Chloramination: Challenges and Solutions

Presented By:
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• History and Background
• Chloramination advantages
• Chloramination challenges
• Chloramination solutions
• Case Studies
• Conclusions and Recommendations
Chloramination has been used in drinking water treatment since the early 1900s. Traditionally, few utilities have used chloramines, but the number is increasing (approximately 30% of PWS). Chloramines are a class of oxidants formed by the reaction of chlorine and ammonia:

- Monochloramine ($\text{NH}_2\text{Cl}$)
- Dichloramine ($\text{NHCl}_2$)
- Trichloramine ($\text{NCl}_3$)

Primarily used as a secondary disinfectant to provide residual in the distribution system.
Chloramine Advantages

- Provide an effective residual in distribution while reducing formation of regulated DBPs such as THMs and HAAs
- More stable and therefore last longer in the distribution system
- Maintains chlorine residual in dead ends and large storage tanks
- Better aesthetic water quality than chlorine (taste and odor)
Chloramine Disadvantages

- Chloramination can be a complex process which can lead to unintended consequences:
  - Nitrification in distribution system
  - Formation of non-regulated DBPs (N-nitrosamines, iodinated DBPs, hydrazine)
  - Deleterious effects on elastometric materials in distribution system
  - Increased leaching of lead in distribution system (Washington D.C. 2001)
As chloramine use grows, water professionals need to understand the various aspects of chloramination with the goal of better managing and operating their systems to minimize unintended consequences.
Monochloramine is the preferred form of chloramine
- Most stable
- Least reactive (less THM)
- Least taste and odor
Rate of Decay Increases as pH Decreases
Titration Based Alkalinity Analyzer
Chloramination Control Challenges

- Maintain adequate disinfectant concentration to ensure safe water
- Prevent/minimize formation of dichloramine and trichloramine and loss of chlorine residual
- Control/minimize nitrification within the distribution system
- Control of chlorine-ammonia ratios is critical to successful chloramination
Nitrification

- Nitrification is estimated to affect approximately 2/3 of systems that use chloramination.
- Can cause growth of coliform bacteria, deplete chlorine residual, and increase nitrate concentrations.
- Ammonia-oxidizing bacteria (AOB) are believed to be part of this mechanism ..... They eat metallic components.
- Water quality, biofilms and various water distribution system conditions contribute to Nitrite formation and Nitrate eventually ..... Complex Inorganic chemistry too.
A Total Chlorine result has 3 possible locations on the breakpoint curve.

Free Chlorine reacts with Monochloramine giving a false reading until beyond the Breakpoint.

First Indication of Free Chlorine is AFTER Dichloramine Formation.
Optimal Chloramination Control Range

Figure: Optimum Cl₂:NH₂-N weight ratios for chloramination found by MWD
(0.6 mg/L NH₂-N; pH 7.4 to 7.8; temperature 25 °C)
Break-point Curve as Read on ChemScan On-Line Analyzer

At ratios below 5:1, Total Chlorine and Monochloramine values are equivalent.

Between the ratios of 5:1 and 8:1, Total Chlorine is greater than Monochloramine as Dichloramine is formed.

At ratio greater than 8:1, Free Chlorine is present.

At ratios below 5:1, Total Ammonia remains constant as Free Ammonia decreases until reaching 5:1.

At ratios greater than 5:1, Total Ammonia decreases and free ammonia is near zero.
Chloramination Control Strategies

• Ratiometric control
  • Cl₂ : NH₃-N ratio between 3:1 and 5:1
  • Measures total chlorine from all forms and total ammonia from all forms (free and combined)

• Residual control
  • Maintain small free ammonia residual
  • Maintain target monochloramine
Test your system to determine if the rate of flow control valves are working to turn up and down properly when pump flow changes.
Case Study - Toronto

ChemScan Chloramination Analyzer Data
City of Toronto  F. J. Morgan WTP
Case Study- Washington DC

- USACE operates two WTPs – DaleCarlia and MacMillan
- Distributes to DC and counties / cities in Metro area
- 180 MGD from Potomac River - 1 Low + 4 High Service Districts
- DC Water operates four treated water pumping stations (Anacostia, Bryant Street, Fort Reno, and 16th & Alaska), and eight reservoirs and elevated tanks.
- The Washington Aqueduct operates the Dalecarlia Pump Station and three reservoirs (Foxhall, Van Ness, and Fort Reno).
DC Water, Fairfax Co, Loudoun Water and US ACE interconnects

ChemScan systems in use at each US ACE WTP since 2005. Shortly after the crisis erupted with lead service lines.

Corrosion control program instituted by USACE and pH management to reduce leeching.

Optimum Monochloramine mgmt and pH control needed to avoid di and tri formation.

Fairfax Water has 2 ChemScans at Griffith and Corballis WTPs serving over 200 MGD in NoVA

Loudoun Water has ChemScan at Goose Creek WTP and new Potomac River WTP
Case Study – Tampa Regional Interconnects

Several different water sources in the area create an intriguing soup to maintain flavor in

Ground water with organics
River water with algae and other weather related influences
Brackish Desal water from the Tampa Bay Desal WTP

Multiple Counties and Cities need to optimize disinfection and delivery
• Pasco County
• New Port Richey
• Pinellas Co
• Clearwater
• Hillsborough Co
• City of Tampa
• MacDill AFB
• St Petersburg
• Sarasota County
• Bradenton Water

All use regional water supply but many monitor multiple sample points w ChemScan analyzers + other parameters
Nitrification Can Result In

- Depletion of chloramine residual
- Increase in HPC
- Increase in nitrite/nitrate
- Decrease in alkalinity, pH and dissolved oxygen
Case Study - San Francisco

• 12 analyzers spread out around the system at WTPs and distribution tanks or water booster ps

• Chloramination suite – FNH3, TNH3, Mono + TCL2 at WTPs but Free NH3 and UV%T in distribution

• Monitor and Boost off FNH3 as it climbs due to temperature and oxidation effects
Case Study- Houston

- Booster System Management at local M.U.D.’s
- Groundwater Subsidence – Order to cease well use
- Add LAS and or CL2 to control Houston city water
- 3 huge WTPs distribute all around the Metro area
- 40-60 miles to remote municipal utility districts
- F NH3 and CL2 decay require active management
Tank & Distribution Control

- OWASA
- High Point
- Burlington
- Greenville, NC
- Houston, TX
- Pasco County, FL
- Hillsborough County, FL
- Miami Dade Water
- Palm Beach County
- Sarasota, FL
Online multiparameter analyzers can make NH2CL control easier

Patented Peak Point Control strategy is proven to work and optimize monochloramine formation as well as boost measurement and distribution control.

Can be used for NOM / TOC monitoring and control for WTPs.

Can be used for Corrosion control dose control by measuring PO4 online to set concentration.
Conclusions and Recommendations

- New LED based analyzers can be utilized in the distribution system for Mono, FNH3, Copper, Nitrite and UV 254
- R+D continues on these Fluoride, Lead, Zinc, Nitrate+ Color
Conclusions

• Carefully evaluate potential effects prior to switching to chloramines
• Consider water chemistry, distribution system and tank configuration, distribution system materials, and engineering and design of system
• Perform preliminary/pilot studies prior to full implementation
Chloramination:
Challenges and Solutions

Questions?

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