities treating Potomac River water;
2. Initiate a corrosion study of brass, pure lead, and lead-solder coupled to copper;
3. Conduct an analysis to help determine the source of particulates;
4. Conduct a nitrification study of DCWASA and other systems obtaining water from the Dalecarlia Plant at different times in the year;
5. If possible, research any relationship between the switch to chloramines and zinc, copper, and lead loads in the sewage treatment plant to characterize when the lead problem started; and
6. Examine whether if the annual switch from chloramine to chlorine (the "chlorine burn") is detrimental to lead control. Examine the basic rationale for switching disinfectants.

In addition, Dr. Edwards recommended that WA initiate a pipe loop study simulating the distribution system and using pipe extracted from the system in order to better study lead corrosion in D.C. See Chapter 2 for further discussion of WA's pipe loop research. Dr. Edwards also worked with DCWASA to develop a method for "lead profiling." Section 3.3 of this report details the lead profile procedure and DCWASA's use of it to analyze lead at several homes before, during, and after the corrosion control treatment changes.

As EPA and DCWASA continued to investigate reasons for the exceedance and revisit possible corrosion control options, another AL exceedance reported in December 2003 (63 ppb) confirmed the need to address this growing problem. In January of 2004, the Technical Expert Working Group (TEWG) convened to facilitate comprehensive research toward a solution to the lead problem in the D.C. distribution system. Since the TEWG's inception, its members (DCWASA, WA, EPA, and other stakeholders) have conducted various studies to determine the source of the lead problem and to identify a solution. These studies are summarized and discussed in Chapter 2 of this report. Based on the results of this research, the TEWG recommended that orthophosphate treatment be initiated as soon as possible to reduce lead levels in drinking water.

Following a successful partial system application, which began in D.C.'s 4th High Service Area in June 2004, EPA Region III officially approved a system-wide application of orthophosphate in a letter dated August 3, 2004. The interim OCCT designation letter (Appendix A) established interim requirements for various WQPs related to orthophosphate treatment. According to the letter, EPA will revise WQPs once it determines that the D.C. distribution system has been passivated.