Optimizing Nutrient Reduction in Small Wastewater Treatment Plants

USEPA Webinar Series
for
Small Wastewater Treatment Plants
December 11, 2019

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The Plan

- The Three Environments
- What goes wrong
- Troubleshooting systems
- Case studies
- Questions and Comments

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The Basics of BNR

Biological Nutrient Removal
2 Processes
Biological Nitrogen Removal
- **Denitrification**
- **Nitrogen Gas leaves the System**

Biological Phosphorus Removal
- **Orthophosphate is taken up by Phosphorus Accumulating Organisms (PAOs)**
- **PAOs are wasted from the System**

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The Basics of BNR

2 Zones for Biological Phosphorus Removal

Anaerobic Zone
Oxic Zone

Each zone requires an environment that will get the bacteria to do a specific job.

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The Basics of BNR

2 Zones for Biological Nitrogen Removal

Anoxic Zone
Oxic Zone

Each zone requires an environment that will get the bacteria to do a specific job.

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The Basics of BNR

3 Zones for Biological Nutrient Removal:

Anaerobic Zone
Anoxic Zone
Oxic Zone

Each zone requires proper environments that will get the bacteria to do a specific job.

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The Basics of BNR

The Anaerobic Zone:

1. Relatively small volume
2. Mixed without diffused air (mechanical mixer)
3. Combines influent wastewater with RAS
4. Needs **Soluble Carbon** to drive the reaction

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The Basics of BNR

The Anaerobic environment

1. No dissolved oxygen
2. No nitrate
3. Low energy mixing

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The Basics of BNR

The Anoxic Zone:

1. Larger volume
2. Mixed without diffused air (mechanical mixer)
3. Combines influent wastewater with nitrified mixed liquor (or RAS) from the Oxic tank

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The Basics of BNR

The Anoxic Environment

1. No dissolved oxygen
2. Nitrate Available (i.e., Combined Oxygen, NO_3-N)
3. Low Energy Mixing
4. Needs **Soluble Carbon** to drive the reaction

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The Basics of BNR

The Oxic Zone:

The Oxic Environment

1. Dissolved oxygen present
2. $cBOD_5$ is converted into bacteria and CO_2
3. Ammonia converted to Nitrate
4. Ortho P released in Anaerobic zone is taken up, and more

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The Basics of BNR

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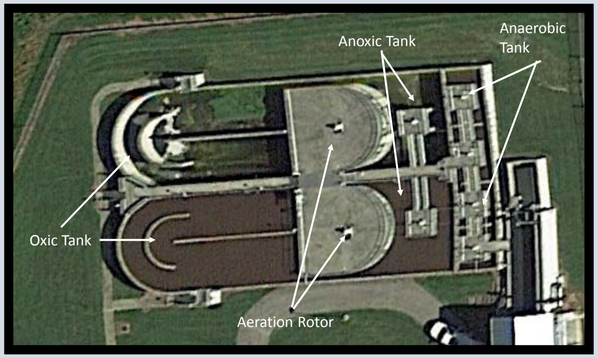
The Basics of BNR



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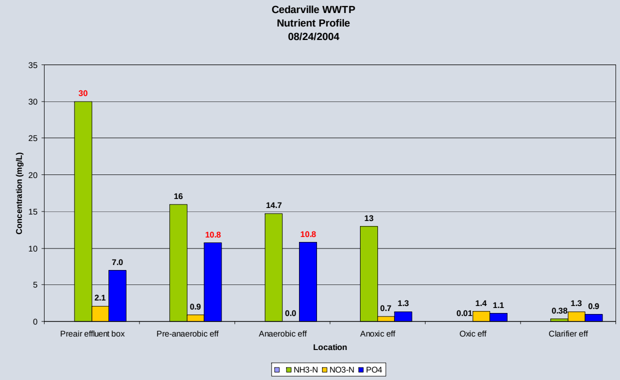
Troubleshooting Systems



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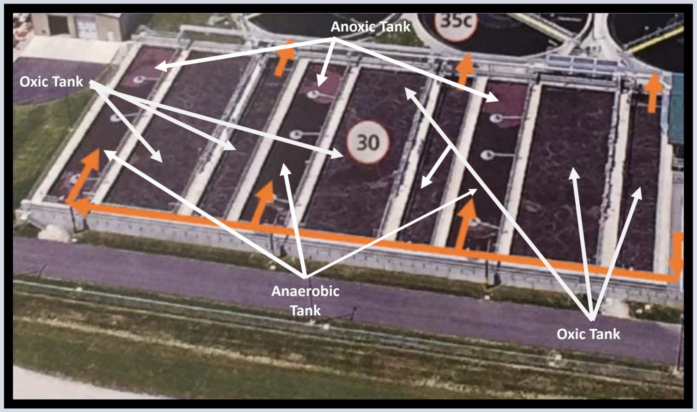
The Basics of BNR



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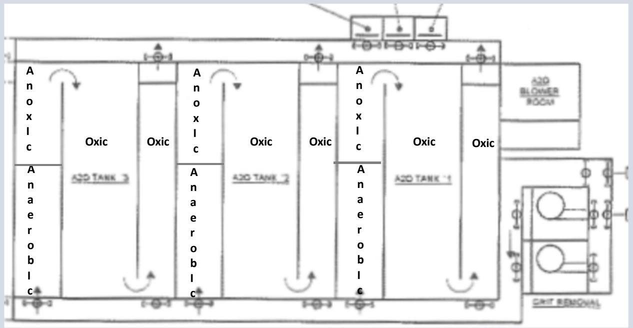
The Basics of BNR



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What goes wrong…

Permit Limits change, and the WWTP doesn't

Nutrients in the natural waters are causing problems

WWTPs are easy to regulate

So, **Nutrient limits for WWTPs are tightening….**

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What Goes Wrong

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What Goes Wrong

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What goes wrong…

Nutrient Control:

Cyanobacteria utilize nitrogen and phosphorus

Tend to flourish when water is warm and nutrients are plentiful

Produce liver toxins, neurotoxins and dermatoxins in the water column

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What goes wrong…

One town's downstream is the next town's upstream

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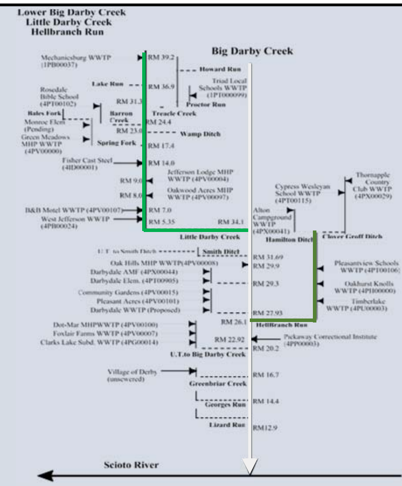

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What goes wrong…

Permit Limits change, and the WWTP doesn't

Land Application of Treated Wastewater Rules Implemented 2014

- WWTPs encouraged to avoid discharging to Waters of the State
- Eased limits since they discharged to impoundments
- WWTPs not designed to meet 10 mg/L TIN in effluent

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What goes wrong…

Effluent limits tighten statewide

Tighter TP limits for some dischargers to Ohio River Basin

Nitrate limits on the horizon?

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What goes wrong…

Design is important

But often design is by the book (and bacteria can't read)

Inattention to influent waste streams will create havoc with BNR

Especially influents with weak organic loadings

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What goes wrong…

Disconnect between design and operation

Design is important
But when design doesn't include operational flexibility,
the hands of the operator are tied

(operators don't get to chose what comes down the pipe)

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Troubleshooting Systems

Process Control is **essential**

- Check the chemical trails that the biology leaves behind
- Field test equipment
- Grab samples, sometimes lots of grab samples
- Cheap, easy, and effective

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Troubleshooting Systems

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Toubleshooting Systems

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Troubleshooting Systems

If the conditions are right, the bacteria will perform

Ammonia, nitrate, and orthophosphate in the inputs to the tanks

Ammonia, nitrate, and orthophosphate in the outputs from the tanks

Measure, don't guess…

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Manufacturing Facility Wastewater Treatment Plant

- Design
  - 1500 gallons per day
  - 6000 gallons per day rate (peak hourly flow capacity)
- Influent Characteristic
  - Ammonia: 121 mg/L
  - $cBOD_5$: 517 mg/L
- All Sanitary Waste
  - Full first shift, small second shift, maintenance on third shift.

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Spray Irrigation Field

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Manufacturing Facility Wastewater Treatment Plant

Sample ID: **Effluent**

Lab Sample # **MP11-17377-01**

The Fecal was analyzed at our Mansfield facility.

Analyte	Results	Units	PQL	Method	Analyst	Extraction Date	Analysis Date/Time
Ammonia-N	0.16	mg/L	0.05	EPA 350.1	TLL		09/26/2011 15:12
Carbonaceous BOD	4.7	mg/L	4.0	SM-5210 B	TLL		09/21/2011 18:00
	Estimate; lab control standard exceeded method limits.						
Nitrite-N	0.98	mg/L	0.05	EPA-353.2/ SM4500NO3	TLL		09/21/2011 17:45
Nitrogen, Total Inorganic	9.65	mg/L	0.20	Calculation	RCM		10/04/2011 15:00
Nitrate/Nitrite-N	9.49	mg/L	0.50	EPA-353.2/ SM4500NO3	TLL		09/27/2011 13:14
Nitrate-N	8.51	mg/L	0.100	EPA-353.2/ SM4500NO3	RCM		10/04/2011 15:00
Total Suspended Solids	27	mg/L	1.0	SM-2540 D	TLL		09/23/2011 16:45
E.Coli	<1.00	MPN/100 mL	1.00	SM 9223B	GLM		09/21/2011 15:10
Total Coliform	1.00	MPN/100 mL	1.00	SM 9223B	GLM		09/21/2011 15:10
Fecal Coliform	<9.0	per 100mL	9.0	SM-9222D	MC		09/20/2001 16:35

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Flow Equalization Tank converted into Anoxic Tank

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Flow Equalization / Anoxic Tank

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Aeration Tank

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Aeration Tank Baffle Installed to Prevent Short Circuiting from Splitter Box to Clarifier

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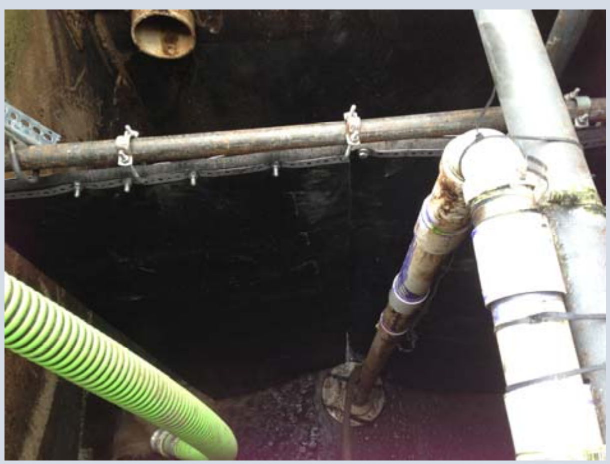
Aeration Tank Baffle and Geyser Pump for Nitrate Recycle to Anoxic Tank



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?

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Glycerin Feed to Supplement Organic Loading of Anoxic Tank

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Case Study: Firestone Trace WWTP

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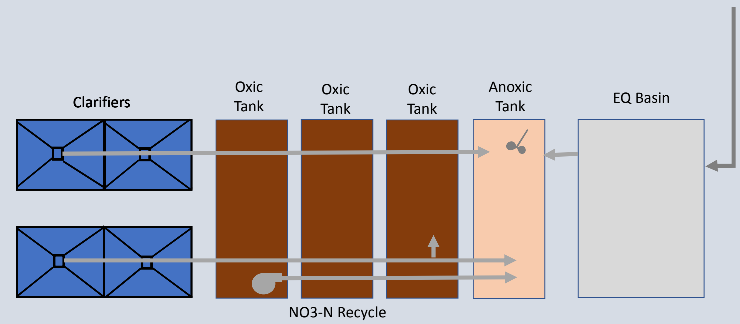
Case Study: Firestone Trace WWTP



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Firestone Trace WWTP

We found:

Everything was running full throttle!

Nitrates are high (anoxic and effluent)
- Turn the Nitrate Recycle Pump down to 15 min ON, 45 min OFF (96 pin timer!)

Influent COD is low

Aeration tanks are very aerobic (NH_3-N ~ 0.00 mg/L)

Expand the Anoxic Tank?

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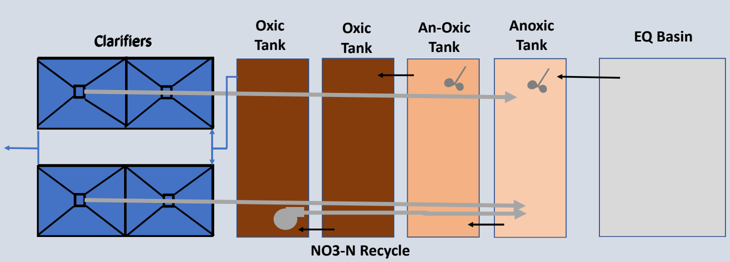
Troubleshooting Systems



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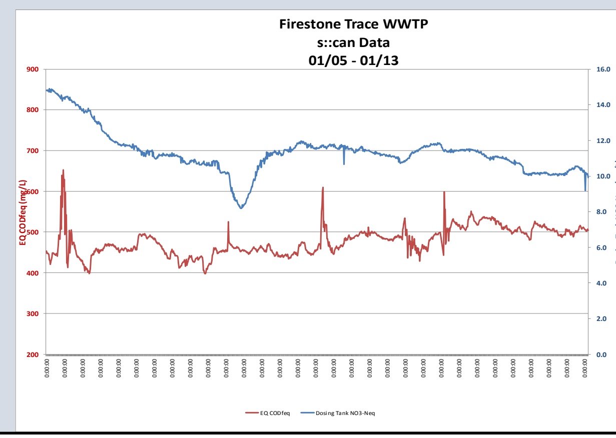

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Firestone Trace WWTP

Continued to run with two anoxic tanks for through the summer of 2011

Flirted with Noncompliance for TIN all summer

Pretty certain that carbon was the limiting factor

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Firestone Trace WWTP

9/12/2011

A 55 gallon drum of Glycerin began to drip into the Anoxic Tank

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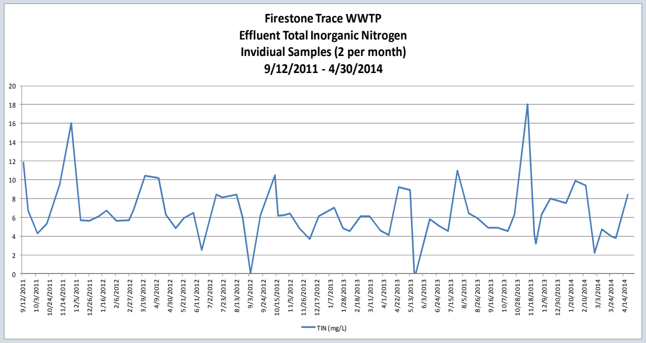

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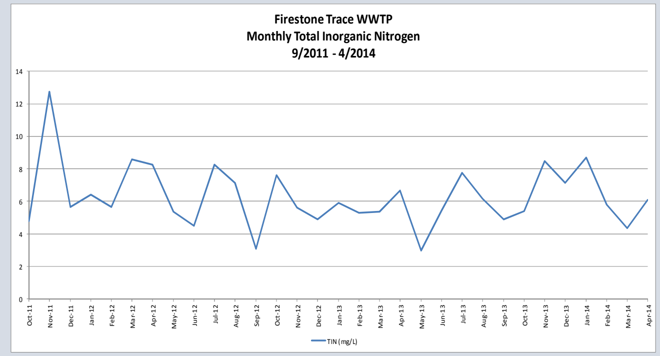

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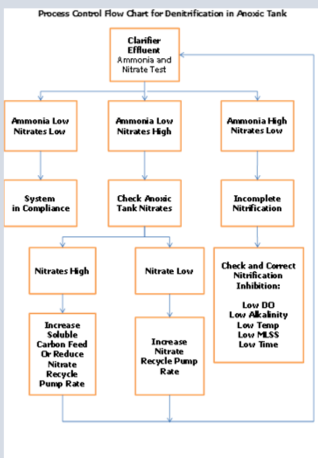

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Firestone Trace WWTP

Optimize Anoxic Zone

- Control Nitrate Recycle
- Control Soluble Carbon
- Process Control:
  - Anoxic Tank NH3-N and NO3-N
  - Aeration Tank NH3-N and NO3-N

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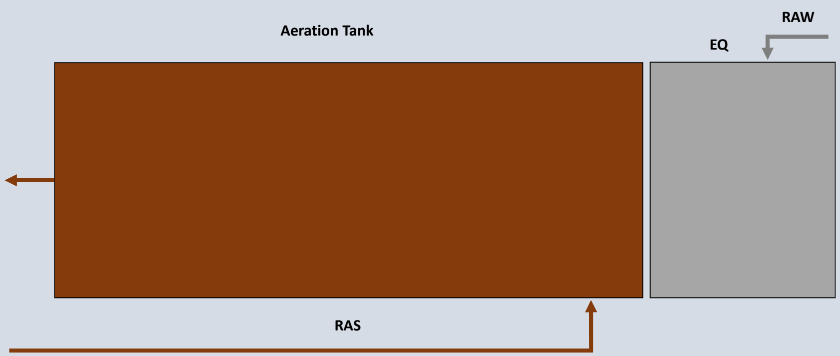
Case Study: Scioto Reserve WWTP



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Scioto Reserve WWTP

0.423 MDG Design Flow

Operates at 50 % design flow at 100+% of online capacity

Land applies treated wastewater to an impoundment for golf course irrigation

In 2012, rules for land application change and implementation of tight limits begins

Effluent limits required 10 mg/L TIN by April 2014

Scioto Reserve WWTP original design does not provide for denitrification

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Scioto Reserve WWTP

Initially, tried to ON/OFF blower operation to denitrify in the aeration tanks

Occasionally TIN would be within permit, but no consistency, no room for safety

December 2013: Drastic measures

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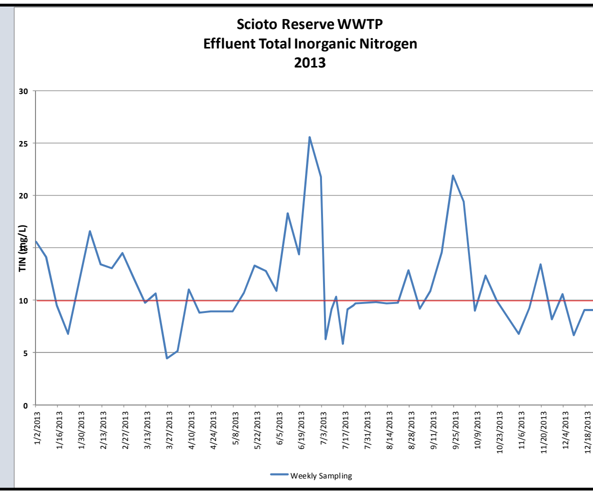

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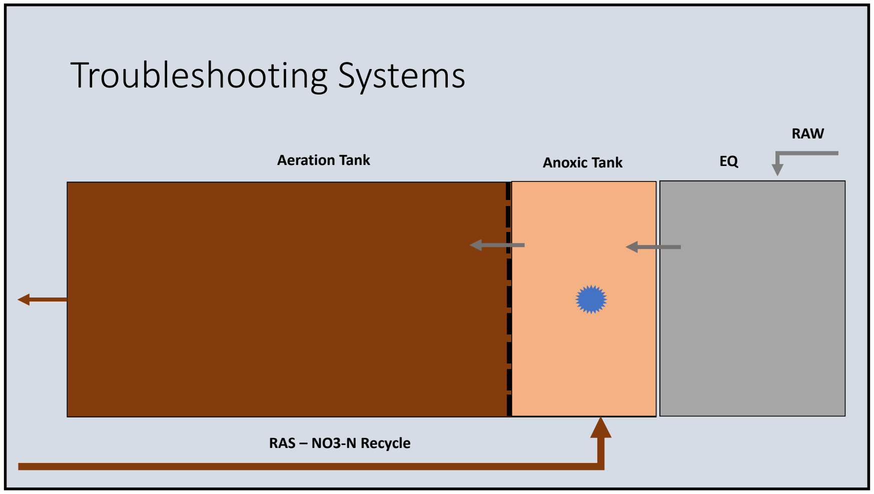
Troubleshooting Systems
RAW
Aeration Tank
Anoxic Tank
EQ
RAS – NO3-N Recycle

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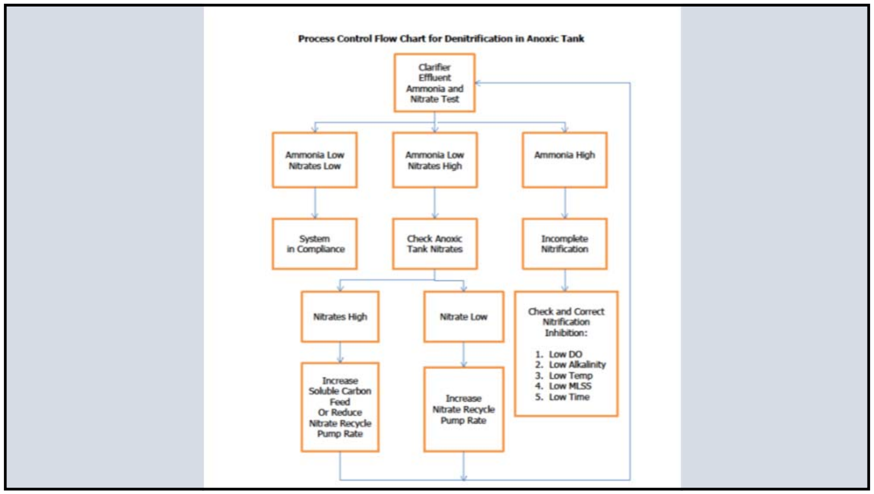
Process Control Flow Chart for Denitrification in Anoxic Tank
Clarifier Effluent Ammonia and Nitrate Test
Ammonia Low Nitrates Low
Ammonia Low Nitrates High
Ammonia High
System in Compliance
Check Anoxic Tank Nitrates
Incomplete Nitrification
Nitrates High
Nitrate Low
Check and Correct Nitrification Inhibition:
1. Low DO
2. Low Alkalinity
3. Low Temp
4. Low MLSS
5. Low Time
Increase Soluble Carbon Feed Or Reduce Nitrate Recycle Pump Rate
Increase Nitrate Recycle Pump Rate

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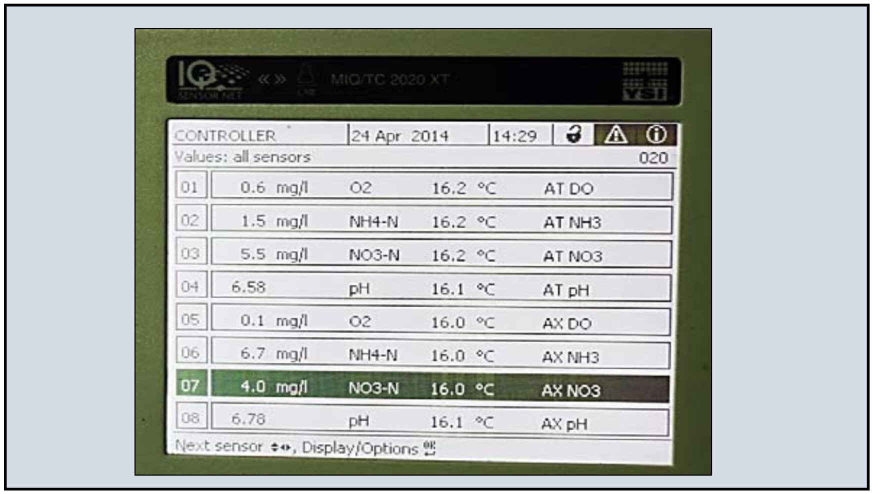
CONTROLLER
24 Apr 2014
14:29
Values: all sensors
020
01 0.6 mg/l O2 16.2 °C AT DO
02 1.5 mg/l NH4-N 16.2 °C AT NH3
03 5.5 mg/l NO3-N 16.2 °C AT NO3
04 6.58 pH 16.1 °C AT pH
05 0.1 mg/l O2 16.0 °C AX DO
06 6.7 mg/l NH4-N 16.0 °C AX NH3
07 4.0 mg/l NO3-N 16.0 °C AX NO3
08 6.78 pH 16.1 °C AX pH
Next sensor, Display/Options

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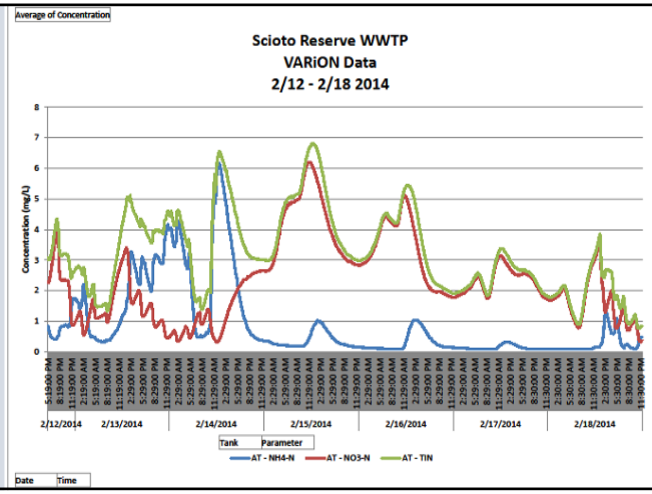

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Scioto Reserve WWTP

- 1) created a mixed Anoxic Zone
- 2) relied on RAS for nitrate recycle
- 3) relied on raw wastewater for carbon source
- 4) Ran blowers ON/OFF during the week
- 5) Ran full aeration during the weekend
- **TIN < 10 mg/L**

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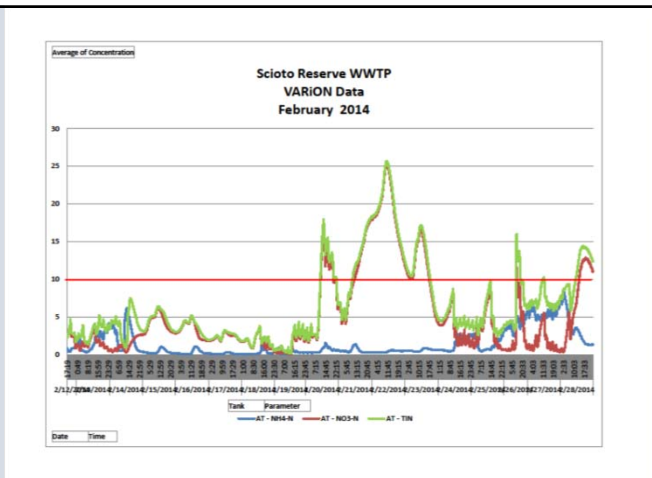

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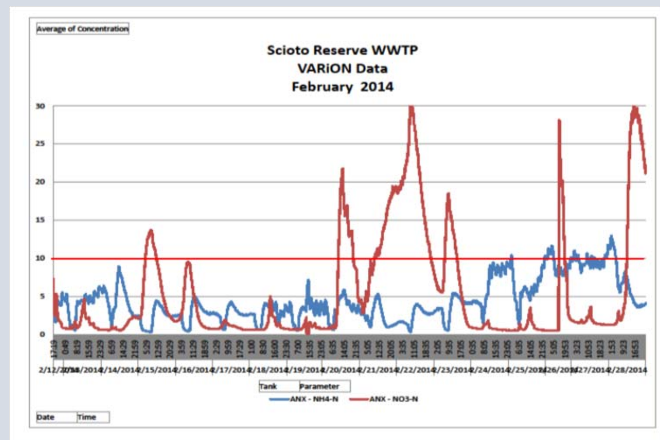

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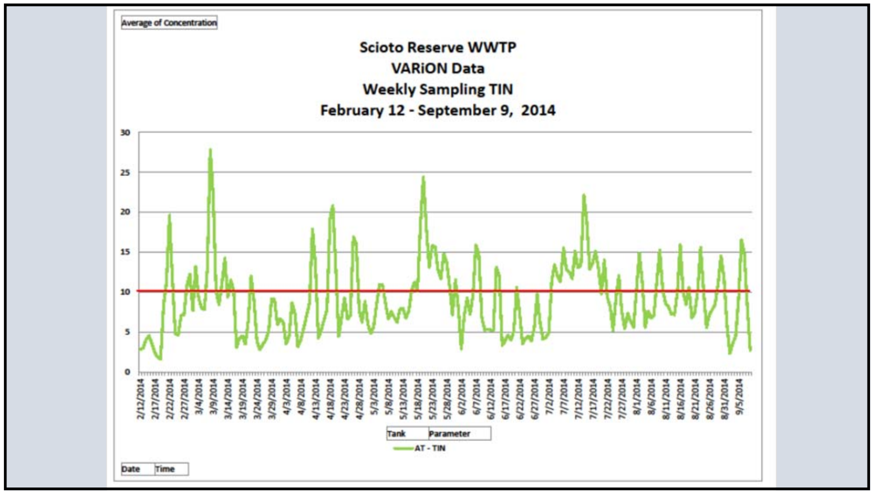
Average of Concentration
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014
Tank
Parameter
AT - TIN
Date
Time

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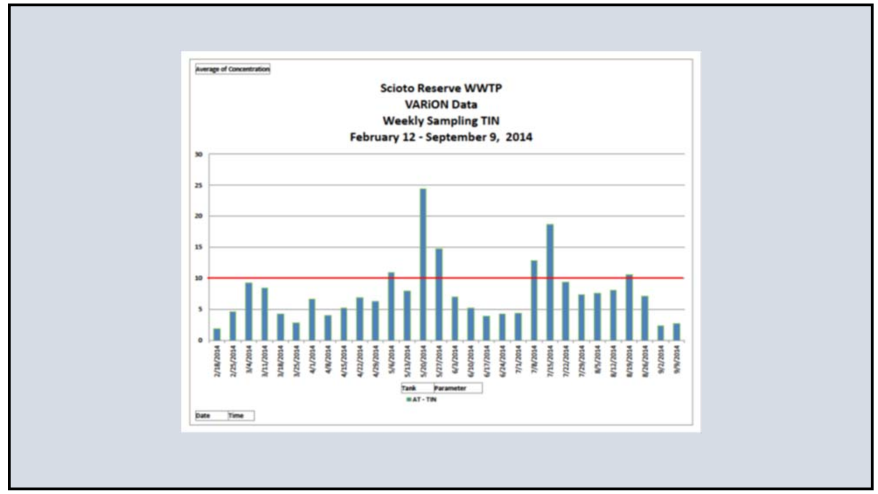
Average of Concentration
Scioto Reserve WWTP
VARiON Data
Weekly Sampling TIN
February 12 - September 9, 2014
Tank
Parameter
AT - TIN
Date
Time

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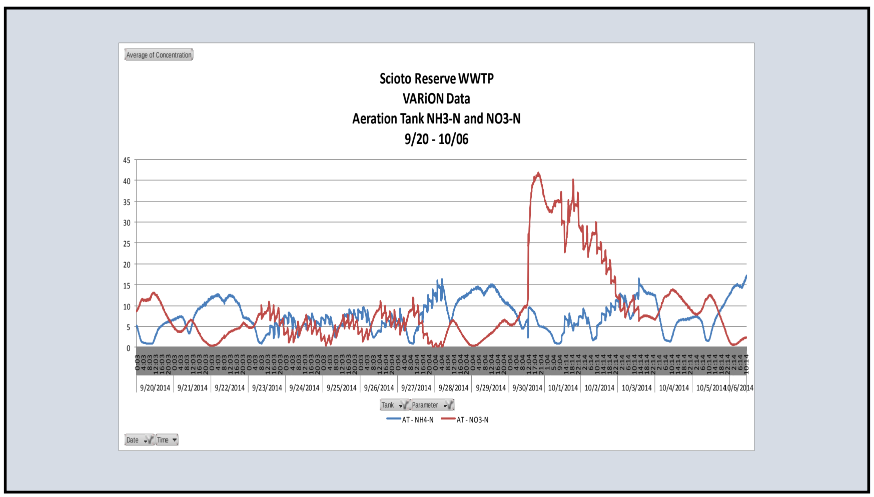
Average of Concentration
Scioto Reserve WWTP
VARiON Data
Aeration Tank NH3-N and NO3-N
9/20 - 10/06
Tank
Parameter
AT - NH4-N
AT - NO3-N
Date
Time

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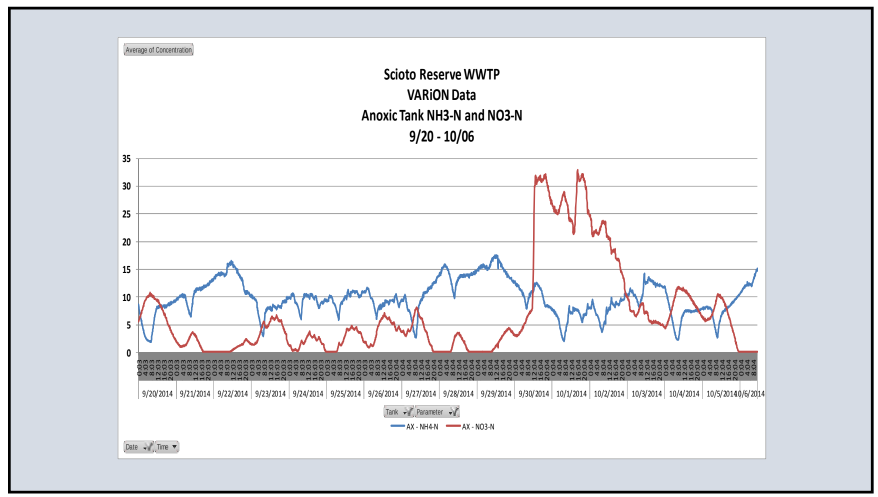
Average of Concentration
Scioto Reserve WWTP
VARiON Data
Anoxic Tank NH3-N and NO3-N
9/20 - 10/06
Tank
Parameter
AX - NH4-N
AX - NO3-N
Date
Time

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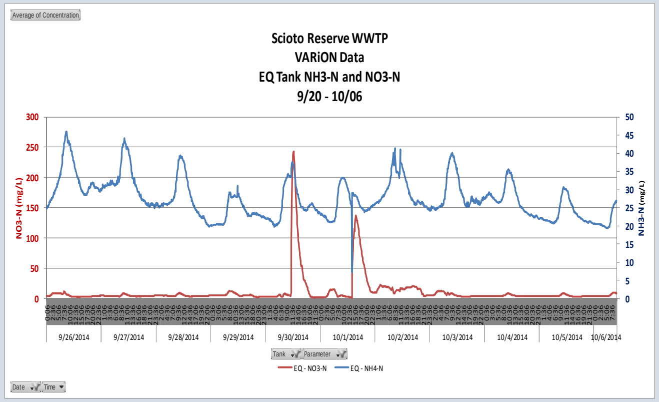

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Troubleshooting Systems: City of Bdfrd WWTP

New WWTP came online November 2013

Constructed a Carrousel Type BNR System

Designed for 0.480 MGD

2017 average flow: ~0.550 MGD (big clarifiers!)

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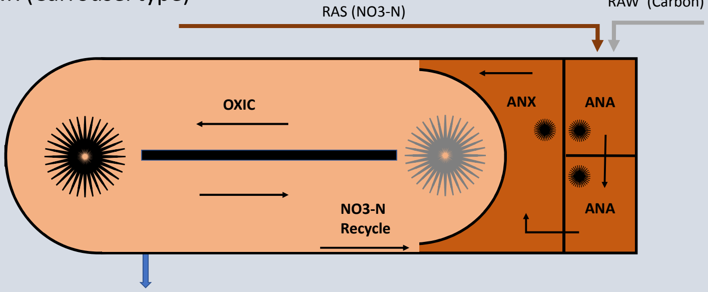
Troubleshooting Systems: City of Bdfrd WWTP

BNR (Carrousel type)



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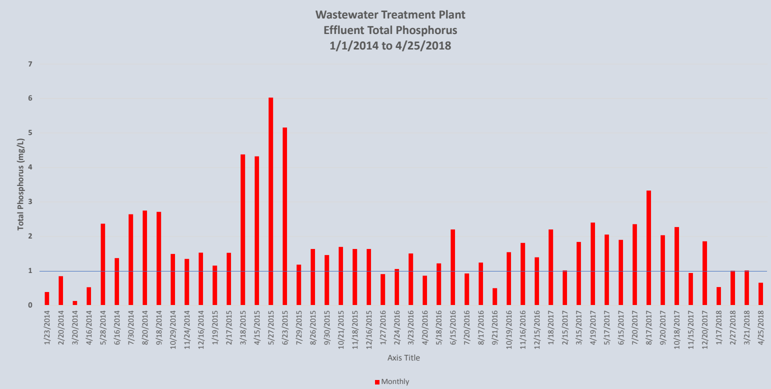

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Nitrate Analysis

Nitrate (mg/L)				
	RAS	Anaerobic	Anoxic	Digester
3/15/2018	14.3	11.9	14.6	
3/19/2018	8.7	12.5	11.9	
3/20/2018	11.6	7.9	11.8	55.9
3/21/2018	11.5	7.5	12.0	
3/22/2018	8.6	8.2	11.1	131.5

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Case Study: **City of Bdfrd** WWTP

Too much Nitrate everywhere

Solution: Manage the Nitrates

1) Close the nitrate recycle gate
2) Run vertical rotor at 38 hertz
3) Turn Anaerobic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
4) Turn Anoxic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
5) Profile Ammonia, Nitrate, and Orthophosphate in each zone

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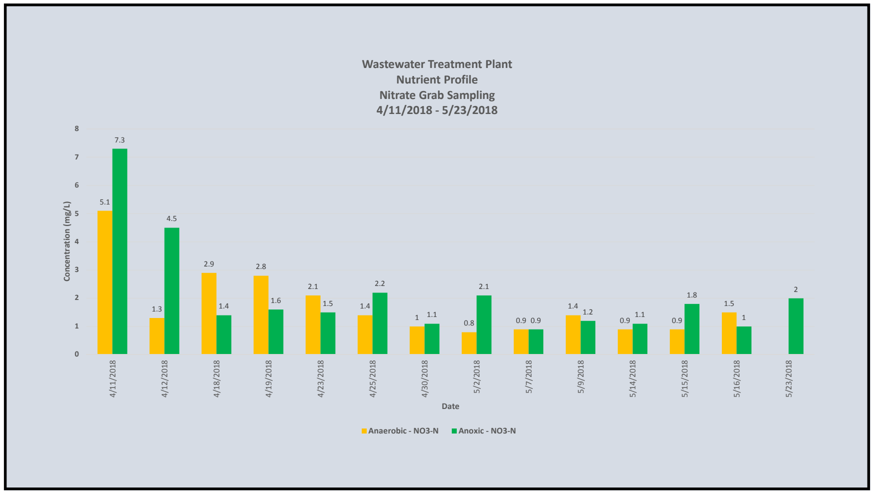

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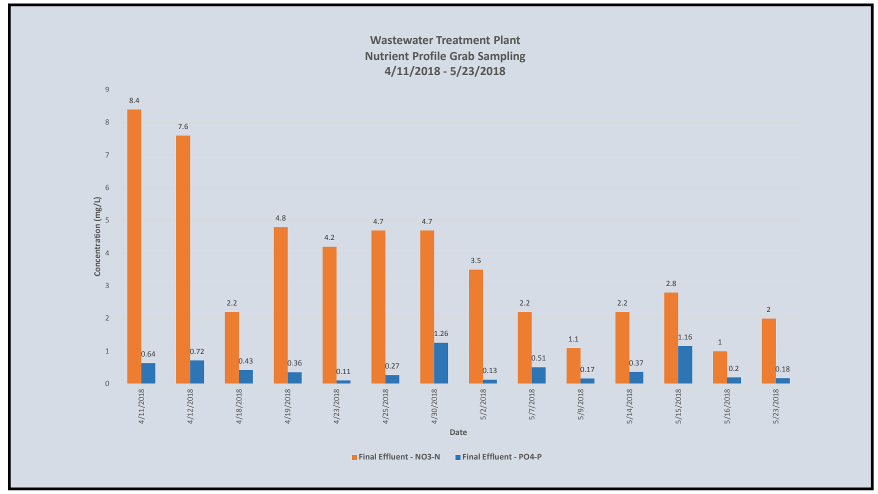

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Case Study: **City of Bdfrd** WWTP

First April sample was high (1.25 mg/L), but the rest of the samples brought the monthly down to 0.66 mg/L

Alum feed was shut down 5/2

May 2018 another consecutive month of compliance for TP

In addition, the village was spending $800 - $1200/month for alum previously.

Electricity demand should also be reduced due to mixer turndown

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Case Study: **City of Bdfrd** WWTP

Keys to BPR:

Process Control!

1) Monitor the nutrients in the Inputs to each zone
2) Monitor the nutrients in Internal Recycles (Digester Supernatant)
3) If the Chemistry is correct in the zones, the bacterial response will be compliant.
4) **Know the chemical environment in each zone of the WWTP.**

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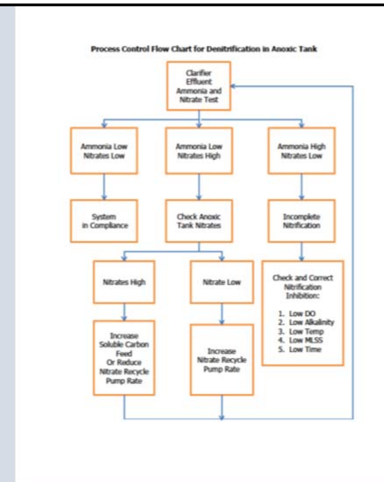

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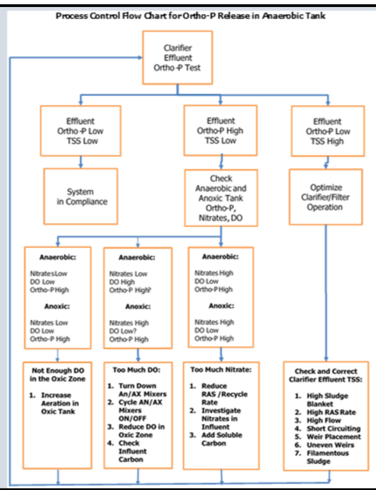

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Questions?

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614-580-5069

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