In response to three deaths attributed to *Naegleria fowleri* (Nf) detected in treated distribution system water supplies, LDH issued an Emergency Rule (ER) on November 6, 2013. The ER required that systems (GW and SW) that **chloraminate** (chlorine with ammonia addition) develop and submit a **Nitrification Control Plan (NCP)** by March 1, 2014. Although the NCPs were submitted and reviewed by the LDH, approval was not a requirement. LDH provided guidance to systems during the development of plans, but the inclusion of specific criteria was not a requirement.

In March of 2016 the Final Rule was promulgated and Part XII amended, finalizing the requirements of the ER. The Final Rule requires that systems submit a NCP no later than January 1, 2017. Unlike with the NCP requirement of the ER, the NCP required by the Final Rule shall conform to the guidelines contained in industry standards such as the American Water Works Association's M56 Manual on Nitrification, and contain, at a minimum, specified monitoring. The requirements of the Final Rule with respect to the NCP are provided below.

Parameters commonly used in NCPs to monitor for or control nitrification, and their usefulness, are summarized in Table 1. Action levels recommended and/or reported in "industry standards" are presented in Table 2. Table 3 presents potential response options that can be taken at the plant, when nitrification is identified or action levels met. Likewise, Table 4 presents potential response options that can be taken in the distribution system in response a nitrification event, or when action levels are met.

In addition to the minimum specified monitoring found in the Final Rule (see below), for a NCP to meet "industry standards", and to be approvable, it will include additional monitoring, as well as action levels, and identify specific responses.

The Final Rule, NCP requirements.

LAC 51:XII §367. Disinfectant Residual Monitoring and Record Keeping

G. Where a continuous chloramination (i.e., chlorine with ammonia addition) method is used or where water that is provided to customers contains chloramines, a nitrification control plan shall be developed and submitted to the state health officer. A public water system in existence as of November 6, 2013 shall submit and comply with such a nitrification control plan no later than January 1, 2017. The plan shall conform to the guidelines contained in industry standards such as the American Water Works Association's M56 Manual on Nitrification and contain at least the following information:

1. at a minimum, the following parameters shall be monitored and recorded in accordance with the following:

    a. free ammonia at least once per week in water being delivered to the distribution system (i.e., point of entry) unless an alternate measurement or method is approved by the state health officer;

    b. nitrite at least once per quarter and in response to an action level trigger within the distribution system at sites prone to nitrification such as storage tanks and low flow areas;

2. a response plan with expected water quality ranges and action levels to control nitrification and ensure compliance with §357 of this Part.

H. Public water systems utilizing chloramination shall review and update the nitrification control plan required under Subsection G of this Section as requested by the state health officer.

1. In addition, the nitrification control plan and monitoring results shall be retained on-site for a minimum of five years and shall be made available to the state health officer upon request and/or when the public water system fails to comply with §357 of this Part.

Questions for NCP review:

1. Is a chlorine to ammonia target ratio (Cl:NH3) specified?

A Cl_2:NH_3 ratio close to **4.1:1** (NH_3 as ammonia) or **5:1** (NH_3 as nitrogen) is typically selected to minimize excess free ammonia entering the distribution system.

2. Is monitoring for chloramine optimization performed at the treatment plant?

The highest priority for monitoring at the treatment plant is 1) total chlorine, mono-chloramine, and free ammonia at the POE, and 2) free chlorine just ahead of ammonia addition. Knowing how much free ammonia is exiting the plant, and minimizing it, is perhaps the most important aspect of nitrification control. Knowing how much mono-chloramine is present with respect to total chlorine is an important indication of chloramine optimization. Total chlorine is already monitored at the POE for regulatory compliance. Monitoring for free chlorine ahead of ammonia addition is essential for determining free ammonia feed rates.

3. Does the Plan emphasize the monitoring of total chlorine and nitrite in the distribution system?

The highest priority for nitrification monitoring in the distribution system is **total chlorine** and **nitrite**. TC monitoring sites should overlap or complement existing regulatory compliance sites. The monitoring of nitrite may be based on a minimum total chlorine trigger. Additional parameters are encouraged to aid in the interpretation of data and to support conclusions.

4. Does the Plan adequately address the monitoring of low flow areas?

5. Does the Plan adequately address the monitoring of storage facilities both at the plant and in the distribution system?

> The highest priority for nitrification monitoring at storage tanks is **total chlorine** and **nitrite**. The monitoring of nitrite may be based on a minimum total chlorine trigger. Additional parameters are encouraged to aid in the interpretation of data and to support conclusions.

6. Are alert and action levels specified?

> Alert and action levels are specific to the system, can be specific to service areas, zones or even individual locations, and should be based on historic data.

7. Does the Plan address distribution system monitoring when a switch to free chlorine (i.e., burn) is made?

> The highest priority for monitoring during a burn is free chlorine. The period of time over which free chlorine residuals are to be maintained, or another target parameter, should be specified (i.e., 30 days). Free chlorine monitoring sites should overlap or complement existing regulatory compliance sites.

8. Is monitoring data archived and accessible for analysis and interpretation?

> Software programs that allow for the trending of data over time are especially beneficial to a utility that wishes to prevent nitrification rather than respond to its effects.

9. Are nitrification parameters assessed at individual locations using trend graphs?

> An assessment of water quality at individual locations in the distribution system and at storage facilities is essential for proper interpretation of data.

10. Is the monitoring plan reviewed annually so that adjustments can be made based on historical data trends, changes in water use patterns, possible changes in treatment process, or plant or distribution system operation?

> The plan should specify that date will be reviewed annually and the plan adjusted if needed. Plans that are revised shall be submitted to the District Office for review and approval.

Table 1 Usefulness of Water Quality Parameters for Nitrification Monitoring

Parameter	*Monit. Location*	*Frequency*	*Usefulness*	*Comment*
Total Chlorine (TC)	**TP/DS**	**Varies**	**VERY**	**Already required at RTCR, ACR and MRT sites for compliance. Additional samples may be appropriate.**
	SF			**Essential since nitrification generally occurs first at these locations. Outlet monitoring should be correlated to operational data at the time of sampling, such as whether or not the tank is filling or draining.**
Free Chlorine (FC)	TP	1/shift	VERY	Monitoring free Cl_2 just ahead of ammonia addition is essential for determining NH_3 dosing.
	DS/SF			Very useful during breakpoint chlorination. Not useful for routine monitoring.
Free Ammonia-N	**TP**	**1/shift @ POE[1]**	**VERY**	**At least 1/week at the POE (per LAC 51: XII §367)[2].**
				Knowing how much free ammonia is entering the distribution system, and minimizing it, is perhaps the most important aspect of nitrification control.
	DS/SF		Varies	Very useful with Cl_2 and nitrite.
Total Ammonia	TP		Useful	Used for determining chemical feed problems or to calculate the amount of free ammonia.
	DS/SF		Limited	Difficult to interpret. Used to support conclusions from the trending of other parameters.
Nitrite-N	TP		Varies	Very useful for determining background levels, and for systems using GAC or bio filters, otherwise only limited usefulness.
	DS/SF	**Weekly[1]**	**VERY**	**≥ 1/quarter AND in response to action level trigger at sites prone to nitrification such as storage tanks and low flow areas (per LAC 51: XII §367)[2].**
				Direct indicator that nitrification is occurring. Monitoring may be reduced to exclude wintertime based on historic data.
Nitrate-N	TP	Weekly	Varies	Very useful as a background or baseline, especially for groundwater systems.
	DS		Varies	Very useful if background levels are consistent; paired with nitrite sample. Cost and reporting time may be an issue.
Heterotrophic Plate Count (HPC)	DS/SF	≥ Monthly	Useful	An increase in HPC may accompany nitrification. More frequent monitoring may be warranted based on historic data. 2-day reporting time.
Adenosine Triphosphate (ATP)	DS/SF	≥ Monthly	Useful	An increase in ATP may accompany nitrification. Advantage over HPC includes real-time reporting.
Temperature	TP/DS/SF		Varies	Elevated water temperatures may be used as a warning that nitrification is more likely to occur.
pH	TP		Varies	Higher pH (around 8.2) is preferable to help maintain chloramine residual.
	DS		Useful	A reduction in pH is a possible indicator of nitrification.
Dissolved Oxygen	DS		Limited	A reduction in dissolved oxygen may accompany nitrification.

Table 1 (Cont.) Usefulness of Water Quality Parameters for Nitrification Monitoring

Parameter	*Monit. Location*	*Frequency*	*Usefulness*	*Comment*
Alkalinity/Hardness	TP	Daily	Limited	Raw & POE; useful for optimizing chemical treatment and establishing background levels.
	DS	Weekly		A reduction in total alkalinity may accompany nitrification. Monitored at low flow and problem areas, and key points that are evaluating pH issues.
TOC	TP		Useful	TOC removal at the plant improves chloramine stability in the distribution system by minimizing loss by oxidation.
	DS		Limited	
Monochloramine	TP		Useful	Monitored at the POE and compared against total chlorine to gauge efficiency and Cl2:NH3 ratio (location on the break-point curve).
	DS/SF			

Note:

[1]Recommendation
[2]Minimum requirement per LAC 51:XII §367
POE – Point-of-entry
TP – Treatment Plant
DS – Distribution System
SF – Storage Facility
VERY - Considered essential to the Nitrification Control Plan. Provides data that can be used to make a decision. These parameters are affected only or mainly by nitrification.
Useful – aids in the interpretation of data.
Limited – can support the conclusions derived from monitoring data results. These parameters may be influenced by factors other than nitrification.
Varies – usefulness varies

Table 2 Water Quality Parameter Action Levels for Nitrification Monitoring

Parameter	*Monit. Location*	*Action Level (mg/L)*	*Comment*
Total Chlorine	TP	Daily/weekly[1]	Based on CT requirements in-plant where chloramine is used for primary disinfection.
	DS	**Varies**	Set at the POE to meet distribution system requirements while maintaining regulatory compliance with maximum and minimum disinfectant levels.
			≥ 0.5 mg/l throughout at all times (per LAC 51: XII §367)[2].
			1.6 – 2.0 mg/l for transmission system (starting point for utilities with no historic data).[3]
			≥ 1.6 mg/l for distribution system pipes (starting point for utilities with no historic data).[3]
			>1.0 mg/l at the system extremities.[4]
			Action level should be set based on historic data and may be location specific.
	SF		**≥ 1.6 mg/l (starting point for utilities with no historic data).[3]**
Free Chlorine	TP	Varies	Based on CT requirements in-plant where free Cl_2 is used for primary disinfection.
			Measured just upstream of NH_3 addition (considered essential).
	DS/SF	0	During normal chloramination, > 0.0 mg/l may indicate breakpoint chlorination or a chemical feed problem.
			0.5 – 1.5 mg/l for storage facilities when break-point chlorinating.[3]
			Maintain free Cl_2 residual ≥ 1.0 in the distribution system and ≥ 2.0 in storage tanks for a minimum of 60-days.[6]
Total ammonia –N	TP/DS/SF	NA	Difficult to interpret.
Free ammonia-N	TP	0.10[3]	At POE. Varies based on desired Cl_2:NH_3 ratio. Free NH_3 decreases as the ratio increases.
	DS	NA	Triggered monitoring (i.e., when total Cl_2 and/or nitrite exceed action levels).[3]
	SF	≥0.20[3]	
Nitrite	TP	≥0.010[3]	≥ 0.010 mg/l at POE (in the case of biological filters supporting nitrification).[3]
			MCL = 1.0 MCL; annual monitoring at the POE (performed by State)
	DS	0.015	≥ 0.015 mg/l, assuming surface water source.[3]
			≥ 0.05 mg/l and falling chloramine residuals triggers breakpoint chlorination.[5]
	SF		≥ 0.015 mg/l, assuming surface water source.[3]

Table 2 (Cont.) Water Quality Parameter Action Levels for Nitrification Monitoring

Nitrate	TP		MCL = 10.0 mg/l; annual monitoring at the POE (performed by State).
			Applicable where biological filters and utilized.
	DS/SF		Background level needs to be established and taken into consideration.[3]
			Triggered monitoring (i.e., when total Cl2 and/or nitrite exceed action levels).[3]

Note:

CT = Concentration x contact time
[1]Based on population
[2]Minimum requirement per LAC 51:XII §357
[3]M56 Nitrification Prevention and Control in Drinking Water, Second Edition
[4]Recommended Standards for Waterworks, 2012 Edition
[5]EPA Distribution System Issue paper, 4601M, 2002
[6]DH recommended response to Nf amoeba detection.

Table 3 Nitrification Response Options - Treatment Plant

Response	*Comment*
Optimize Cl_2:NH3 Ratio Minimize excess free ammonia at POE	Evaluate the chlorine to ammonia ratio, and free ammonia level at the POE; ensure target Cl_2:NH_3 ratio is consistently being achieved with minimal excess free NH_3 entering the POE. Accurate chlorine and ammonia feed rates and Cl residual monitoring ahead of NH3 addition are essential.
pH Adjustment	The chloramine species generated and the rate of formation are dependent on pH. Monochloramine and its rate of formation are optimized at higher pH (>7).
Removal of Natural Organic Matter (NOM)	Reducing NOM by TOC removal through the treatment plant will minimizing chloramine decay in the distribution system, improving its stability. TOC removal can be accomplished by the addition of disinfectants and oxidants such as ozone, chlorine dioxide, and potassium permanganate.

Table 4 Nitrification Response Options - Distribution System

Response	*Comment*
Breakpoint Chlorination (Burn)	Discontinue chloramination; maintain a free chlorine residual throughout the distribution system for a set time.
Booster Chlorination (BC) Booster Chloramination (BC)	Chlorination (free) or chloramination of a specific area. Monitoring for free and total chlorine during BC is essential.
Unidirectional Flushing (UDF)	Strategic closing of valves and opening of hydrants to flush one segment of main in a SINGLE DIRECTION (UDF). Higher velocities ($\geq$ 5 fps is desirable) scour and remove sediment and deposits from water mains. Effective where nitrification is primarily due to a lack of system cleanliness.
Directional Flushing (DF)	Strategic closing of valves and opening of hydrants to flush multiple mains in a SINGLE DIRECTION (DF). Effective where nitrification is primarily due to a lack of system cleanliness. Velocities > 2.5 fps are desirable. DF is less effective than UDF.
Spot Flushing Automatic Flushing Device	Directed at reducing water age and raising disinfection residuals. Not intended to scour sediments and deposits. Velocity is typically held to < 2.5 fps. Less effective than UDF or DF.
Pigging	Pigging is more effective than flushing, but requires considerable expertise, materials, and time.
Valve Exercise Program	Helps to locate closed values and ensures looped pipelines are operating as designed.
pH adjustment	Higher pH (>8.3) favors chloramine stability, minimizes potential for ammonia release, and maximizes residuals.
Modify Dist. System Configuration/Capacity	Oversized mains and dead end lines may result in excessive water age and loss of chloramine residual. Replace oversized lines, add loops to dead-end lines, etc. Expensive.
Pipe Replacement	Heavily corroded or tubercled pipe may exert excessive chloramine demand and shield nitrifiers. Expensive.