United States Environmental Protection Agency

Distribution System Water Quality

Impact of Corrosion Control on Disinfectant Residual

Corroding metals and associated corrosion products in finished water can react with disinfectants, causing areas of low disinfectant residual in the distribution system. Low disinfectant residual can increase the potential for microbial growth including the growth of opportunistic pathogens. Effective corrosion control treatment and distribution system maintenance can reduce corrosion products on the metal surfaces and in the bulk water and sediment, and lower disinfectant demand, allowing for better control of microbial growth and other benefits. This fact sheet is part of EPA's Distribution System Toolbox developed to summarize best management practices that PWSs, particularly small systems, can use to maintain distribution system water quality and protect public health. For information about corrosion control to reduce lead concentrations, please see: https://www.epa.gov/dwreginfo/lead-and-copper-rule-implementation-tools#CCT.

How Pipe Corrosion Affects Disinfectant Residual

- Exposure of metal pipes to drinking water may cause corrosion and metal release into the water if pipes are not protected. Effective corrosion control can reduce the degree of corrosion and by-product build-up by decreasing disinfectant demand, thereby increasing disinfectant residual.
- Poor corrosion control can result in areas of the distribution system with low disinfectant residuals; thick corrosion layers or tubercles/scale; and corrosion-related sediment. These corrosion by-products in the bulk water, on the pipe walls and deposited in the distribution system can accumulate organic sediments that create a disinfectant demand and that act as a habitat and nutrients for opportunistic pathogens. Low disinfectant residual due to a lack of corrosion control can result in water quality changes and opportunistic pathogen growth.
- Corrosion tubercles can also contain more coliform bacteria than finished water or untreated source water.
- When thick scales or biofilms occur, the bacteria near the pipe wall may fully consume oxygen and may release corrosive products. This is called microbially-induced corrosion (MIC). The bacteria can use sulfur compounds, nitrite, or iron or metal oxides as their energy source instead of oxygen and release acids as a waste product. The acid acts as the corrosive agent at the point of MIC.

Strategies for Finding Potentially Corrosive Microbial Growth

Monitor across distribution system for spatial differences:

- Little to no dissolved oxygen compared to the treated water at the distribution system entry point, while having total nitrate/nitrite increase or pH fluctuation.
- Copper concentration higher in flowing sample than in treated water.
- Conductivity much higher in distribution sample than in treated water.

Awareness of distribution system issues and indicators:

- Areas of low water use or low velocity with little to no disinfectant residual.
- Pipe replacements: iron pipe with tubercle scale and red outermost layer and taste & odor complaints (e.g., earthy-muddy water, rotten egg or sulfur smell).
- Blue water from copper corrosion.
- Pipe replacements: blue green stains on copper piping.

Examples of Utility Actions

In an urban PWS in the northeast United States, low chlorine residual was found in pockets of the distribution system due to seasonal, high temperatures and low water use. Unlined cast iron pipe in one of the pockets had recurring chlorine residual losses not resolved by seasonal low velocity flushing. To resolve the issue, the cast iron pipe was replaced with ductile iron pipe and low velocity flushing restored the disinfectant residual above the required minimum.

An Air Force base found high copper concentrations and low disinfectant residual during monitoring in newly constructed facilities, including a daycare center. Flushing didn't resolve the problem, so a corrosion control plan using orthophosphate was initiated. After a passivation period, flushed samples showed consistent disinfectant residual in the distribution system and reduced copper levels below the action level.

Potential Strategies to Address Corrosion-Related Considerations

- Effective corrosion control treatment can reduce chlorine demand from corrosion products and help maintain adequate disinfectant residual. Methods employed to limit corrosion within a pipe may include pH/alkalinity adjustment or addition of corrosion inhibiting chemicals such as phosphates and silicates. The optimal treatment strategy is based on system-specific factors including water quality and pipe materials.
- Preventive maintenance using high-velocity unidirectional scour flushing or pigging originating at treatment and progressing through the distribution system to problematic areas can remove sediment and scales.
- Water main rehabilitation can remove corrosion tubercles and protect pipe surfaces with liners. This restores the smooth interior pipe wall.
- Under federal regulation 40 CFR 141.90(a)(3), before changing long-term corrosion control or disinfection chemicals or source water, notify the primacy agency and comply with regulatory requirements to assure corrosion control remains optimized.
  - Disinfectant residuals should be kept at levels that will maintain minimum disinfectant residual requirements, especially in areas having difficulty maintaining them.
- Additional benefits of a corrosion control plan are that it can extend the life of infrastructure; decrease metal release and concentrations at the tap; reduce hydraulic issues from pipe scale build up and decrease pumping costs; diminish aesthetic issues (e.g., color, taste, and odor); reduce infrastructure failures; and help to reduce biofilm growth.
- For pipe installation or replacement in areas with corrosive or salty soils use poly-wrapped or poly-encased pipe.

High Velocity Unidirectional Flushing to Remove Hydraulically Mobile Contaminants

Spot Flushing Application

Image Source: Confluence Engineering Group. Used with permission.

Table 1. Resources and Guidelines related to Corrosion Control and Disinfectant Residual

Resource Title and URL	Relevance to Corrosion Control and Disinfectant Residual
AWWA Staff. (2017). What Are Some Best Practices for Internal Corrosion Control? *Opflow*, 43(11), 8-9. https://doi.org/10.5991/OPF.2017.43.0076 Note: There may be a fee associated with obtaining this resource.	Review of how to approach creating a corrosion control plan.
Lytle, D. A., & Liggett, J. (2016). Impact of water quality on chlorine demand of corroding copper. *Water Research*, 92, 11-21. https://doi.org/10.1016/j.watres.2016.01.032 Note: There may be a fee associated with obtaining this resource.	Evaluates how water chemistry shifts from the addition of pH and orthophosphate impact corrosion and chlorine concentrations.
Grace, S., Lytle, D. A., & Goltz, M. N. (2012). Control of new copper corrosion in high-alkalinity drinking water. *JAWWA*, 104(1), E15-E25. https://doi.org/10.5942/jawwa.2012.104.0002 Note: There may be a fee associated with obtaining this resource.	Highlights the interactions between new copper pipes, a change in corrosion control, and the consumption of free chlorine.
AWWA. (2017). M68 Manual of Water Supply Practices. Water Quality in Distribution Systems. https://www.awwa.org/ Note: There may be a fee associated with obtaining this resource.	Describes factors affecting corrosion-related water quality. Explains how to select an appropriate corrosion control method and the role of corrosion in disinfectant residual management.
Tang, M., Fields, R. E., Buse, H.Y., Lytle, D. A., Schock, M. R., Harmon, S., Kireta, A., and Triantafyllidou, S. (2021). How to Prevent Copper Corrosion in Drinking Water Pipes. https://doi.org/10.1002/opfl.1574 Note: There may be a fee associated with obtaining this resource.	Describes copper corrosion-related water quality and strategies for solving the blue water phenomenon.
Prest, E., Hammes, F., van Loosdrecht, M. C. M., & Vrouwenvelder, and J. S. (2016). Biological Stability of Drinking Water: Controlling Factors, Methods, and Challenges. https://doi.org/10.3389/fmicb.2016.00045	Describes biological stability of drinking water including descriptions of interactions between biofilm, sediment, and bulk water. Also discusses advanced approaches for assessment of biological stability.

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