United States Environmental Protection Agency

Distribution System Water Quality

Protecting Distribution System Water Quality through Control of Nitrification

Systems using chloramines for secondary disinfection may experience nitrification when the system has high source water ammonia levels and/or when the system adds too much ammonia. The breakdown of chloramines, releasing free ammonia, can also contribute to nitrification. Nitrification in distribution systems is undesirable because it can cause biofilm growth, water quality degradation (e.g., disinfectant depletion, coliform occurrences, and nitrite/nitrate formation), and subsequent non-compliance with existing regulations (e.g., disinfectant residuals below regulatory limits). 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 serving nearly 500,000 people in the southern U.S. had two nitrification episodes in the period of two years, each resulting in a boil water notice for low chlorine residuals and elevated coliforms. In response to these nitrification episodes, PWS staff improved their Nitrification Action Plan. They performed more water quality monitoring in the distribution system and undertook corrective actions: e.g., eliminating dead-end mains and implementing a new tank cycling strategy to reduce water age. At the time of reporting, three years after the corrective actions were implemented, the PWS had not experienced any more nitrification events.

A PWS serving 8,600 people in the northeastern U.S. was having difficulty maintaining chloramine residuals and found evidence that nitrification was occurring. The PWS conducted a study to evaluate the age and quality of water entering the distribution system. The PWS determined that the chloramine residual was unstable and rapidly decreased. Coagulant dosing was modified, and the coagulation/flocculation process was improved to remove natural organic matter more effectively. The PWS also improved mixing during chloramine formation and increased the chloramine residual entering the distribution system. The treatment changes led to improved chloramine residual stability and higher chloramine concentrations in the distribution system.

Understand Nitrification Causes

- Nitrification is a two-step biological process:
  - First, ammonia-oxidizing microbes oxidize ammonia to nitrite.
  - Second, nitrite-oxidizing bacteria oxidize nitrite to nitrate.
  - Some microorganisms can perform both steps.
- Distribution system nitrification occurs when ammonia-oxidizing microbes grow faster than they are inactivated by the disinfectant residual.
- Factors that favor nitrification: high free ammonia concentration, low disinfectant residual concentration, high water age, high temperature, sediments or deposits that consume disinfectant residual and protect bacteria.
- In general, the following water quality progression occurs with nitrification:
  - As chloramine residual decreases, free ammonia concentration will initially increase. Chloramine residual will continue to decrease and eventually approach zero.
  - Free ammonia decreases as free ammonia is consumed by ammonia-oxidizing microorganisms, forming nitrite.
  - Increasing nitrite concentration favors the growth of nitrite-oxidizing bacteria resulting in nitrate formation, indicating a nitrification event.
- Comprehensive Nitrification Action Plans or Nitrification Control Plans are used by water system operators to prevent and respond to nitrification in their distribution systems.
- Some states require systems using chloramination to have a Nitrification Action Plan or Nitrification Control Plan to help maintain disinfectant residual. Details on state requirements may be found at individual state web sites.

Nitrification Action or Control Plans

- The major components and considerations included in a Nitrification Action Plan or Nitrification Control Plan include:
  - Description – historical nitrification occurrence in the system
  - Objectives – regulatory compliance and specific water quality objectives
  - System details – pertinent information about the system, including treatment and monitoring locations
  - Monitoring plan – sampling locations, parameters, and frequency
  - Data analysis – process for analyzing collected data
  - Water quality benchmarks (triggers)

Nitrification Action or Control Plans (continued)

- Response strategies – actions to be taken when nitrification occurs
- Prevention strategies – actions to be taken to prevent nitrification

- PWSs review and update their Nitrification Action Plan or Nitrification Control Plan on a regular basis to ensure the plan is effective and representative of current system operations.

Nitrification Prevention Strategies

- Nitrification prevention strategies will be specific to a given water system, but may include:
  - Optimizing treatment processes to improve organic matter removal.
  - Ensuring that the correct chlorine-to-ammonia ratio is used for secondary disinfection.
  - Keeping the distribution system clean through regular flushing, pigging, swabbing, or other measures.
  - Developing and implementing a Nitrification Action Plan or Nitrification Control Plan.
  - Reducing water age in the distribution system.
  - Optimizing storage tank operations to improve turnover and mixing performance.
  - Conducting a seasonal (e.g., spring) conversion to free chlorine for secondary disinfection.

Nitrification Response Strategies

- Once started, nitrification is difficult to stop. Therefore, it is desirable not only to take steps to prevent nitrification episodes, but also to be prepared to detect and correct them quickly when they do occur.
- The most common responses used to halt nitrification episodes include:
  - Distribution system flushing – effective for limited, localized nitrification
  - Draining and disinfecting storage tanks – effective if the nitrification source is the storage tank
  - Temporary conversion to free chlorine – removes the food source (i.e., ammonia) and causes nitrification to stop, although results may be short-lived.
- Unintended consequences associated with nitrification response strategies should be considered: for example, conversion to free chlorine could result in increased disinfection byproduct formation.
- Once nitrification is brought under control, the underlying causes of the nitrification event should be understood and corrected, or nitrification is likely to occur again.

Table 1. Resources and Guidelines for Distribution System Nitrification Prevention and Response

Resource Title and URL	Relevance to Nitrification Prevention and Response
TCEQ. 2021. Controlling Nitrification in Public Water Systems with Chloramines. https://www.tceq.texas.gov/drinkingwater/disinfection/nitrification.html	Provides information related to controlling nitrification in drinking water systems, including detection and response actions.
ASDWA. 2020. Distribution System Survey White Paper https://www.asdwa.org/	Summarizes information about state requirements for Nitrification Action Plans.
Ybanez, C.; Ramirez, G.; Becker, W.; and Santos, M. 2020. When the Distribution System Needs a NAP: Tackling One City's Nitrification Action Plan. *Journal AWWA*. 112(1), 40–51. https://doi.org/10.1002/awwa.1430. Note: There may be a fee associated with obtaining this resource.	Illustrates an example where a Nitrification Action Plan was implemented to address nitrification in a municipal drinking water distribution system.
AWWA. 2017. M68 Manual of Water Supply Practices. Water Quality in Distribution Systems, 1st Edition. https://www.awwa.org/. Note: There may be a fee associated with obtaining this resource.	Discusses nitrification prevention, monitoring, and response in drinking water distribution systems, including an example Nitrification Action Plan.
AWWA. 2013. M56 Manual of Water Supply Practices. Nitrification Prevention and Control in Drinking Water, 2nd Edition. https://www.awwa.org/. Note: There may be a fee associated with obtaining this resource.	Summarizes information and best practices related to nitrification prevention, nitrification monitoring, and responses to nitrification episodes in drinking water distribution systems.