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Opflow

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Distribution Systems

Corrosion Control Aids Residuals

by Y. Koby Cohen, Calvin G. Abernathy, and Christopher P. Hill

Unlined cast-iron and steel pipes, which are abundant in the Southern California Water Company–Southwest District distribution system, are known to have water quality problems because of higher disinfectant demands and higher biofilm density. Keeping ahead of the loss of disinfectant residual was labor intensive and costly, so the District conducted a pilot study to investigate alternatives.

Several bench-scale studies have documented that an effective corrosion control program may increase disinfectant residuals and improve water quality because fewer corrosion products are formed. So, over a three-year period, the District studied the long-term effect of corrosion inhibitors on disinfectant residuals, distribution system hydraulics, and water quality. The study proved that the use of polyphosphate-blend corrosion inhibitors is effective in maintaining residuals and will help limit water lost to and labor spent on flushing. The District is in the process of implementing the program systemwide.

District Disinfectant Demand

Unlined cast-iron and steel pipes, installed between 1930 and the late 1950s, comprise about 53 percent of the 410 miles of water distribution pipelines owned by the District. The remaining pipelines are ductile iron, polyvinyl chloride, and asbestos cement. The large number of unlined

continued on page 4

Inside Opflow

Corrosion Control Aids Residuals

(from page 1)

cast-iron and steel pipes promotes significant disinfectant demand in some sections of the distribution system. The demand can be divided into two major categories:

- the demand of the bulk fluid, and
- the demand of the pipe wall surface.

The disinfectant demand of the bulk fluid is exerted by reactions with organic, inorganic, and bacterial constituents of the water. Reactions with corrosion products, oxidation of dissolved iron originating from the pipe walls, biofilms that reside on the pipe surface, and the organic and inorganic constituents that accumulate within the corrosion product–biofilm matrix cause disinfectant demand.

Loss of disinfectant residual, especially in low-flow areas, increases biofilm accumulation, nitrification, and customer complaints about objectionable taste and odor, color, and particles in the water. To minimize these water quality problems and reduce consumer complaints, the District has a comprehensive flushing program that includes annual systemwide flushing, unidirectional flushing, dead-end flushing, and routine flushing of problem areas. These flushing programs use approximately 100 acre-ft (32.6 mil gal) of water per month and require three to four people to perform the flushing.

Corroded pipes comprise about 40 percent of the District's distribution system.

Polyphosphate-Blend Corrosion Inhibitors

Bench-scale studies done at the Montana State University–Biofilm Institute showed that polyphosphate-blend (approximately 77 percent polyphosphate and 23 percent orthophosphate) corrosion inhibitors produce corrosion products that are physically much softer and less cohesive than corrosion products formed with zinc orthophosphate-based corrosion inhibitors. Based on these studies, the District anticipated that use of this polyphosphate-blend would produce corrosion products that would be easier to remove by flushing. Because of the reduction in corrosion products, we expected an additional benefit of less disinfectant demand and a smoother and hydraulically superior pipe surface.

A short-term disadvantage of polyphosphate-blend corrosion inhibitors is that existing corrosion products on pipe wall surfaces are softened and removed shortly after adding the blend. The sloughing of these corrosion products may lead temporarily to increased disinfectant demand and increased microbial activity in the distribution system.

Study Description and Setup

The polyphosphate-blend-addition pilot study began in November 1998, in a less than 1 mi^2 isolated area of the distribution system. The District expanded the study in June 1999 to about a 3.6 mi^2 area. Pipes in the study area vary from 4 to 12 in. in diameter and are approximately 50 percent unlined cast iron, 25 percent cement-lined cast iron, and 25 percent asbestos–cement pipe. The study area, comprised of approximately 80 percent residential and 20 percent commercial and light industrial facilities, is representative of the rest of the distribution system.

Polyphosphate-blend solution

Y. Koby Cohen, PE, is vice president of quality assurance for Suburban Water Systems and chair of the AWWA Water Quality in Transmission and Distribution System Committee. Contact him at (626) 543-2551 or kcohen@suburbanwatersystems.com. Contact Calvin G. Abernathy, PhD, PE, associate professor at the University of Memphis, Department of Civil Engineering, at (901) 678-3283 or cgabrnth@memphis.edu. Reach Christopher P. Hill, PE, an engineer with Malcolm Pirnie, at (614) 430-2683 or chill@pirnie.com.

was added at the effluent of five groundwater plants and at a treated surface water connection from Metropolitan Water District of Southern California. Each water source was disinfected using chloramines at a concentration of 2.5 to 4.0 mg/L total chlorine.

The polyphosphate-blend dose varied based on water quality parameters. It was dispensed at a rate of 1 mg/L per 1 mg/L of iron (Fe), manganese (Mn), and all divalent metals, plus 1 mg/L per 200 mg/L of hardness measured as calcium carbonate ($CaCO_3$) and 0.15–0.3 mg/L for polyphosphate-blend residual and corrosion control. In all cases, the polyphosphate-blend solution was injected after the chlorine and ammonia addition in the plant effluent line.

To evaluate changes in water quality, a number of parameters (Table 1) were measured regularly at five primary distribution system locations, each representing one of the plants. The same parameters were also monitored at each of the groundwater wells and 25 other locations within the distribution system. At each of the distribution system monitoring sites, orthophosphate was measured weekly, and heterotrophic plate counts (HPC) and total coliforms were monitored monthly to determine bacterial activity. Background data were collected three weeks prior to the startup of the pilot study at four of the five primary distribution system locations.

Constituent	Frequency	Importance
Total Chlorine	Daily/Weekly	Determine changes in disinfectant residual concentration
Total Ammonia	Weekly	Determine chlorine:ammonia ratio Nitrification indicator
Nitrite	Weekly	Nitrification indicator
Turbidity/Odor/Color	Weekly	Determine water quality and aesthetic properties
Orthophosphate	Weekly	Determine residual polyphosphate concentration
Manganese	Weekly	Determine effect on manganese solubility
Iron	Weekly	Determine effect on iron solubility
Larson Indexes	Monthly	Corrosion rate measurements
Total Coliforms	Weekly	Determine bacterial activity
HPC	Weekly	Determine bacterial activity
HPC using R2A media	Weekly	Determine bacterial activity
Customer Complaints	Ongoing	Indication of water quality
Orthophospate*	Weekly	Determine background orthophosphate level
Total Coliforms*	Monthly	Determine bacterial activity
HPC*	Monthly	Determine bacterial activity

Table 1. Water quality parameters measured in the distribution system or (*) at each source.

Results and Discussion

Water used in flushing activities. Prior to polyphosphate-blend addition, flushing typically required 20 to 30 acre-ft/month, and occasionally as much as 65 acre-ft/month. Following polyphosphate-blend addition that began June 1999, the required flushing volume dropped to 2 to 3 acre-ft; three years later, it has fallen as low as 0 to 1 acre-ft/month.

A crew of two to three people flushed the area as frequently as twice per week. In general, flushing was done until water quality goals were met.

Customer Complaints. One of the primary goals of the polyphosphate-blend addition was to reduce the number of customer complaints. During the summer of 1998, the number of complaints was as high as 35 per month. Because of its color-sequestering ability, the polyphosphate-blend addition had an immediate impact, reducing the number of complaints to fewer than five per month. The number of complaints has consistently remained fewer than five

continued on page 6

District Operator Profile

Name: Mike Cory **Age:** 38

Title: Quality Assurance Supervisor

Operator Certification Level: Water Treatment Operator Grade 2/Water Distribution Operator Grade 3

Education & Experience: Some college, presently working on a bachelor's degree in business administration. 19 years in water supply operations; four months in current position

How were you involved in the process described in the article? I was a water quality technician responsible for taking water quality samples from the distribution system and coordinating the flushing activities. I handled customer complaints, evaluated water quality data, and made recommendations for operational changes to improve water quality.

How does this process help make your job easier or more efficient? Since the introduction of polyphosphate-blend to the distribution system we have reduced the time spent on customer complaints, water loss to distribution system flushing, and unnecessary manpower spent resolving water quality problems.

Are there any changes or improvements you would make to the process? I would like to have the necessary resources for flushing the system during the first two weeks after the initial introduction of the polyphosphate blend.

Corrosion Control Aids Residuals

(from page 5)

per month, including a number of summer months in which zero complaints were received (Figure 1).

Total chlorine residuals. Total chlorine residual was monitored in the field, using pocket colorimeters

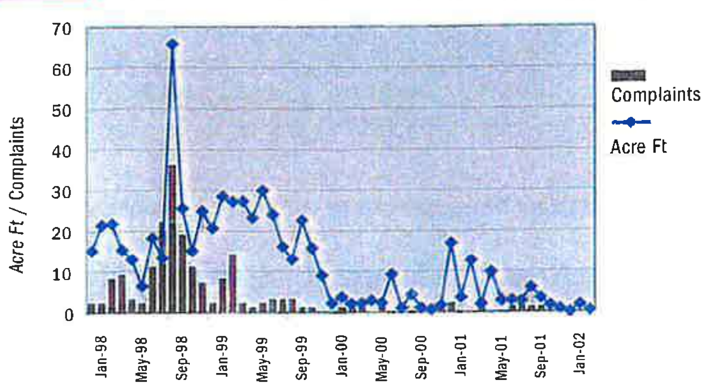

Figure 1. Flushing volume vs. complaints

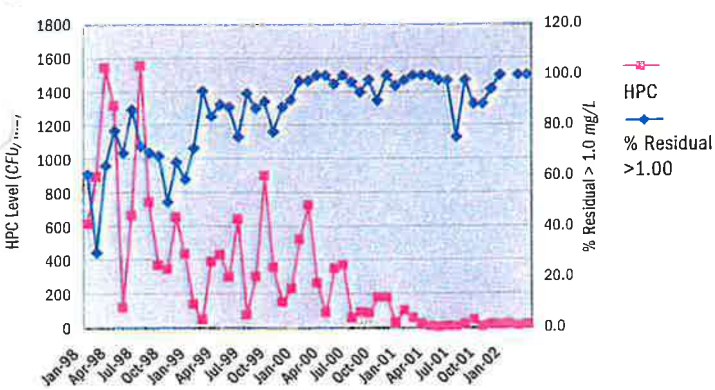

Figure 2. HPC vs. total chlorine residual level

with DPD-method procedures to determine if the District goal to maintain a total chlorine residual greater than 1.0 mg/L was being met. Prior to the addition of the polyphosphate blend, as few as 30 percent of monthly samples had a measured total chlorine residual greater than 1.0 mg/L. Approximately six months later, 90 to 100 percent of the residuals in the study area were greater than 1.0 mg/L. Also, less water was used in flushing to achieve the goal.

HPC bacteriological analyses. HPC levels, which are the main indicator of bacterial activity in the study area, also decreased significantly following the addition of polyphosphate blend. However, it took almost two years for the level to consistently remain below 100 colony forming units/mL, which is the District goal. We suspect that initially the polyphosphate-blend agent dissolves the corrosion product–biofilm matrix on the pipe wall, resulting in higher HPC levels. Throughout the study period, all bacteriological samples were absent of coliform bacteria.

For this system, a minimum of two years of polyphosphate-blend addition is required to establish low HPC levels. The length of time following polyphosphate-blend addition required to reduce HPC levels depends on the type and age of the water mains and characteristics of the biofilms and corrosion products. Newer systems, which may contain thinner biofilms or fewer corrosion by-products, may be able to reduce HPC concentrations in less time. Older systems that have unlined cast-iron and steel water mains with firmly established biofilms may require longer than two years (Figure 2).

Recommendations

Over the three-year study period, the results showed continual improvement in water quality (evidenced by frequent months in which no customer complaints were received), an ability to continuously maintain the desired total chlorine residual, and a reduction in HPC levels to below the District's goal. The District achieved these improvements while conducting limited flushing in the study area.

Conclusions and recommendations to utilities considering polyphosphate-blend addition include

- Polyphosphate-blend addition can soften and remove existing biofilm layers and corrosion tubercles. Implementation of a well-coordinated flushing program may minimize short-term water quality degradation associated with corrosion product and biofilm detachment events and speed up removal of biofilm layers.
- Short-term episodes of low disinfectant residuals and high HPC levels should be expected shortly after the implementation of polyphosphate blend as a result of sloughing of pipe biofilms and dissolution of corrosion products in the system. Therefore, it may be necessary to temporarily increase the plant effluent disinfectant residual.
- Immediate reduction in customer complaints can be achieved.
- Improvement in overall water quality may take as long as three years to achieve based on type and age of pipes.