United States Environmental Protection Agency

Distribution System Water Quality

Protecting Water Quality Through Water Age Management

Excessive water age can lead to a deterioration of distribution system water quality, including increased disinfection byproduct (DBP) formation, disinfectant residual consumption, and microbial growth. Water age can be managed by using design and operational practices that optimize flow through the distribution system while maintaining pressure requirements. This fact sheet is part of EPA's Distribution System Toolbox developed to summarize best management practices that public water systems (PWSs), particularly small systems, can use to maintain distribution system water quality and protect public health.

Examples of Utility Actions

A PWS in the southern U.S. serving 2.2 million people violated the Total Coliform Rule and continued to have high numbers of positive total coliform results and low disinfectant residuals for a four-week period. In response, the city conducted hydraulic modeling and valve checks and found that 44 isolation valves that had been closed during maintenance work had not been re-opened, leading to excessive water age in parts of the system. Some valves could not be operated because of poor condition. The city took corrective actions including valve repairs and spot flushing, and achieved compliance. To prevent future violations, the city implemented routine valve checks and increased disinfectant residual monitoring.

Water age contributed to DBP violations at a wholesale water system in the southeastern U.S. directly serving 28,000 people and at three of its consecutive systems, each serving fewer than 5,000 people. In response, the wholesale system increased water quality monitoring at dead ends, large mains, and tank outlets. They also cleaned storage tanks, optimized tank operations, conducted flushing to reduce water age, and optimized treatment practices to reduce the water's total organic carbon concentration. As a result, the DBP concentrations in the wholesale system decreased by 43 percent. One consecutive system had a 36 percent decrease in DBP concentrations after taking similar corrective actions.

What is Water Age?

- Water age is the time water spends in the distribution system prior to use.
- Water age can become excessive when water usage is low, when piping or storage tanks are larger than needed, or when water circulation is poor.
- Poor water circulation can be a particular problem at dead-end water mains and behind closed valves. It can also occur where accumulated air blocks water flow at high points in the distribution system. Poor water circulation can occur in storage tanks when thermal stratification limits vertical mixing, increasing water age in portions of the tank.

How Does Water Age Affect Water Quality in the Distribution System?

Water quality can deteriorate in the distribution system when there is more time for biological, chemical, and physical reactions to occur within the bulk water or between the bulk water and wetted surfaces. For example:

- Particles and corrosion products can settle in piping and tanks, creating sediment.
- Chlorine can react with organic and inorganic constituents in sediment and on the pipe wall, or in the bulk water, causing the chlorine residual to be consumed.
- Low chlorine residuals provide conditions where microbial growth can increase, and in some cases microbial corrosion can leach metals from pipe scales.
- In excessively aged water, chlorine may have more contact with natural organic matter, increasing DBP formation.
- At PWSs that use monochloramine for secondary disinfection, nitrification can occur in the distribution system under conditions of high water age and warm temperatures.
- Water that is stagnant in storage tanks and dead-end mains can increase in temperature, contributing to increased microbial growth and DBP formation.
- Changes in water chemistry associated with water age can enhance biofilm growth on pipe and tank walls and allow opportunistic pathogens such as *Legionella* to proliferate.

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Strategies for Finding Areas of the Distribution System with High Water Age

- Review monitoring data to identify areas with low disinfectant residual, high DBP levels, high bacterial counts, or high nitrite/nitrate levels, and review customer complaints.
- Measure disinfectant residual at potential problem areas such as dead-end water mains and tank outlets.
- Measure water temperature at different depths in storage tanks to identify thermal stratification that could cause poor water circulation.
- Construct a hydraulic or water quality model and use it to evaluate planned or possible changes in water demand and tank operating conditions.
- Conduct a tracer study by adding a tracer chemical (e.g., calcium chloride) and measure it at various locations and times to better understand water movement in the distribution system.

Design Strategies for Water Age Management

- Use hydraulic models to right-size water mains and storage tanks.
- Install tank mixers and/or optimize the placement of inlets and outlets to improve water circulation in tanks.
- Eliminate dead-end water mains: for example, by installing new pipe to form a closed loop.
- Optimize valve operations to promote water circulation.
- Install sampling taps and automatic monitoring equipment to monitor residual chlorine at finished water storage tanks and other locations.
- Install air valves at high points in the distribution system to remove accumulated air, which can block pipelines and reduce water circulation.

Use of Low Velocity Flushing for Bulk Water Turnover without Scouring

Source: Confluence Engineering Group. Used with permission.

Operational Strategies for Water Age Management

- Use gentle bulk water turnover flushing to remove stagnant water and temporarily restore disinfectant residual.
- Optimize pumping and tank filling/draining operations.
- Regularly measure disinfectant residual at dead-ends, tank outlet lines, and low water usage areas.
- Exercise valves to maintain valve operations, verify that valves are set in the correct position (open or closed), and identify repair needs.
- Use hydraulic models to evaluate flow direction and flow rate, determine optimal valve positions (open or closed), and run water age analysis.
- Make sure that valves are reopened after repair work.

Table 1: Resources and Guidelines for Water Age Management

Resource Title and URL	Relevance to Water Age Management
ASDWA. 2020. State Drinking Water Distribution System Survey. http://www.asdwa.org/	Summarizes the results of a survey on topics that include state policies, recommendations, and regulations related to maximum residence time, valve exercising, flushing, and disinfectant residual monitoring.
GLUMRB. 2018. Ten States Standards. https://www.mngovpublications.com/ Note: There may be a fee associated with obtaining this resource.	Provides guidance on distribution system topics like tank sizing, location, and appurtenances; water main sizing; provisions for adequate flushing; isolation valve spacing; and air relief valve location.
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 how to properly size pipes, valves, and storage to provide adequate capacity and avoid water age problems. Explains how to estimate water age using hydraulic models, tracer studies, and system hydraulic and water quality records.

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