Sample Collector's Handbook: Chapter 18 – Nitrification Action Plan

A Community Water Supply (CWS) that employs chloramination as a means of disinfection or a CWS that has source water containing ammonia is required to implement a Nitrification Action Plan (NAP) pursuant to Section 604.140 of Title 35 of the Illinois Administrative Code. The NAP is a tool for identifying areas of the distribution system that may experience nitrification issues resulting in depleted disinfectant residuals, potential biofilm growth, and bacteriological contamination.

The NAP should include specific monitoring requirements for various parameters to optimize the chloramination process and ensure that chloramine disinfection is successful in preventing and/or responding to nitrification events. The NAP should also include specific levels of monitoring parameters that trigger corrective actions and should delineate corrective actions that will be implemented when monitoring indicates that nitrification may be present.

What is Nitrification?

Nitrification is the microbial process of converting ammonia, or ammonium, into the nitrogen compounds of nitrite and nitrate. Ammonia may be present in drinking water through naturally-occurring processes or through ammonia addition in the formation and use of chloramines as a disinfectant in the water treatment process.

The first step in the nitrification process is the conversion of ammonia, or ammonium, into nitrite through oxidation. *Nitrosomonas* is the most identified genus associated with this process. The second step is the oxidation of nitrite to nitrate in the presence of *Nitrobacter. Nitrosomonas* and *Nitrobacter* are the most common bacteria present in the nitrification conversion process.

It is important to understand the chloramination process when ammonia is present during the treatment of water for potable usage. Ammonia can often be present in the source water, well or surface water, or can be added in the treatment scheme to produce chloramines as a disinfectant. Chloramines are often used as a disinfectant for controlling disinfectant by-products and because of the persistent nature of chloramines as a disinfectant.

However, improper monitoring and control of ammonia in a distribution system can result in detrimental health effects. Excess ammonia levels can result in the depletion of disinfectant residuals, promotion of biological growth, nitrite and nitrate formation, reduction in pH and alkalinity, and concerns related to taste and odor. It is important to note that Nitrite-N and Nitrate-N are regulated contaminants with acute maximum contaminant levels of 1 milligram per liter (mg/L) and 10 mg/L, respectively.

Who is required to implement a Nitrification Action Plan (NAP)?

Any CWS that adds ammonia in the treatment process to form chloramines as a primary disinfectant must develop and implement a NAP. In addition, a CWS that has ammonia in the source water must meet the same requirements unless monitoring indicates that breakpoint chlorination is consistently achieved at the treatment application point.

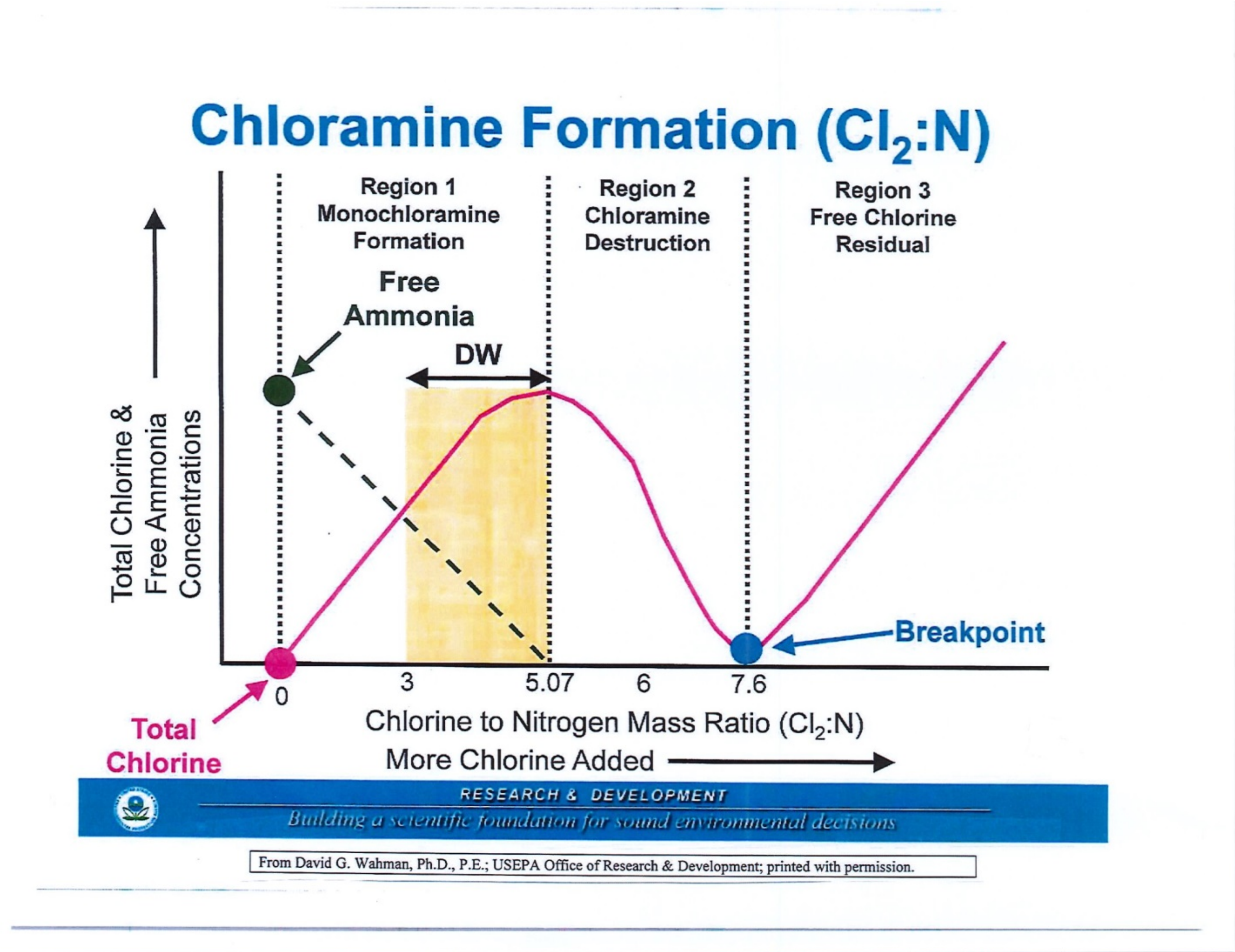
Monitoring of each raw water source must be conducted to determine presence and quantification of ammonia in the respective source waters. This includes monitoring of all wells and surface water sources at an appropriate frequency to reflect seasonal variations of the source water ammonia levels. Historical data, quantifying the ammonia concentrations, can also be evaluated using the Drinking Water Watch website at http://water.epa.state.il.us/dww/.

A CWS that purchases potable water for redistribution may be required to develop and implement the NAP based on the disinfection practices of the CWS that is providing the water. Specifically, if the CWS providing potable water is required to implement the NAP, the purchasing, or consecutive, CWSs will also be required to do the same.

Sampling Requirements

Identification of optimized chloramination disinfection treatment and distribution nitrification problems requires monitoring of several parameters. The quantification of these parameters is critical in understanding and optimizing the chloramination process and identifying areas within a distribution system where nitrification problems may exist. To implement the NAP, the CWS should monitor total ammonia-N, free ammonia-N, nitrite-N, nitrate-N, monochloramine residuals, dichloramine residual, and total chlorine residual. Understanding the chlorination curve (see Figure 18-1) and the relevance of these monitoring parameters provides the information necessary to make adjustments in the treatment scheme to optimize the chloramination process and minimize the risk of nitrification. Additional process management may include monitoring of free chlorine and pH. When nitrification is suspected to be present, speciation and quantification of the bacteria found can be used as a means of measuring the extent of nitrification.

Figure 18-1



Sampling Sites for the NAP

Sampling sites must be representative of the raw water source when determining if the presence of ammonia exists in the source water. Specifically, the sample tap of a source water, well or surface water, must be located prior to any disinfection application. When multiple wells are used simultaneously, the sample tap must be representative of the combined discharge of all wells being used. This information is particularly important in determining optimal chlorine and supplemental ammonia feed rates for obtaining the desired disinfection results.

In addition to source water quality monitoring, point-of-entry monitoring is necessary to establish water quality characteristics at all points subsequent to treatment and at the point-of-entry to the distribution system. Point-of-entry monitoring establishes a baseline of water quality entering the distribution system and can be used in a comparative analysis of water quality throughout the distribution system. It is important to note that when multiple treatment application points are provided, monitoring for each treatment application point is necessary. For systems that purchase water, water quality monitoring is required at each point of connection to the water supply provider(s).

Distribution monitoring requires careful consideration to properly assess impacts related to nitrification. Identification of sample sites should consider factors including water age, disinfectant residuals, and areas of overall water quality concerns. Typically, extended water age represents the most significant risk for nitrification occurring. Sample sites should be chosen that reflect areas in the distribution system where the residence time is the greatest. Distribution coliform sample sites can be used for NAP monitoring given that those sites should reflect water residing in the system the longest. In addition, sample sites should be chosen to reflect an "average" age of water. These average water age sites can be used in comparison with other distribution monitoring data for determining the locational extent of the nitrification and isolate where corrective actions must be implemented.

Sample sites should also be representative of all pressure zones within a distribution system. A hydraulic analysis of the system may be necessary to determine areas where an average water age and extended water age exists.

Sample Frequency

The NAP sample frequency for an effective and comprehensive strategy is dependent on numerous factors and can vary from system to system. Initial sampling frequency is critical in establishing a sufficient baseline of data that accurately characterizes water quality at the point-of-entry and distribution system. Additionally, sampling should account for temporal variance and reflect seasonal changes that may play a significant role maintaining consistent and adequate disinfectant residuals.

Upon establishing the characterization of water quality at the point-of-entry and the distribution system, a monitoring plan must be established for maintaining optimal disinfection practices while reducing the risk of nitrification occurring. Minimum sampling frequencies for maintenance monitoring are provided in Figure 18-2. Additional monitoring may be necessary where finished water storage facilities impact water quality or water quality variations indicate frequent changes occur in portions of the distribution system. Similar to any monitoring protocol, it is imperative that proper lab analyses and techniques are used, including appropriate calibration of monitoring equipment, to provide reliable and accurate monitoring data.

Figure 18-2

	Point of Entry	Distribution	Prior to and after any chlorine or ammonia injection points
Total Chlorine	daily	daily	**
Mono-chloramine	daily	weekly	**
Di-chloramine***	monthly	monthly	**
Free Ammonia	daily	weekly	**
Total Ammonia	daily	weekly	**
Nitrate and Nitrite	*weekly	monthly	**

*   nitrate and nitrite monitoring can be reduced to monthly if source and treatment variations indicate minimal variations.

** monitoring of all parameters should be done prior to, and subsequent to making any feed rate adjustments to chlorine and/or ammonia

*** dichloramine can be determined using amperometric titration procedures or can be calculated as the difference between the total chorine and monochloramine residual.

Monitoring Results and Trigger Levels

Results generated from the monitoring previously described should be closely analyzed when determining actions that may be required to address potential distribution nitrification issues. Included in the NAP are operating "goals" for each monitoring parameter that indicate that disinfection practices are optimal and residuals are being maintained at a level where nitrification is not evident. Comparison of actual monitoring results with the operating "goals" will result in operating conditions being classified into three categories:

- Normal Operations: disinfection practices are optimized and nitrification does not appear to be evident based on monitoring results. However, proactive and preventative actions may be appropriate for maintaining disinfection optimization.
- Yellow Flag Alert: occurs when monitoring data indicates that nitrification may be occurring in the system and corrective action are required.
- Red Flag Alert: when monitoring data conclusively indicates that nitrification has progressed in the system resulting in depressed disinfectant residuals, elevated nitrite and/or nitrate levels, reduced pH levels and potential taste and odor concerns. Red Flag Alerts require immediate remedial actions and the issuance of a precautionary boil order when minimum disinfectant levels are not met.

Trigger levels established by a CWS are system-specific and based on numerous factors. Among those factors are the variabilities in water main material, presence of biofilm in the distribution system, hydraulic conditions, and other factors affecting disinfectant residual longevity.

Corrective Action Response

When monitoring data indicates that nitrification is evident, corrective actions must be taken to remediate the problems associated with the nitrification and return the system to normal operation where disinfection practices are optimized. Remedial actions warranted are dependent on the severity of the suspected nitrification. However, verification of the monitoring data should be conducted prior to undertaking any corrective actions. The verification process includes supplemental sampling of the parameters being monitored.

When verification confirms that nitrification may be occurring, corrective actions must be implemented as specified in the NAP. Delineation of the area impacted by nitrification should be included in the corrective action plan and efforts should be implemented to minimize that area. Based on the severity of the suspected nitrification, remedial actions may include, but not limited to, water main flushing, unidirectional flushing, free chlorine conversion, supplemental chlorination or chloramination, finished water storage maintenance (including, but not limited to, interior tank inspections), revisions to storage practices (including, but not limited to, adjustments to quantity of water stored, water destratification, etc.), pH adjustment, water main pigging, and/or water main looping. In many cases, the corrective actions may require the issuance of a construction and subsequent operating permit by the Illinois Environmental Protection Agency (Agency).

A sample NAP is provided in Figure 18-3. It should be noted that this is only an example and that the format and values included are provided only for guidance purposes and do not reflect the values that should be included in the Nitrification Action Plan for every Community Water System, as previously discussed.

It is also important to note that professional assistance may be required for some remedial actions. As mentioned previously, some actions may require the issuance of applicable permits from the Agency, which requires the submittal of plans and specifications from a registered professional engineer. Due to emerging and changing technologies, the use of professional assistance may be necessary to determine an appropriate and effective treatment or corrective action. Specifically, when converting from chloramine to free chlorine disinfection, or vice versa, professional guidance may be necessary to insure that enhancement of the nitrification does not occur. Additional guidance regarding disinfectant conversion is provided below.

NITRIFICATION ACTION PLAN

CITY OF , COUNTY, ILLINOIS PWS ID NO. IL

Prepared by Curry & Associates Engineers, Inc. Date Project No.

YELLOW AND RED FLAG TRIGGERS & ACTIONS

Chloramine Effectiveness Sample Suite (adapted from Texas Commission on Environmental Quality)

			Yellow Flag		Red Flag	
Site	**Parameter**	**Goal**	**Trigger**	**Actions**	**Trigger**	**Actions**
Entry Point	Total Cl	3.5	3.0	*1) Verify results.*	2.8	*1) Verify results.*
	Monochloramine	3.5	3.0	*2) Check & adjust dose.*	2.8	*2) Check & adjust dose.*
	Dichloramine	0.05	0.1	*→ Until return to normal.*	0.2	*→ Until return to normal.*
	Total NH3-N	0.69	0.75		0.9	
	Free NH3-N	0.01	0.2		0.3	
Ave. Water Age	Total Cl	2.5	2.0	*1) Verify results.*	2.0	*1) Verify results.*
	Monochloramine	2.5	2.0	*2) Measure nitrite & nitrate.*	2.0	*2) Measure nitrite & nitrate.*
	Dichloramine	0.1	0.15	*3) Adjust dose.*	0.2	*3) Adjust dose.*
	Total NH3-N	(A)	(B)	*4) Identify affected area (check*	(C)	*4) Identify affected area (check*
	Free NH3-N	0.1	0.2	*upstream & downstream).*	0.3	*upstream & downstream).*
High Water Age				*5) Flush area.*		*5) Flush area.*
	Total Cl	1.5	1.2	*6) Flush dead-ends.*	1.1	*6) Flush dead-ends.*
	Monochloramine	1.5	1.2	*→ Until return to normal.*	1.1	*→ Until return to normal.*
	Dichloramine	0.1	0.15		0.2	
	Total NH3-N	(A)	(B)		(C)	
	Free NH3-N	0.2	0.3		0.4	

(A) Not to exceed mg/L monochloramine/5.06.

(B) Not to exceed (mg/L monochloramine/5.06) +0.2.

(C) Not to exceed (mg/L monochloramine/5.06) + 0.4.

Nitrite-N (MCL = 1.0 mg/L) and Nitrate-N (MCL = 10.0 mg/L)
(adapted from Texas Commission on Environmental Quality)

			Yellow Flag		Red Flag	
Site	**Parameter**	**Baseline**	**Trigger**	**Actions**	**Trigger**	**Actions**
Source Water	Nitrite-N					
	Nitrate-N					
Entry Point	Nitrite-N		0.02	*1) Verify results.*	0.03	*1) Verify results.*
	Nitrate-N		?	*2) Evaluate cause for source change.*	?	*2) Identify affected area.*
Ave. Water Age				*3) Identify area.*		*3) Flush area.*
	Nitrite-N		0.15	*4) Flush area.*	0.25	*4) PERFORM FREE Cl BURN.*
	Nitrate-N		?	*5) Flush dead-ends.*	?	*→ Until return to normal.*
High Water Age				*→ Until return to normal.*		*Convert back to mono.*
	Nitrite-N		0.2		0.3	
	Nitrate-N		?		?	

Monoochloramine to Free Chlorine and Free Chlorine to Monochloramine Conversion

Regulatory requirements pursuant to 35 IAC 604.700(d) state that:

> Notification of a change in disinfection practices and the schedule for the changes must be made known to the public; particularly to hospitals, kidney dialysis facilities and fish breeders.

To comply with this requirement and standards of good practice, *advance* notice must be given before switching the form of disinfectant residual.

The following are procedural considerations for conversion of monochloramine to a free chlorine residual:

- The free Cl residual at the point of entry must be high enough to assure that its reaction with:
  - NH_3-N associated with the monochloramine already in the system,
  - Free NH_3-N already in the system due to monochloramine decay,
  - Nitrite-N already in the system due to nitrification,
  - nitrification and other bacteria in the system that exert chlorine demand

  … will not produce a residual near the breakpoint, where the residual could be less than the regulatory limit of either 1 mg/L combined Cl residual or 0.5 mg/L free Cl residual.

- It is preferable to simultaneously "flush-in" the free Cl residual while "flushing-out" the water with monochloramine residual; intermingling of waters having monochloramine residual and free Cl residual will likely produce unpredictable residual.

- Give special attention to water storage reservoirs. It may be necessary to manually introduce a Cl source chemical into the reservoirs to accomplish the conversion without being near breakpoint where the residual could be near zero.

- Monitor all portions of the system to assure that a strong free Cl residual is present at all locations. Additional flushing may be necessary to accomplish this objective, while simultaneously removing nitrification bacteria residue from the system.

The following are procedural considerations for conversion of free chlorine to a monochloramine residual:

- When initially switching from free Cl residual to monochloramine residual at the treatment plant, it will be necessary to over-feed the NH_3-N source chemical to deliver the right amount of "surplus" free NH_3-N to completely react with free Cl residual already in the system, in order to convert the system free Cl residual to monochloramine residual.

- It is preferable to simultaneously "flush-in" the new monochloramine residual while "flushing-out" the water with free Cl residual; intermingling of waters having monochloramine residual and free Cl residual will likely produce unpredictable residual.

- Give special attention to water storage reservoirs. It may be necessary to manually introduce a NH_3-N source chemical into the reservoirs to accomplish the conversion without being near breakpoint where the residual could be near zero.

- Monitor all portions of the system to assure that a strong monochloramine residual is present at all locations. Additional flushing may be necessary to accomplish this objective, while simultaneously removing nitrification bacteria residue from the system.

- Monitor all portions of the system, and flush as required, to assure that all free NH_3-N is removed from the system.

Agency review of Nitrification Action Plans

The Agency Field Operations Section will review the NAP for each CWS as part of the routine inspection to ensure that all the provisions of Section 604.140 (35 Ill. Adm. Code 604.140) are being met. When addressing a nitrification event, as indicated by the trigger levels previously discussed, the CWS should notify appropriate Regional Office of the Agency. Guidance for the implementation of the NAP can also be requested by contacting the Regional Office.

Monitoring Forms

Examples of monitoring report forms are included at the end of the Chapter. The examples provided are not intended as required report forms and may not include all the information necessary to assess every CWS. A CWS may develop site-specific forms to include the necessary information relevant to monitoring nitrification in their respective systems.

Raw Source Water NAP Monitoring Record

SW-1

(Does not apply to consecutive systems)

Nitrification Action Plan: ______________________________ **IL-**______________

Name of Public Water System *ID No.*

Sample location description: ____

Date	By	Total NH_3-N mg/L	Nitrite-N mg/L	Nitrate-N mg/L

(form developed by the Texas Commission of Environmental Quality)

Point of Entry NAP Monitoring Record

Tap 001

Nitrification Action Plan: ____________________________________ **IL-**________________

Name of Public Water System *ID No.*

Sample location address: ___________________________ Owner: _____________________

		Total Cl	Free Cl (a)	Mono-chloramine	Di-chloramine	Total NH_3-N	Free NH_3-N	Nitrite-N	Nitrate-N
Sample Frequency									
Goal, mg/L									
Yellow Alert Trigger, mg/L									
Action Code									
Red Alert Trigger, mg/L									
Action Code									
Date	**By**								

(a) Measure as a check.

(form developed by the Texas Commission of Environmental Quality)

Mid-System, Ave. Water Age Monitoring Record

Location MS-1

Nitrification Action Plan: ______________________________________ **IL-** ________________

Name of Public Water System *ID No.*

Sample location address: ____________________________ Owner: ______________________

		Total Cl	Free Cl (a)	Mono-chloramine	Di-Chloramine	Total NH_3-N	Free NH_3-N	Nitrite-N	Nitrate-N
Sample Frequency									
Goal, mg/L									
Yellow Alert Trigger, mg/L									
Action Code									
Red Alert Trigger, mg/L									
Action Code									
Date	**By**								

(a) Measure as a check.

(form developed by the Texas Commission of Environmental Quality)

Mid-System, Ave. Water Age Monitoring Record

Location MS-2

Nitrification Action Plan: ______________________________ **IL-**______________

Name of Public Water System *ID No.*

Sample location address: ______________________ Owner: ________________

		Total Cl	Free Cl (a)	Mono-chloramine	Di-Chloramine	Total NH_3-N	Free NH_3-N	Nitrite-N	Nitrate-N
Sample Frequency									
Goal, mg/L									
Yellow Alert Trigger, mg/L									
Action Code									
Red Alert Trigger, mg/L									
Action Code									
Date	**By**								

(a) Measure as a check.

(form developed by the Texas Commission of Environmental Quality)

Remote-System, Highest Water Age Monitoring Record

Location RS-1

Nitrification Action Plan: ______________________________________ **IL-** _______________

Name of Public Water System *ID No.*

Sample location address: ____________________________ Owner: ______________________

		Total Cl	Free Cl (a)	Mono-chloramine	Di-Chloramine	Total NH_3-N	Free NH_3-N	Nitrite-N	Nitrate-N
Sample Frequency									
Goal, mg/L									
Yellow Alert Trigger, mg/L									
Action Code									
Red Alert Trigger, mg/L									
Action Code									
Date	**By**								

(a) Measure as a check.

(form developed by the Texas Commission of Environmental Quality)

Remote-System, Highest Water Age Monitoring Record

Location RS-2

Nitrification Action Plan: ______________________________________ **IL-**________________

Name of Public Water System *ID No.*

Sample location address: _____________________________ Owner: ______________________

		Total Cl	Free Cl (a)	Mono-chloramine	Di-chloramine	Total NH_3-N	Free NH_3-N	Nitrite-N	Nitrate-N
Sample Frequency									
Goal, mg/L									
Yellow Alert Trigger, mg/L									
Action Code									
Red Alert Trigger, mg/L									
Action Code									
Date	**By**								

(a) Measure as a check.

(form developed by the Texas Commission of Environmental Quality)