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Nitrification (M68 Chapter 6)

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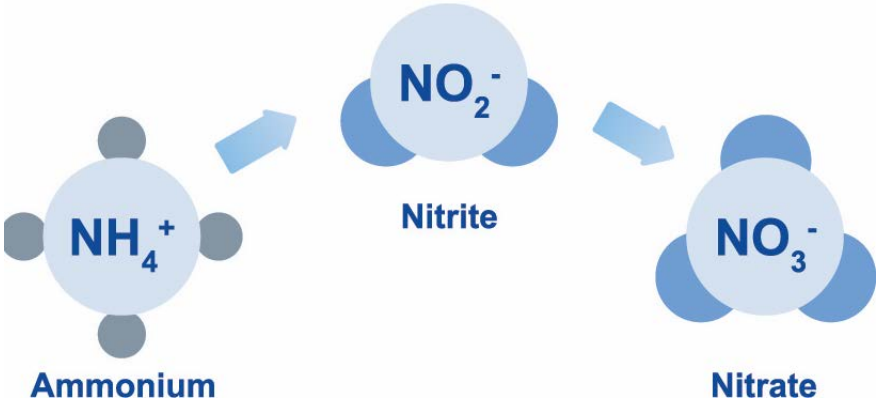
Outline

- What is nitrification?
- Causes of distribution system nitrification
- Indicators of nitrifications
- Responses to control nitrification
- Nitrification monitoring and control plan

- Case study

Nitrification

- Two-step aerobic, biological process



- Nitrifying bacteria
  - Ammonia oxidizing bacteria (AOB)
  - Nitrite oxidizing bacteria (NOB)
- Where does ammonia come from?

Chloramines

- Utilities that use chloramines as a secondary disinfectant (AWWA, 2005):
  - 30% +
  - 8-12% contemplating conversion in future

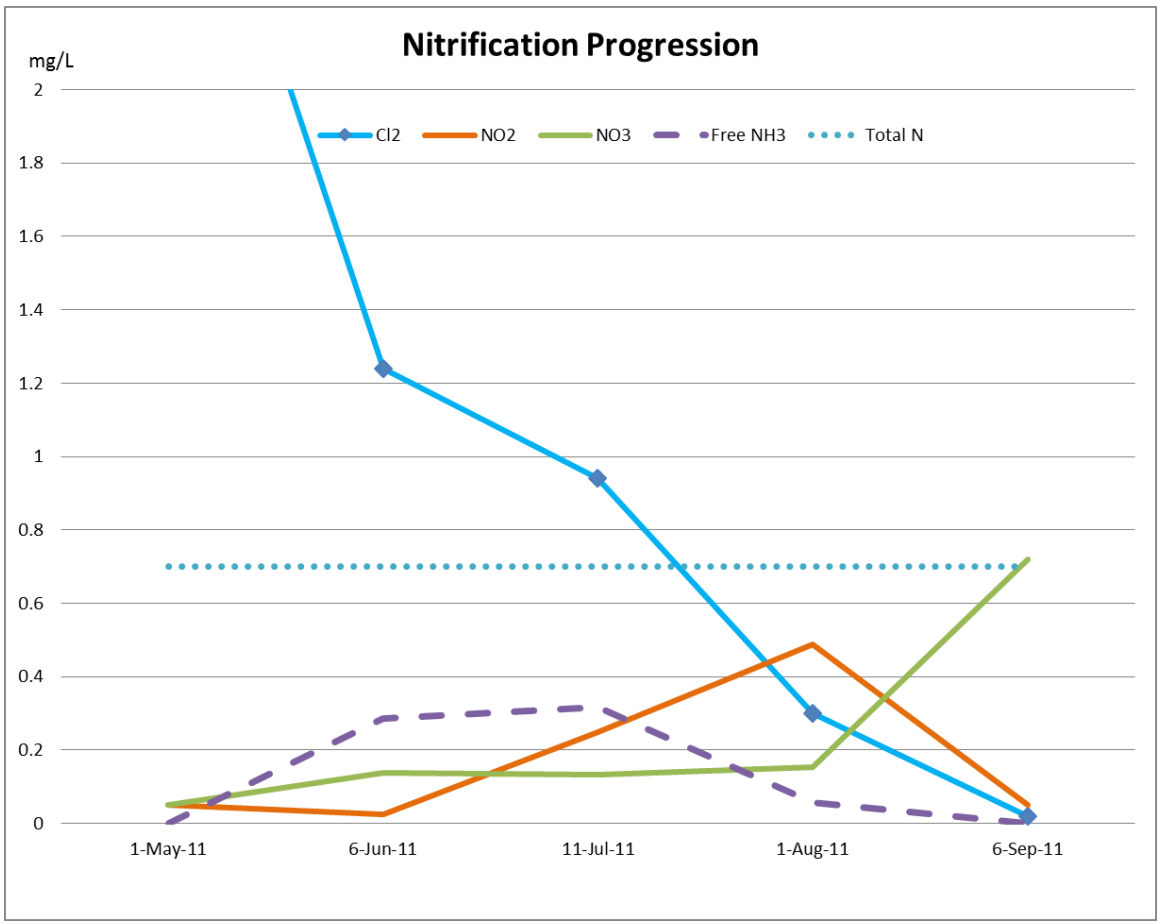
$$HOCl + NH_3 \leftrightarrow \underset{\text{monochloramine}}{NH_2Cl} + H_2O$$

  - Chloramines decay in the distribution system which releases free ammonia
- Free ammonia can also be present in source waters (both groundwater and surface water)

Causes of Nitrification

- Presence of free ammonia
- Low Cl:N mass ratio
- High water age
- Insufficient chlorine residual
  - pH, total organic carbon, bromide, etc.
- Warm temperature

Examples of Nitrification



Examples of Nitrification

Consecutive System, LA

Parameters (during site investigations on 9/26/16)	Fill Cycle (water entering tank)	Drain Cycle (water exiting tank)
Total chlorine (mg/L)	2.04	0.4
Monochloramine (mg/L)	1.47	**0.07**
Free ammonia (mg/L as N)	0.40	0.26
Nitrite (mg/L as N)	0.047	**0.271**

Indicators of Nitrification

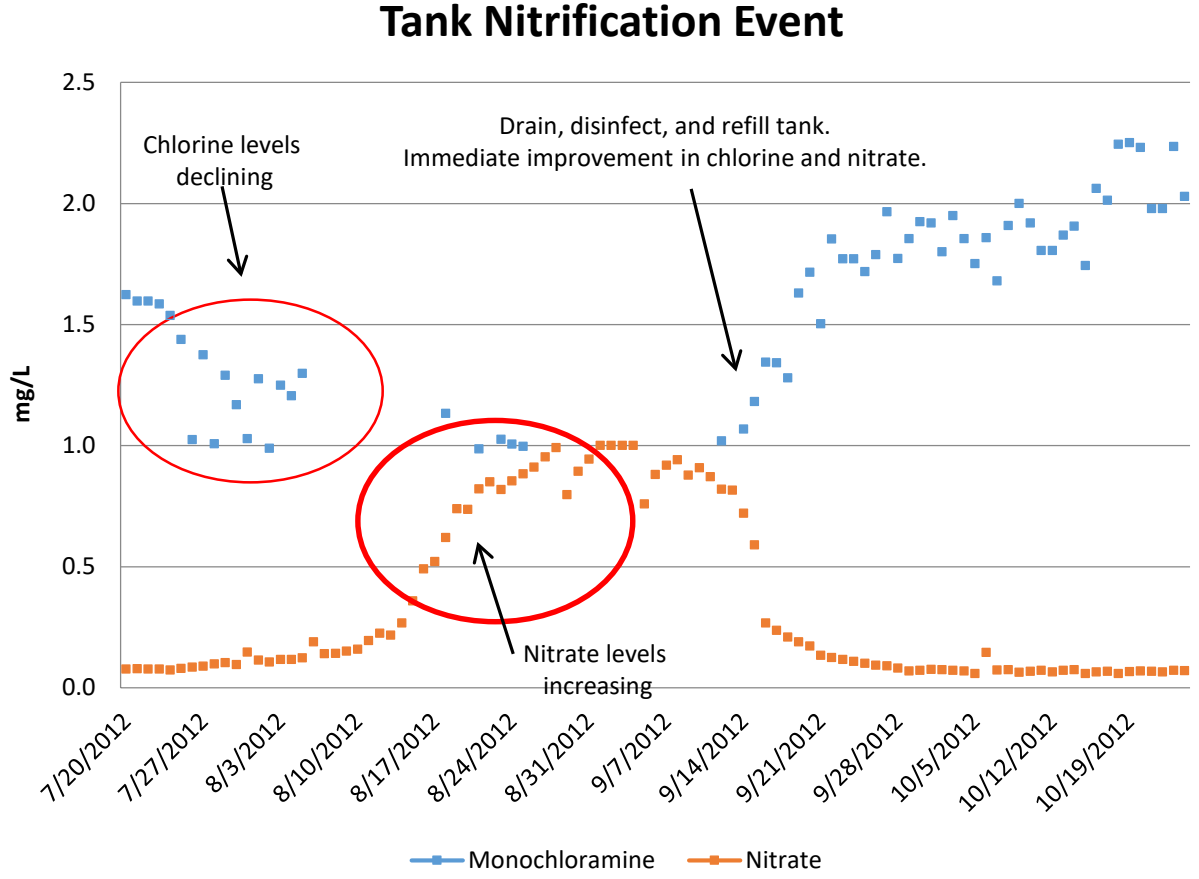
- Increase in nitrite and/ or nitrate
- Decrease in chloramine residual
- Change in free ammonia
- HPC increase
- Decrease in DO
- Decrease in alkalinity
- Increase in corrossivity

Responses to Control Nitrification

- Localized flushing
- Drain and disinfect impacted storage tanks
- Temporary conversion to free chlorine

- System specific evaluation is needed to develop appropriate response plan

Responses to Control Nitrification



Nitrification Monitoring and Control Plan

- Provides early indication of worsening distribution system water quality
- Allows adoption of proactive measures which are less resource intensive than reactive measures
- Regulatory requirement in several states

Nitrification Monitoring and Control Plan

- Objectives
- System details
- Monitoring plan
- Data analyses
- Benchmarks and action plans
- Response strategies
- Prevention strategies

Nitrification Monitoring (M56 Chapter 7)

At WTP:

Table 7-2 Usefulness of water quality parameters at a treatment plant for nitrification monitoring

Parameter/Usefulness		
Very Useful	Useful	Limited Usefulness
Free chlorine	TOC	Hardness
Total chlorine	Chloramine decay	Alkalinity
Free ammonia-N		Nitrate-N[1]
pH		Nitrite-N[2]
Temperature		Total ammonia-N

In Distribution System:

Table 7-3 Usefulness of water quality parameters for distribution system nitrification monitoring

Parameter/Usefulness		
Very Useful	Useful	Limited Usefulness
Total chlorine	Nitrate-N[2]	Dissolved oxygen
Nitrite-N	Total ammonia-N	TOC
Free ammonia-N	HPC-R2A	Hardness
Temperature	pH	Alkalinity
Free chlorine[3]		AOB[4]

Note: AOB, ammonia oxidizing bacteria; TOC, total organic carbon.

Goals, Alert Levels, Action Levels

System specific levels need to be determined
Example from one utility

Parameters	Goal	Alert Level	Action Level
Total Chlorine	>1.5 mg/L	<1.0 mg/L	**<0.3 mg/L**
Nitrite-N	<10 ug/L	>25 ug/L	**>100 ug/L**
Free ammonia-N	<0.1 mg/L	>0.1 mg/L	**>0.3 mg/L**
Temperature	monitor	>59oF	**NA**
Optional Parameters	Goal	Alert Level	**Action Level**
Nitrate-N	NA	Increase of 0.3 mg/L	**NA**
HPC (R2A)	<500 cfu/mL	>500 cfu/mL	**NA**
pH	**7.3**	**Decrease in 0.2 units**	**NA**

Nitrification Prevention Strategies

- Control chlorine: ammonia-nitrogen mass ratio
- Minimize free ammonia leaving the WTP
- Maintain sufficient monochloramine residuals
- Provide good corrosion control
- Routinely clean storage facilities and distribution system piping
  - E.g. spot flushing in problem areas, UDF system-wide
- Minimize water age
- Develop and execute a nitrification monitoring and control plan

Recommended Practices for Nitrification Control

Planning

Best Practices for Nitrification Control	Level
Prepare a nitrification control plan that includes both response and prevention actions, review and update plan annually	Basic
Develop budget cost estimates and prepare capital projects as needed to support the above best practices	Advanced

Recommended Practices for Nitrification Control

Monitoring/ Detection

Best Practices for Nitrification Control	Level
Develop and implement a nitrification monitoring plan	Basic
Monitor key parameters at TCR/DBP sites (nitrite, nitrate, ammonia, chloramine)	Basic
Monitor storage tank inlet and outlet water quality	Basic
Monitor source water quality for nitrification related parameters	Basic
Identify critical control points representing: • Fresh water: from WTP or wholesale supplier • Average water age • High water age: storage tanks, far reaches, low-usage areas	 Basic Basic Basic
Monitor additional indicator parameters to find nitrification (alkalinity, pH, DO, etc.)	Advanced
Perform a chloramine decay study	Advanced

Recommended Practices for Nitrification Control

O&M at WTP

Best Practices for Nitrification Control	Level
Control the chlorine to ammonia-nitrogen ratio between 4.5 and 5:1 in the finished water leaving the water treatment plant (or request an upstream supplier to do so). If possible, control between 4.75 and 5:1	Basic
	Basic
Maintain sufficient monochloramine residuals: • >2.0 mg Cl_2/L leaving the treatment plant • >0.5 mg Cl_2/L in the distribution system, preferably >1.5 mg Cl_2/L	Basic Basic
Consider seasonal adjustment of chloramine residual (higher residual in nitrification season)	Advanced
Provide good corrosion control	Basic

Recommended Practices for Nitrification Control

O&M in Distribution System

Best Practices for Nitrification Control	Level
Routinely clean storage facilities and distribution system piping	Basic
Practice spot or automatic flushing of problem areas	Basic
Practice systematic (unidirectional) distribution system flushing	Advanced
Monitor storage tanks for stratification	Advanced
Perform hydraulic study of distribution system and storage tanks	Advanced
Minimize distribution system water age • Eliminate dead ends and low flow areas	Basic/Advanced
Minimize storage facility water age: • Maximize storage facility turnover and cycling • Maximize hydraulic mixing • Optimize storage volume	Basic Advanced Advanced

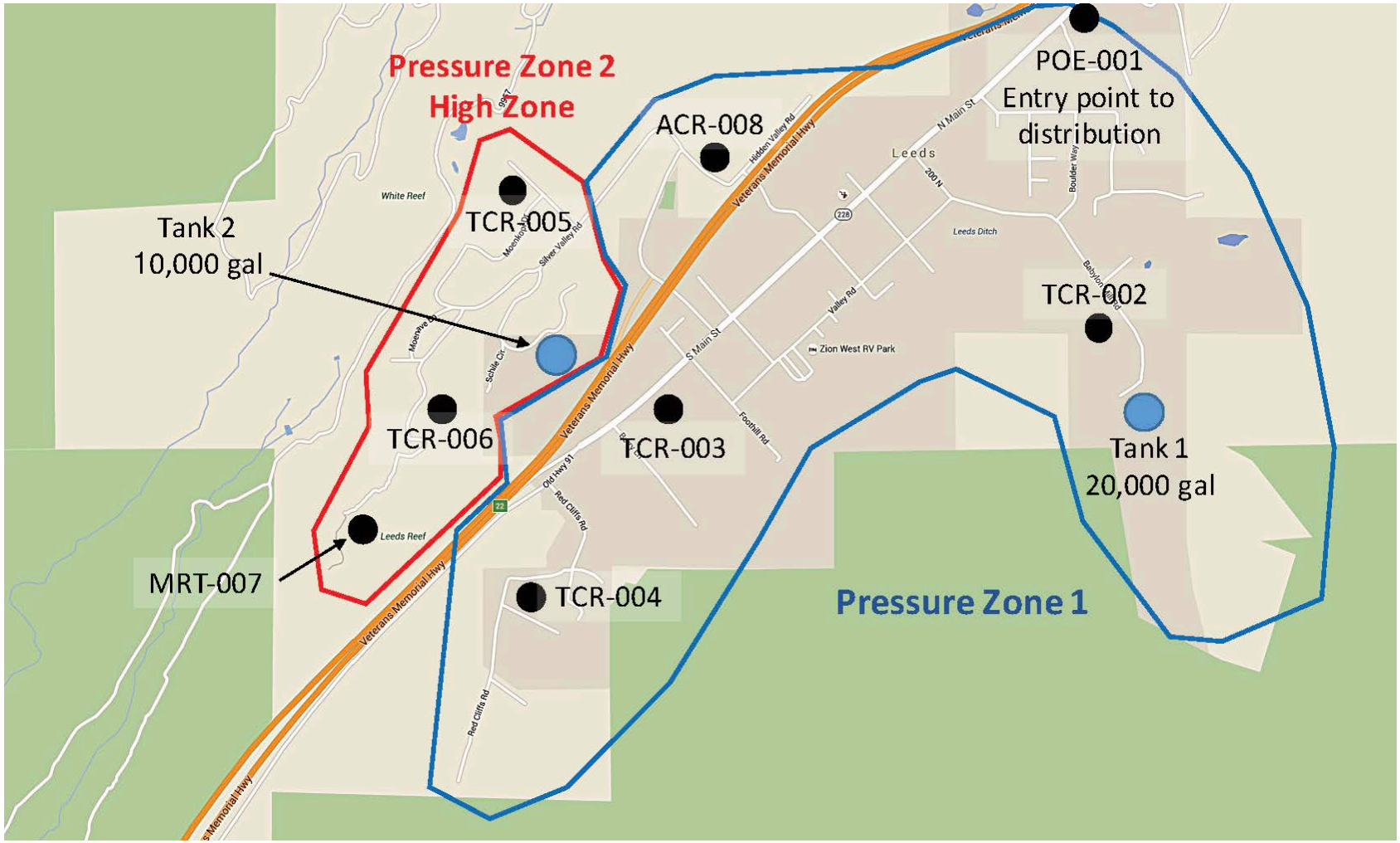
Recommended Practices for Nitrification Control

Responses to Nitrification

Best Practices for Nitrification Control	Level
Perform localized flushing	Basic
Drain, disinfect, and clean affected storage tanks	Basic
Develop a free chlorination strategy for temporary conversion to free chlorine and evaluate its effectiveness by monitoring for return of nitrification; free chlorination may be localized or system wide	Basic/Advanced

Nitrification Case Study

Small Water System, UT



System information

- Consecutive system
- Surface water
- Chloraminated
- Population of 1,201
- 2 pressure zones (low, high)
- Flushing for customer complaints or low residuals

System information

- Leaving the wholesalers treatment plant:
  - Target ratio chlorine to ammonia is 4.5:1
  - Target residual is 2.5 mg/L Oct. through May
  - Target residual is 3.5 mg/L June through Sept.

System information

Tank 1

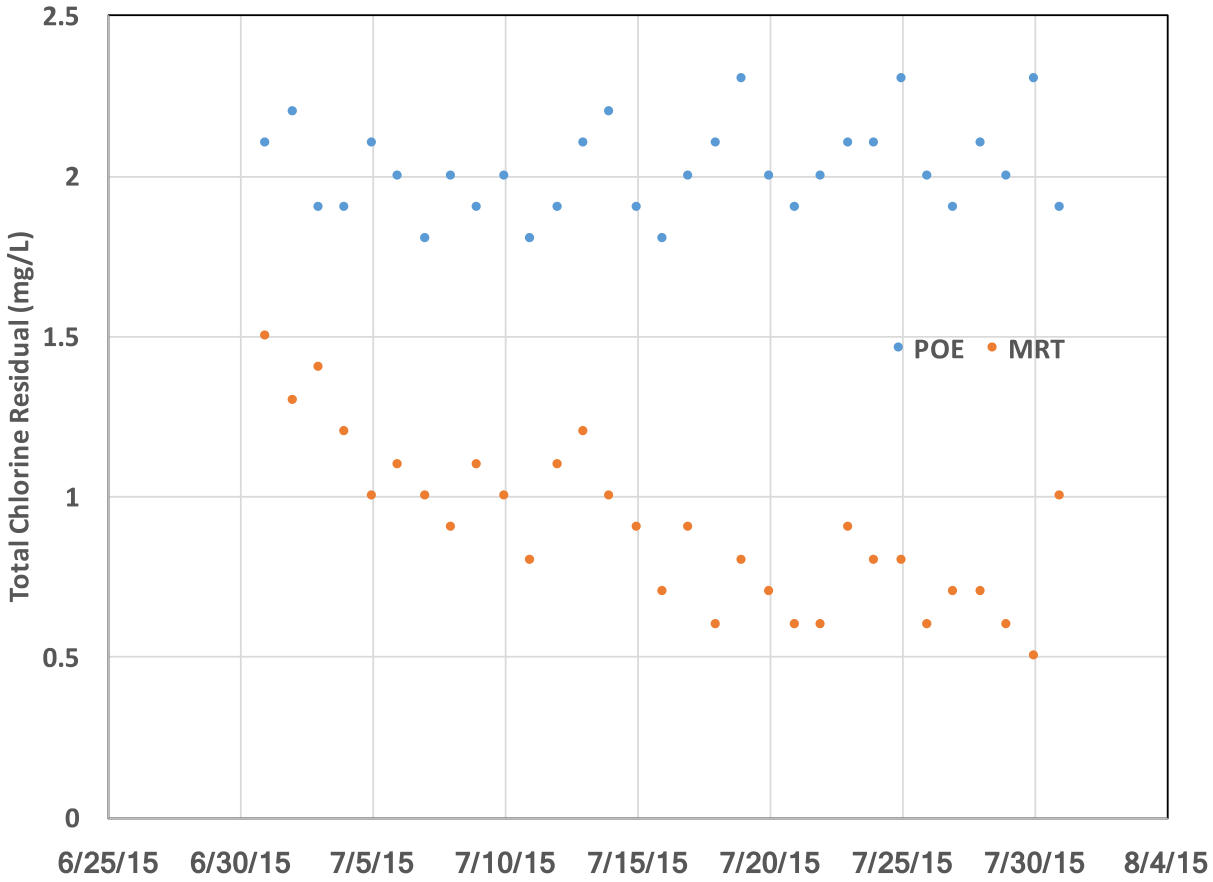
- In low pressure zone
- 20 kgal, gravity fed
- Common inlet and outlet
- Average turnover 30% each day
- Last cleaned in 2014

System information

Tank2

- In the high pressure zone
- 10kgal, gravity fed
- Common inlet and outlet
- Standpipe
- Average turnover 8%
- Last cleaned in 1983

Chlorine Residual Loss



Sample Data

	POE-001			MRT-007		TCR-002	TCR-005
	Total Cl	Total ammonia	Free ammonia	Total Cl	Nitrite	Total Cl	Total Cl
Date sampled	mg/L	as N mg/L	as N mg/L	mg/L	mg/L	mg/L	mg/L
7/1/15	2.1			1.5			
7/4/15	1.9			1.2			
7/8/15	2	0.7	0.3	0.9	0.04	1.8	
7/15/15	1.9	0.6	0.4	0.9		1.6	0.7
7/22/15	2	0.7	0.3	0.6		1.7	0.4
7/29/15	2	0.7	0.4	0.6		1.5	0.5

Questions

- What is the chlorine: ammonia ratio coming in to the system?
- Is nitrification system-wide, or local?
  - Can you identify a likely source of water quality degradation?
- What would you do to address nitrification here?
  - Do you need additional monitoring or data?
  - Response measures?

More Data

Date sampled	POE-001			MRT-007		TCR-002	TCR-005
	Total Cl	Total ammonia	Free ammonia	Total Cl	Nitrite	Total Cl	Total Cl
	mg/L	as N mg/L	as N mg/L	mg/L	mg/L	mg/L	mg/L
7/1/15	2.1			1.5			
7/4/15	1.9			1.2			
7/8/15	2	0.7	0.3	0.9	0.04	1.8	
7/15/15	1.9	0.6	0.4	0.9	0.07	1.6	0.7
7/22/15	2	0.7	0.3	0.6	0.11	1.7	0.4
7/29/15	2	0.7	0.4	0.6	0.18	1.5	0.5

Questions?

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