Water Quality Monitoring and Nitrification Control in Chloraminated Distribution Systems

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Outline

- Chloramine Optimization Overview
- Distribution System Monitoring Approach
- Investigative Sampling Case Studies
- Operational Considerations
- Summary

Optimization Program Background

- Encourages drinking water quality beyond compliance levels to increase public health protection through:
  - Enhanced process monitoring and control
  - Using existing staff and facilities
  - Measuring performance relative to optimization goals
- Program began in 1989, with microbial optimization at surface water treatment plants (WTP) and has expanded to other areas, which includes the optimization of chloraminated distribution systems (DS)
  - Currently, EPA's Technical Support Center supports an Area Wide Optimization Program (AWOP) network of over twenty states
  - Participating states utilize technical tools and implementation approaches to improve drinking water quality with their systems

Chloraminated Distribution Systems

- Increasing number of systems are switching from free chlorine to chloramines (AWWA, 2008) for various reasons:
  - Forms fewer regulated disinfection by-products (DBPs)
  - More stable, longer lasting disinfectant residual
  - Improved biofilm and *Legionella* control (Flannery, et al., 2006)
- Unique challenges associated with chloramination (AWWA, 2013):
  - Nitrification can lead to non-compliance with various regulations
  - Basic understanding of chloramine chemistry is necessary
  - Increased level of monitoring and process control in both the WTP and DS

Optimization Goals for Chloramine Systems

- Disinfectant Residual Goal
  - *Maintain ≥ 1.50 mg/L monochloramine residual at all monitoring sites in the distribution system, at all times, to provide a disinfection barrier against both microbial contamination and nitrification prevention*
- Basis:
  - At a monochloramine residual of 1.5 to 2.0 mg/L, 99% of ammonia-oxidizing bacteria (AOB) are inactivated in < 30 minutes (Regan, 2001)
  - Several studies recommend that a monochloramine residual > 2.0 mg/L may prevent the onset of nitrification (Kirmeyer, et al., 1995; Odell, et al., 1996; Harrington, et al., 2002)
  - Monochloramine is a relatively weaker disinfectant than free chlorine (USEPA, 2013)

Optimization Goals for Chloramine Systems

- Ammonia Dosing Control Goal
  - *Minimize free ammonia residual to ≤ 0.10 mg/L as NH_3-N in the plant effluent*
- Basis:
  - Free ammonia is the basic nutrient for nitrification (AWWA, 2013)
  - Overfeeding ammonia, as a result of poor process control, is a major cause of nitrification (AWWA, 2013)
  - Limit excess free ammonia leaving the plant to as low as possible, at least < 0.10 mg/L as NH_3-N, but preferably < 0.05 mg/L as NH_3-N (AWWA, 2013)

Distribution System Monitoring Approach

Monitoring Locations and Frequency

- Suggested Monitoring Locations:
  - Entry point(s)
  - Regulatory sample locations
  - Areas with complaints
  - Storage tanks
  - Areas with higher water age
  - Various pipe materials and pressure zones
- Suggested Frequency:
  - At least monthly, but more frequently during critical times

Samples collected using hydrant sampler (Sekhar & Dugan, 2009)

Water Quality Analysis

- Water quality samples are analyzed in the field using a portable parallel analyzer (PPA) or a colorimeter and pH meter
- Baseline Parameters:
  - Monochloramine
  - Total Chlorine
  - Free Ammonia
  - pH
  - Temperature
- Nitrification Parameters:
  - Nitrite
  - Nitrate (optional)
  - HPC w/R2A agar (optional, lab only)
- Optional Parameters:
  - Alkalinity
  - Total Organic Carbon
  - DBPs (e.g., TTHM, HAA5, NDMA)

Method Limitations, Suggestions, and Observations

- Monochloramine and Free Ammonia Indophenol Methods
  - Updates needed:
    - Colorimeter software (per manufacturer's recommendation) to correct performance issues
    - Certificates of analysis for existing secondary standards
    - Free ammonia method reagent, procedure, and program number
  - Use hardness reagent in free ammonia samples with moderate to high hardness (≈ 100 mg/L as $CaCO_3$ or greater) to prevent scale build up on sample cells
  - Prior to analysis:
    - Gently invert sample cells to remove fine air bubbles that may form on the inside of the plastic cells
    - Wipe outside of sample cells to remove condensation

Method Limitations, Suggestions, and Observations

- Total Chlorine DPD Method
  - Prone to interferences from various oxidizing agents (e.g., organo-chloramines, iron, manganese) that will over-quantify active disinfectant
  - Samples with high alkalinity (> 250 mg/L as $CaCO_3$) can depress total chlorine measurements
- Nitrate Cadmium Reduction Method
  - Sample shaking time and technique strongly influence sample results, reproducing similar results form the same sample can be challenging
  - Appropriate nitrate method range (i.e., LR, MR, HR), should be selected based on historical entry point nitrate data

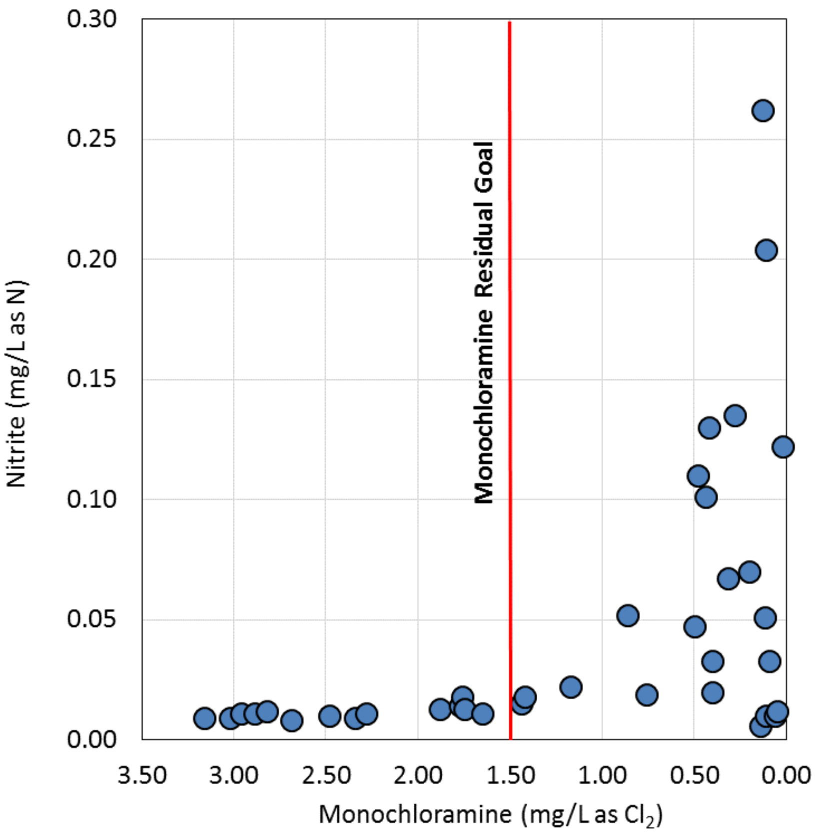
Method Limitations, Suggestions, and Observations

- pH Analysis
  - Measure pH immediately to obtain most accurate results
  - Clean electrodes periodically for optimal performance
  - Performance of portable pH meters can vary
- Bottom Line – read method protocols, provided by the manufacturer to understand potential interferences, limitations, and procedures
- Check manufacturer's website periodically for method updates

Investigative Sampling Case Studies

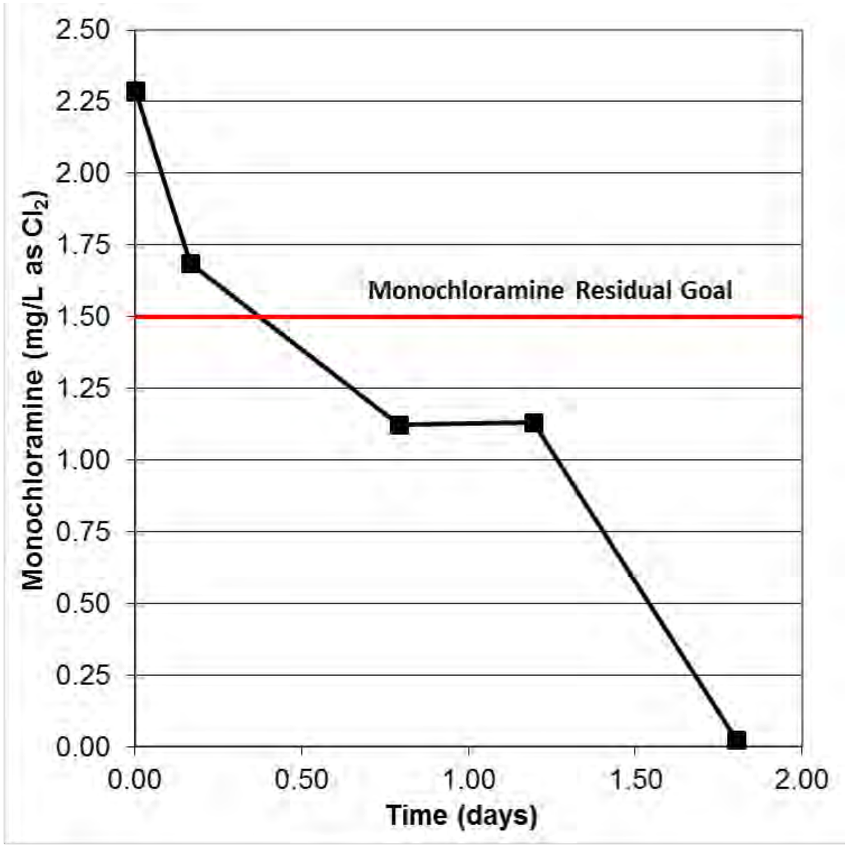
Case Study #1

- Small community water system with small service area (25 mi^2)
- Conducted multiple sampling studies throughout system during the summer of 2010
  - Significant nitrification problems
  - Unable to maintain monochloramine in some areas of the system
- Poor DS water quality a result of poor treatment (i.e., ammonia dosing, TOC removal)



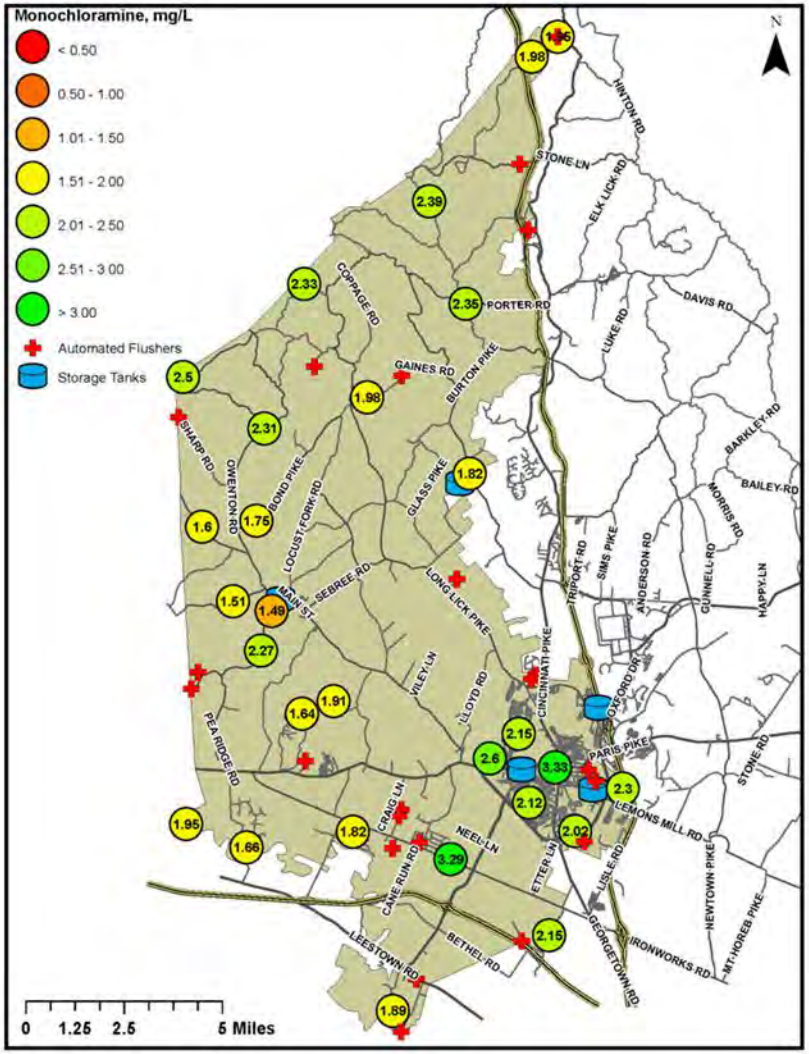
Case Study #2

- Small community water system (≈0.8 MGD) with ≈2,700 meters
- Conducted three day evaluation of DS and chloramine dosing process
  - Unstable disinfectant residual resulted in areas of very low residual
  - Some evidence of nitrification
- Poor ammonia mixing prior to finished water sample tap
  - Process control data unreliable
  - Often underfed NH_3 and formed $NHCl_2$



Case Study #3

- Rural water system with large service area (160 mi^2)
- Conducted multiple sampling studies throughout system during the summer of 2011
  - Lowest measured monochloramine residual was 1.49 mg/L
  - No evidence of nitrification issues
- Sustained water quality through:
  - Stable finished water quality
  - Automated flushing program



Operational Considerations

Treatment Considerations

- Adequate mixing of chlorine and ammonia is needed to prevent dichloramine and trichloramine formation
- Representative process control monitoring is critical
  - Sample taps should be located after reaction is complete
  - Poorly located taps can result in unreliable data for operational decisions
- Minimize free ammonia in finished water
  - Assess free ammonia concentration and chlorine demand in source water
  - Adjust chemical feeds to compensate for variable raw water quality and flow
- Monochloramine stability
  - Demand: natural organic matter, nitrite, iron, manganese
  - Decay (Auto-Decomposition): pH, alkalinity, temperature

Distribution System Considerations

- Water Age Management
  - Water quality-based flushing program
  - Re-routing flow to redistribute consumer demand
  - Future design (e.g., perceived storage needs with water quality)
- Tank Operations – both adequate turnover and mixing are needed
- System "cleanliness" can minimize monochloramine demand
  - Unidirectional Flushing
  - Tank Cleaning
  - "Chlorine Burns"

Summary

- Optimization of a chloraminated distribution system can be achieved by:
  - Adopting operational performance goals to target
  - Developing a distribution system monitoring plan to assess performance
  - Making operational changes that are supported by water quality and other operational data
  - Continuing to reassess performance to determine if additional operational changes are needed

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Questions?

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