Nitrification Action Plan (NAP) Summary

The Texas Commission on Environmental Quality (TCEQ) has information about nitrification on our web site at: www.tceq.texas.gov/drinkingwater/disinfection/nitrification.html.

The TCEQ's data for Texas public water systems (PWSs) is available at: http://dww2.tceq.texas.gov/DWW/.

This summary is intended to describe and supplement the rule requirements of Title 30, Texas Administrative Code (30 TAC) Chapter 290. In the event of any unintended discrepancy between the rule and this guidance, the rule language shall apply.

Purpose of NAP: The purpose of a Nitrification Action Plan (NAP) is to ensure that chloramine disinfection is successful by preventing and/or responding to nitrification.

NAP Sampling: The rule gives the minimum requirements. It may be necessary for PWSs to perform additional sampling to characterize the adequacy of disinfection in their distribution system.

Critical Control Conditions for Chloramination

Total Chlorine	• Total chlorine is the **sum of all active chlorine species.** It is the regulated level. • The minimum allowable total chlorine residual is 0.5 mg/L throughout the distribution. • The maximum residual disinfectant level (MRDL) for total chlorine is 4.0 mg/L based on the running annual average (RAA) of all samples collected in distribution. Maintaining a residual over the 4.0 mg/L at entry points is not a violation in and of itself. • The minimum and maximum residuals in distribution are reported on the Disinfectant Level Quarterly Operating Report (DLQOR) or the Surface Water Monthly Operating Report (SWMOR).
Mono-chloramine	• Monochloramine is the disinfecting member of the chloramine family. • Ideally, all of the total chlorine will be present as monochloramine. • Keeping track of the ratio of monochloramine to total chlorine can help alert you to possible nitrification.
Free Ammonia	• Free ammonia reacts with free chlorine to make monochloramine and other chloramines. Then, as the monochloramine decays, free ammonia is released. • Free ammonia and total ammonia may be present in source water.
Nitrite	• Nitrite is formed by ammonia-oxidizing bacteria which 'eat' ammonia. • Nitrite may be present in source water. • Nitrite has a health-based maximum contaminant level (MCL) of 1 mg/L at entry points, but is not regulated at distribution system sample sites. However, it is still a public health concern when it is over the MCL.
Nitrate	• Nitrate is formed by nitrite-oxidizing bacteria which 'eat' nitrite. • Nitrate is often present in source water, especially groundwater. • Nitrate has a MCL of 10 mg/L at entry points, but is not regulated at distribution system sample sites. However, it is still a public health concern when over the MCL.

Other process management parameters

Free Chlorine	• You are not required to measure free chlorine, except during a temporary conversion to free chlorine performed as a preventive or corrective action.
pH	• A decrease in pH can indicate nitrification. Therefore, pH measurement is recommended at systems with low alkalinity. • PWSs that use pH elevation for corrosion or nitrification control should also monitor pH in the distribution system. • Some PWSs are required to measure pH as part of the Lead and Copper Rule requirements for WQP (water quality parameter) testing.
HPC	• HPC means 'heterotrophic plate count' bacteria. • HPC can be a useful tool to measure the concentration of a broad range of bacteria. An increase in HPC can indicate nitrification. • PWSs are not required to measure HPC.

Other process management parameters	
Other indicators	*Nitrification/denitrification indicators used in wastewater treatment such as dissolved oxygen, alkalinity, oxidation-reduction potential may be useful for drinking water in future, but need further research.*

NAP Sample Sites

Sample sites must represent the distribution system and all entry points. In addition to routine NAP sample sites, additional locations will need to be sampled when taking action to identify the area where nitrification is happening.

Storage Tanks: Storage facilities can increase water age. Consider the impact of storage when determining sample sites.

Sample Sites Before and After Chemical Injection

Sources	
Groundwater	• All wells are required to have pre-disinfection sample taps representing the raw water. • If only **one well and one entry point** are present, entry point nitrite/nitrate sample results may be used to represent source water nitrite/nitrate levels. • If more than one well feeds one entry point**, nitrite, nitrate, and free ammonia sampling must be performed at each well.**
Surface water (and GUI)	• Surface water systems must monitor raw water for nitrite, nitrate, and free ammonia representing each raw water intake. • GUI is groundwater under the direct influence of surface water. GUI must meet the requirements for surface water.
Purchased Water	• For purchased water, the source sample site is usually the entry point sample site. • Systems that purchase and redistribute potable water must measure total chlorine, monochloramine, free ammonia, nitrite, and nitrate immediately after the water enters their system.

Entry Point(s)

- Entry points are defined as a point where treated water enters distribution. All entry points are required to have a representative tap.
- Entry points are numbered. You can verify this number on TCEQ's website: 'Drinking Water Watch' at http://dww2.tceq.texas.gov/DWW/.
- For the purposes of a NAP, entry point sampling is the same regardless of the water source type.

Sampling is required to make sure that the correct chlorine-to-ammonia (Cl:N) ratio exists. The Cl:N ratio is calculated from the mass of free chlorine to the mass of free-ammonia-nitrogen.

- The desired range of Cl:N is ~4:1 to 5:1.
- The range from 5:1 to 8:1 is undesirable because of di-and trichloramine formation; above 8:1 all nitrogen is lost and free chlorine is present.

PWS staff should become familiar with breakpoint chemistry. Good mixing during treatment is very important. Poor mixing can cause ineffective disinfection.

Order of addition	• When chlorine is injected upstream of any other disinfectant, the ammonia injection point must be downstream of the chlorine injection point. • When chlorine and ammonia are added to distribution water that has a chloramine residual, ammonia should be added first. • When chlorine and ammonia are added to distribution water that has a free chlorine residual, chlorine should be added first.

Entry Point(s)

Before chemical addition	• Sampling must be performed upstream of the chlorine or ammonia chemical injection point, whichever is furthest upstream. • If free ammonia is present in the source, raw water sampling should be performed weekly. • If the source is purchased potable water, total chlorine, monochloramine, and free ammonia must be monitored at least weekly and dosing should consider influent levels.
During treatment	• Chlorine must be injected before ammonia. • Sampling must be performed downstream of all the chlorine and ammonia chemical injection points.
Booster disinfection	• The free ammonia (as nitrogen) and monochloramine residuals must all be monitored if the treatment occurs in the distribution system. The monitoring must occur at the same time as a total chlorine compliance sample. • If potable water is redisinfected, the disinfectant residual must not fall below the minimum anywhere, including right before treatment. • The residual of the chemical injected upstream should be determined to properly dose the downstream chemical.

Distribution System Sample Sites

- Routine coliform and/or disinfectant residual sites may be used for NAP sample sites.
- Sites must represent the distribution system and represent average and high water age. Small systems may be adequately represented with two or three sites; medium and large systems will need to specify more sites to adequately detect and prevent potential nitrification. The rule does not specify the exact number of sample sites because of the diversity among PWSs.
- It is recommended that 'critical control points' be selected. In distribution, these may be at interconnections between major mains, storage facilities, pump stations, and interconnections with other PWSs.
- Sample sites must represent all pressure planes

Average water age	• As a first estimate, average water age can be estimated from historical data as locations with average total chlorine residual. • Enough average water age sites must be selected to represent multiple pressure planes.
High water age	• High water age may occur at the far reaches of the distribution system, in under-used areas, or as a result of storage. • Sites should represent all pressure planes.

NAP Sample Frequency

Sample Frequency: The rule lists the minimum sampling requirements. It may be necessary for PWSs to perform additional sampling to characterize their distribution system.

	At or after all **Entry Point(s)**	In the **distribution system**	Before and after any **chlorine or ammonia injection points**
Total Chlorine	Weekly.	Daily/weekly.[a]	Weekly and before and after adjusting the chlorine or ammonia feed rate.
Mono-chloramine	Weekly.	At least weekly.[b]	Weekly and before and after adjusting the chlorine or ammonia feed rate.
Free Ammonia	Weekly.	At least weekly.[b]	Weekly and before and after adjusting the chlorine or ammonia feed rate.
Nitrite and Nitrate	Monthly for six (6) months, then quarterly.	At least quarterly and in response to action triggers.	Routine sampling not required.

[a.] Total chlorine must be collected weekly or daily, based on the system size, in accordance with §290.110.
[b.] When collecting a routine sample such as a bacteriological or routine disinfectant residual sample.

Methods

The methods used must be accurate enough to measure changes that can indicate nitrification. You must document the method and/or laboratory for total chlorine on your PWS Laboratory Approval Form (Form # TCEQ-10450) attached to your Monitoring Plan. The methods and/or laboratories used for monochloramine, free ammonia, nitrite and nitrate must be documented in your NAP.

	Required Accuracy	
Total Chlorine	0.1 mg/L	• Total chlorine must be analyzed in the field. • Amperometric titration, DPD ferrous titration, or DPD colorimetric are the required methods. • Check the range of your kit. If a sample is outside range, dilute and reanalyze.
Mono-chloramine	0.15 mg/L	• Monochloramine must be analyzed in the field. • Any method approved for the drinking water matrix is acceptable.
Free Ammonia (as nitrogen)	0.1 mg/L	• Free ammonia must be analyzed in the field. • Ammonia is measured as 'free available ammonia as nitrogen.' • Check the range of your kit. The most common one pegs out at 0.55 mg/L. Samples over that level must be diluted and re-analyzed. • Any method approved for the drinking water matrix is acceptable.
Nitrite (as nitrogen)	0.01 mg/L	• Nitrite and nitrate may be analyzed in the field and/or in an accredited or approved lab. • If samples are analyzed at an outside approved lab, keep a copy of that lab's accreditation documents with your NAP.
Nitrate (as nitrogen)	0.1 mg/L	

Goals and Baselines

Goals and baselines are the normal, good levels at each point in the distribution system.

- **'Goals' are set for total chlorine, monochloramine, and free ammonia** to make sure that disinfection is maintained correctly.
- **'Baselines' are set for nitrite and nitrate**, because they come from source water, and are less under a system's control.

Initial results and historical data are used to set goals and baselines.

Ongoing, routine sampling is used to detect potential nitrification and take appropriate action.

Total chlorine and Mono-chloramine Goals	• Total chlorine and monochloramine should always be about the same, so their goals can be set at the same value. • The entry point goal should be high enough so that the maximum water age site can achieve its goal over the minimum of 0.5 mg/L plus a safety factor.
Free ammonia Goal	• Ideally, water at entry points just after treatment would have zero free ammonia residual because free ammonia is 'food' for the nitrifying bacteria. • Having a trace of free ammonia shows that the water is in the monochloramine zone. • Free ammonia naturally increases with time. The free ammonia goals in average and high water age locations should represent good, normal operating conditions.
Nitrite and nitrate Baselines	• The nitrite and nitrate baselines are the concentrations in the source water. • The nitrite and nitrate in the distribution system should always be the same as the source water. • The only thing that can change them is either nitrification, backflow or cross connection, or source water changes.

Triggers: Yellow Flag Alerts, Red Flag Alarms	
Yellow flag 'alert' triggers: Yellow flag levels are somewhat out of the norm, indicating that nitrification may have started. Some action to get back to normal is needed, but it is probably a routine type of action like flushing.	
Red flag 'alarm' triggers: Red flag levels happen when it becomes difficult to maintain a compliant total chlorine residual, and there is a strong possibility that nitrification is the culprit. If routine actions don't get the system back to normal, more intense action will be needed.	
Total chlorine	• Total chlorine is the regulated value, so most systems have more data for total chlorine than any other constituent. Therefore, PWSs should have at least a year of historical weekly or daily data to use for setting triggers. • If a nitrification event has occurred, the exact levels where nitrification took place can be used. Otherwise, yellow and red trigger levels should be estimated.
Mono-chloramine	• Ideally, 100% of the total chlorine should be present as monochloramine. • Systems may have characteristic ratios of monochloramine-to-total, for example: 80% or 90%.
Free ammonia	• Ammonia will decrease during nitrification. If ammonia is not detected, nitrification is the likely cause.
Nitrite	• Nitrite may increase or decrease during nitrification. Therefore, any significant deviation of the nitrite level could indicate nitrification. • During the initial stages of nitrification, nitrite will increase; as nitrification progresses, nitrite will drop as it is converted to nitrate.
Nitrate	• Nitrate increases when nitrification is very bad. • The only possible reasons to for nitrate to increase are: o Nitrification, o Cross-connection, backflow, or backsiphonage of sewage or fertilizer, or o Source water contamination. Any of these is a major issue.

Actions	
Note: The TCEQ provides these examples of actions for guidance only. Each PWS that uses chloramines must select actions appropriate to its unique circumstances.	
• **Normal operations:** When disinfection is going well, preventive actions are used to keep it going that way. This is the 'green zone.'	
• **Yellow flag 'alert' actions:** When your nitrification indicators hit yellow flag levels, some action is needed to get back to normal. Often these corrective actions are similar to the preventive actions, like sampling and flushing.	
• **Red flag 'alarm' actions:** When the total chlorine residual drops to low levels, nitrification may have progressed far enough that more extreme measures are needed to get back on track. If not, there may be another problem like cross-connection or treatment failure that needs attention.	
Routine Preventive Actions / Yellow Flag Alert Corrective Actions	
Sample verification	• (yellow) Before making a decision on what further action to take, it's a good idea to double-check the first measurement. • (green) It is a good idea to double-check accuracy routinely to document the variability of the analysis method.
Nitrite / nitrate sampling	• (yellow) Nitrite is a key indicator of nitrification. If chloramine-effectiveness measurements are off-spec, nitrite and nitrate sampling is necessary to determine if nitrification is happening. • (green) Although the rule only requires 6 samples to set baselines, more nitrite and nitrate data will improve your ability to respond to potential nitrification.
Determine affected area	• (yellow) Nitrification is a biological process, so it can 'bloom' in one portion of the distribution system while other areas remain okay. Determining what area is affected will allow a targeted response to effectively stop the nitrification.

Actions	
Flushing	• Flushing can bring fresh water with a strong chloramine residual to a location where disinfectant levels are decreasing. However, it is only a short-term solution because of the conservation, economic and customer relation impacts. • Every PWS is required to flush every dead-end main (DEM) each month.
Uni-directional flushing	• Unidirectional flushing (UDF) is a way of organizing flushing to achieve a velocity of 5 feet-per-second (fps) in the pipe. At 5 fps, suspended sediment is effectively removed. UDF can be used to target a problem area.
Pigging	• Pigging is the process where a cylindrical 'pig' is forced through a water main with hydraulic pressure, forcing sediment to be scraped off the walls then removed at a flush point. Pigging is best used where the system has been designed with entry and exit points for the pig. Pigging is not considered practical for old, weak pipe.
Storage tank operation	• Storage is often a cause of increased water age. Optimizing storage tank operations means selecting the best operating levels, where there is enough water for use, but not so much that it sits in the tank decaying too long.
Free chlorine conversion	• Free chlorine conversion is often called a 'burn', 'shock', or 'refresh'. When free chlorine is present, it starves nitrifying bacteria. • Although a free chlorine conversion is sometimes thought of as an extreme measure, there are numerous PWSs that perform routine, annual free chlorine conversion as a preventive measure. • Email the TCEQ at *DBP@tceq.texas.gov* 30 days before doing a free chlorine conversion.
Red Flag Corrective Actions	
Routine Actions	• The same actions (listed above) that are used for preventive maintenance and yellow-flag correction may be a part of the corrective actions used for red-flag actions.
Free chlorine conversion	• Free chlorine conversion is often used to respond to nitrification. **Contact TCEQ at 512-239-4691 or DBP@tceq.texas.gov to discuss scheduling a free chlorine conversion.**

Seek professional help for engineered modifications	
TCEQ's Plan and Technical Review Section can assist you with questions related to the process of getting approval for engineered solutions at 512-239-4691 or on the web at TCEQ Plan Review Website.	
Looping mains	• If a PWS identifies nitrification due to dead-end mains (DEMs), it may be appropriate to perform infrastructure replacement in the problem area to manage water age. • Every PWS is required to have a program to minimize stagnation of water due to DEMs.
Tank changes	• Tanks can be a source of major water age. In some cases, a PWS may choose to completely eliminate tanks or replace larger tanks with smaller ones. • Some PWSs have found mixing to be helpful in eliminating chloramine residual loss due to tank stratification. • Tanks must always have a compliant disinfectant residual.
Booster disinfection	• If the size and shape of a distribution system are very challenging, the addition of booster chloramination may be appropriate. Usually, both chlorine and ammonia injection should be at the booster station. However, if the water upstream of the booster contains free ammonia, it is possible to inject chlorine to tie up that free ammonia and form monochloramines. In that case, ammonia injection may not be needed.
pH adjustment	• Monochloramine is more stable at a higher pH. Nitrifying organisms grow more rapidly at pH 7.5 than at pH 8. For these reasons, a PWS may choose to adjust pH. If pH adjustment is used, the impact on corrosion control should be considered.

Seek professional help for engineered modifications	
Free chlorine & aeration	• Some groundwater systems with high total organic carbon have used free chlorination followed by aeration to volatize chloroform to make it possible to meet disinfection byproduct regulations with a free chlorine distribution system residual.
Chlorite feed	• Research shows that the presence of chlorite may slow or stop nitrification from developing. It will not necessarily work to stop nitrification that has already started. Chlorite is a regulated disinfection byproduct of chlorine dioxide. A system considering a chlorite feed should be prepared to perform chlorite sampling in distribution.
Other solutions?	*Research continues on nitrification. Some new methods may be snake oil, but others may turn out to be successful. Use professional development opportunities to learn about new technology.*

This is a template for starting a NAP. It is provided for guidance; a PWS must develop a site-specific NAP and map.

Example: Nitrification Action Plan Template
Chloramine-Effectiveness Sample Suite

Site	Chemical	Goal	Yellow Flag		Red Flag	
			Trigger	Actions	Trigger	Actions
Entry Point	Total / Mono	___ mg/L	___ mg/L		___ mg/L	
	Ammonia	___ mg/L	___ mg/L		___ mg/L	
Average water age	Total / Mono	___ mg/L	___ mg/L		___ mg/L	
	Ammonia	___ mg/L	___ mg/L		___ mg/L	
High water age	Total / Mono	___ mg/L	___ mg/L		___ mg/L	
	Ammonia	___ mg/L	___ mg/L		___ mg/L	

Nitrite/Nitrate

Site	Chemical	Baseline	Yellow Flag		Red Flag	
			Trigger	Actions	Trigger	Actions
Entry Point	Nitrite	___ mg/L	___ mg/L		___ mg/L	
	Nitrate	___ mg/L	___ mg/L		___ mg/L	
Source water(s)	Nitrite	___ mg/L	___ mg/L		___ mg/L	
	Nitrate	___ mg/L	___ mg/L		___ mg/L	
Blended water	Nitrite	___ mg/L	___ mg/L		___ mg/L	
	Nitrate	___ mg/L	___ mg/L		___ mg/L	