

Optimizing for Biological Phosphorus Removal

**Operator Training Committee of Ohio
April 3, 2024**

Presented by:

Jon van Dommelen

Ohio EPA – Compliance Assistance Unit

**Troubleshooting Noncompliance
in
Small Communities
and
Larger Communities**

And maybe save some cash as well.....

Troubleshooting BNR Systems in Small and Large Communities

Causes of Noncompliance in Small BNR Systems:

1) System operators are not trained very well to run BNR systems

Troubleshooting BNR Systems in Small and Large Communities

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Troubleshooting BNR Systems in Small and Large Communities

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- 3) Systems are designed using textbook characteristics for influent waste streams**

Troubleshooting BNR Systems in Small and Large Communities

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- 2) Systems typically do not have their own labs to run process control tests**
- 3) Systems are designed using textbook characteristics for influent waste streams**
- 4) Systems often suffer from inadequate soluble carbon that drives denitrification and orthophosphate release reactions**

Troubleshooting BNR Systems in Small Communities

How BNR is supposed to work:

Most Important – A good soluble influent cBOD₅

Second Most Important – Low nitrates in Anaerobic Zone

Third Most Important – Low nitrates in Anoxic Zone

Fourth Most Important – Process Control so you know!

Troubleshooting BNR Systems in Small Communities

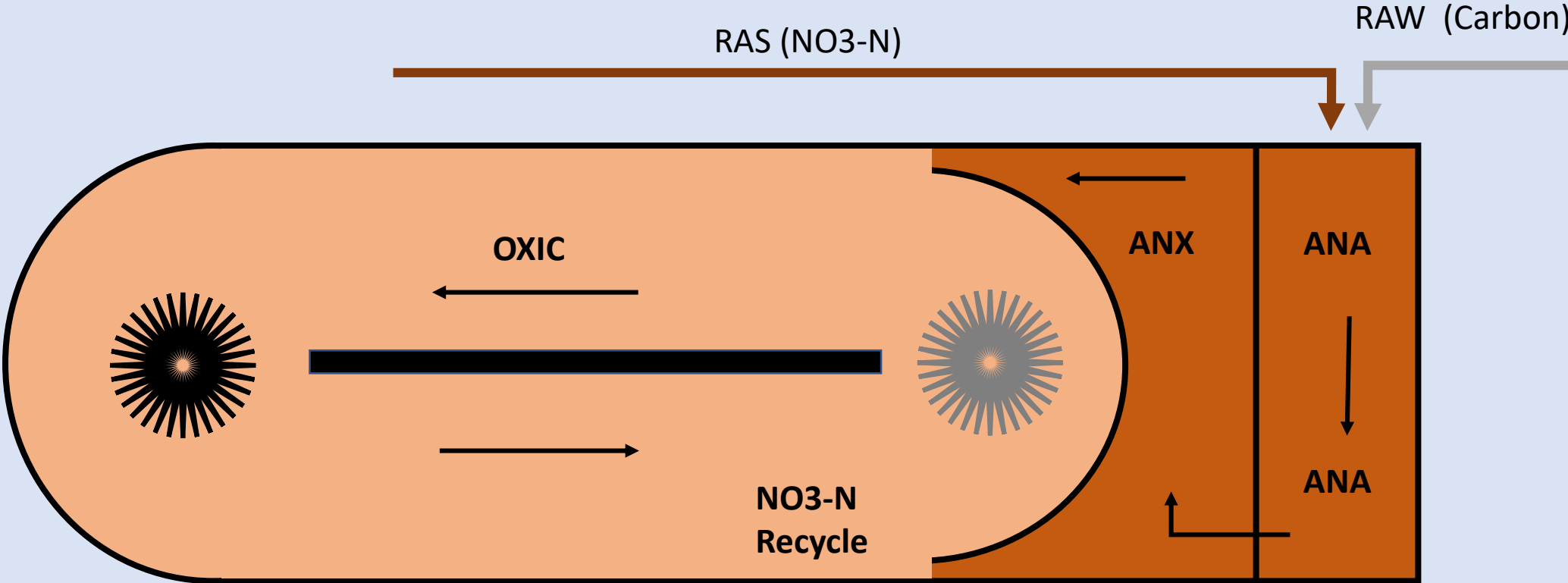
First, we will look at a small community:

- That abandoned one wastewater treatment plant**
- Constructed a new BNR wastewater treatment plant**
- Suffered from nearly random compliance for 4 years**
- Then reached out to the Compliance Assistance Unit to visit their BNR system.**



Troubleshooting BNR Systems in Small Communities

BNR (Carrousel type)





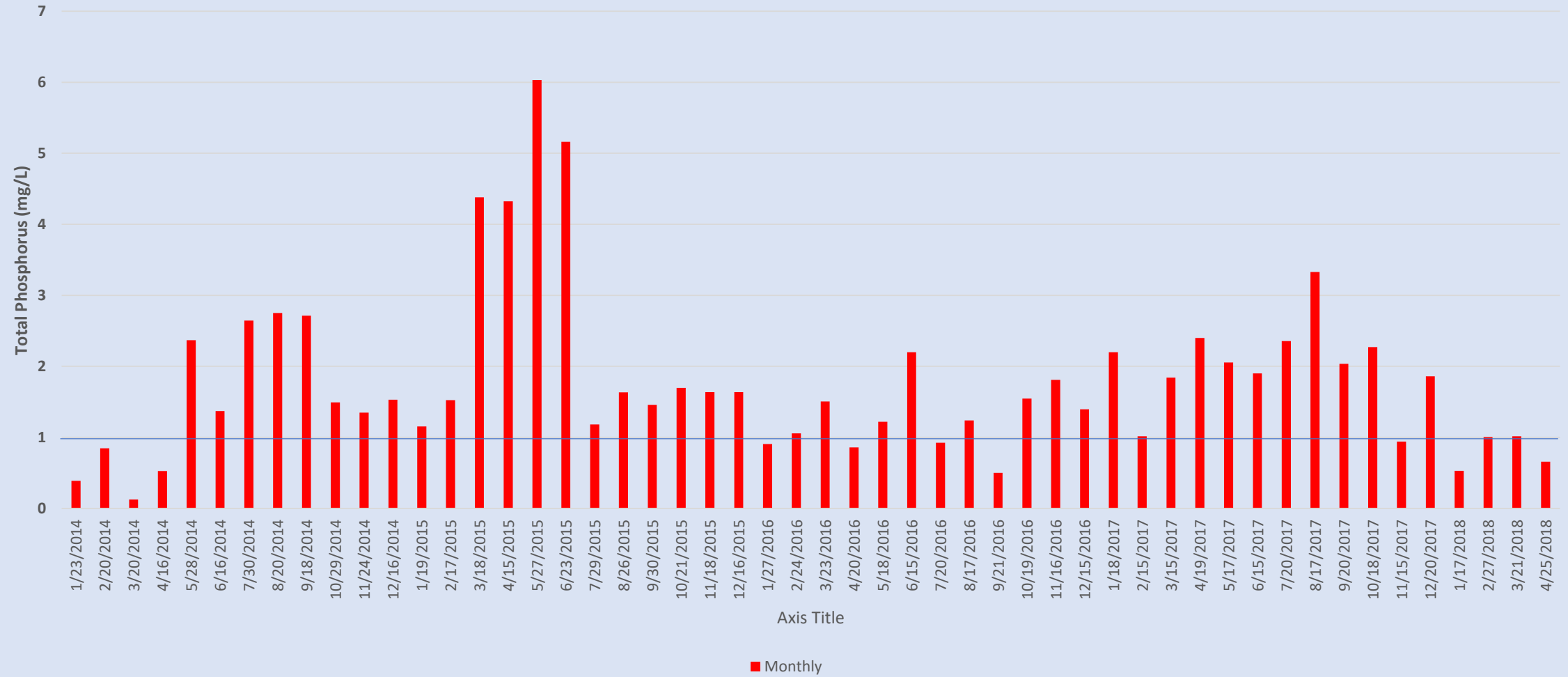








Bradford Wastewater Treatment Plant
Effluent Total Phosphorus
1/1/2014 to 4/25/2018



Troubleshooting BNR Systems in Small Communities

Date Range	Monthly Average Reported	Compliant	% Compliant	Noncompliant	% Noncompliant
Jan 2014 to Mar 2018	51	10	19.6	41	80.4

Troubleshooting BNR Systems in Small Communities

Location	COD	NH3-N	NO3-N	PO4-P
Standard (300 mg/L)	299			
Influent	190	19.0		1.27
Anaerobic Tank	119	4.5	11.9	1.01
Anoxic Tank	113	0.1	14.6	0.99
Oxic Tank		0.02	14.7	0.99
Final Effluent	99	0.09	13.9	0.79
RAS			14.2	

Note all samples are grab samples (Samples run on 3/15)

Troubleshooting BNR Systems in Small Communities

Nitrate Profile (mg/L)			
	RAS	Anaerobic	Anoxic
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
3/21/2018	11.5	7.5	12.0
3/22/2018	8.6	8.2	11.1



Troubleshooting BNR Systems in Small Communities

Too much Nitrate everywhere

Solution: Manage the Nitrates

Troubleshooting BNR Systems in Small Communities

Solution: Manage the Nitrates

- 1) Closed the nitrate recycle gate completely
- 2) Run vertical rotor at 38 Hertz
- 3) Turned 2nd Anaerobic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
- 4) Turned Anoxic Zone Mixer OFF for 3.5 hours, ON for 30 minutes
- 5) Profile Ammonia, Nitrate, and Orthophosphate in each zone



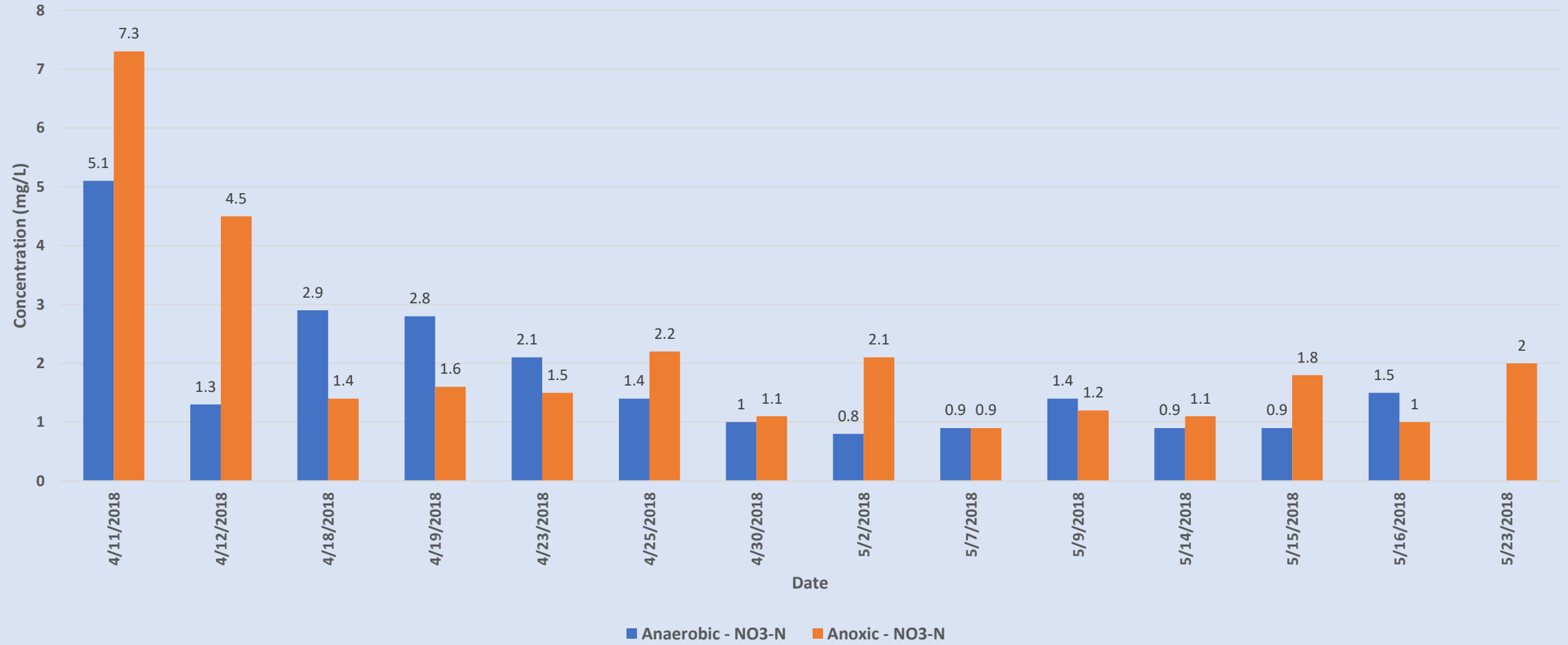
Troubleshooting BNR Systems in Small Communities

	ANOXIC	NH ₃ N	ORTHO	Nitrate
4-23	ANAEROBIC	X	.45	2.8
	ANOXIC	X	.97	1.5
	DITCH	.025	.11	4.2
4-25	DITCH ANAEROBIC	X	.48	2.1
	ANOXIC	X	.38	2.2
	DITCH	.936	.27	4.7
4-30	ANAEROBIC	X	1.56	1.4
	ANOXIC	X	1.65	1.1
	DITCH	.081	1.26	4.7
5-2	ANAEROBIC	X	1.04	1.0
	ANOXIC	X	1.09	2.1
	DITCH	.050	.13	3.5

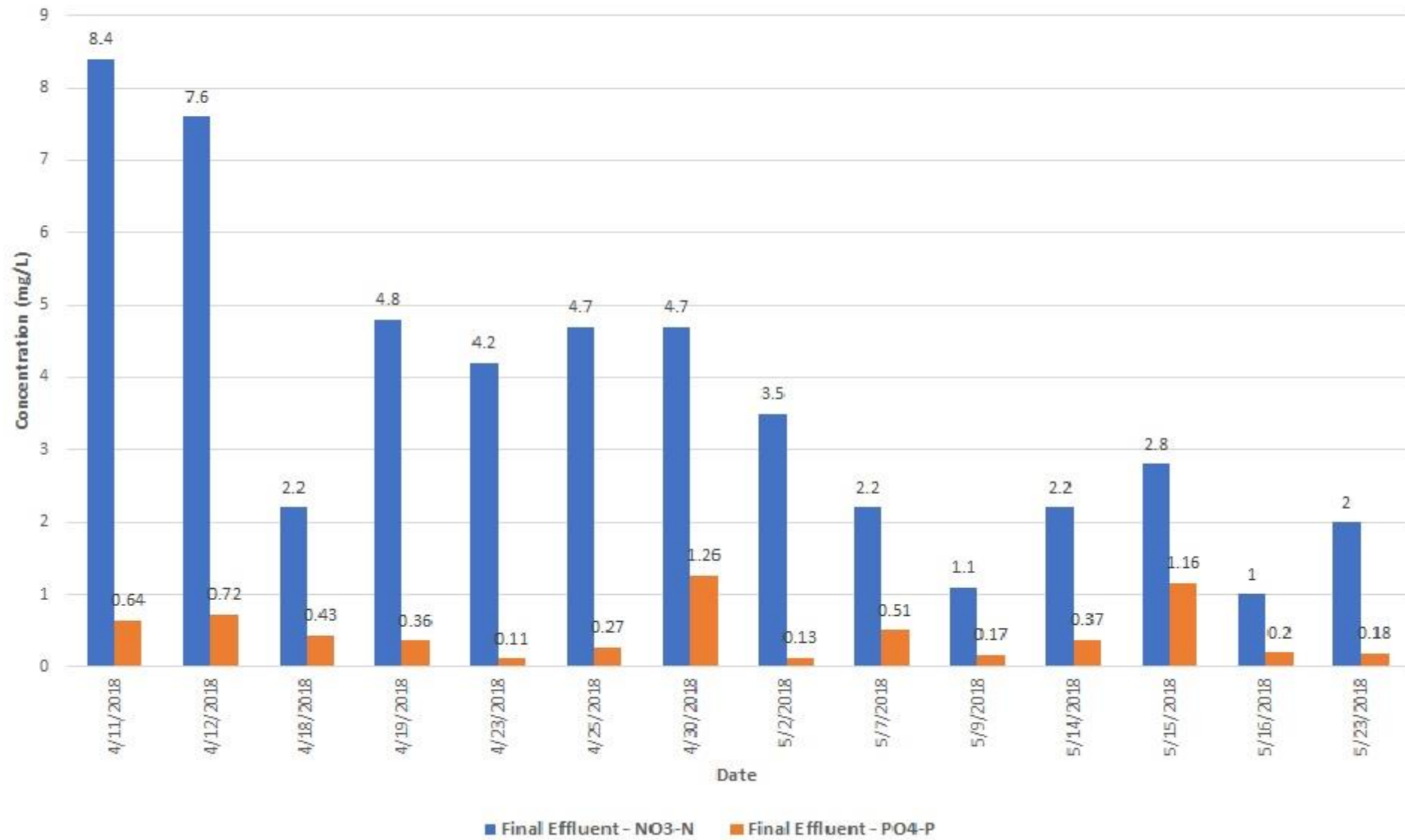
TOLL FREE **1-888-GET LEAK** (888-438-5325)

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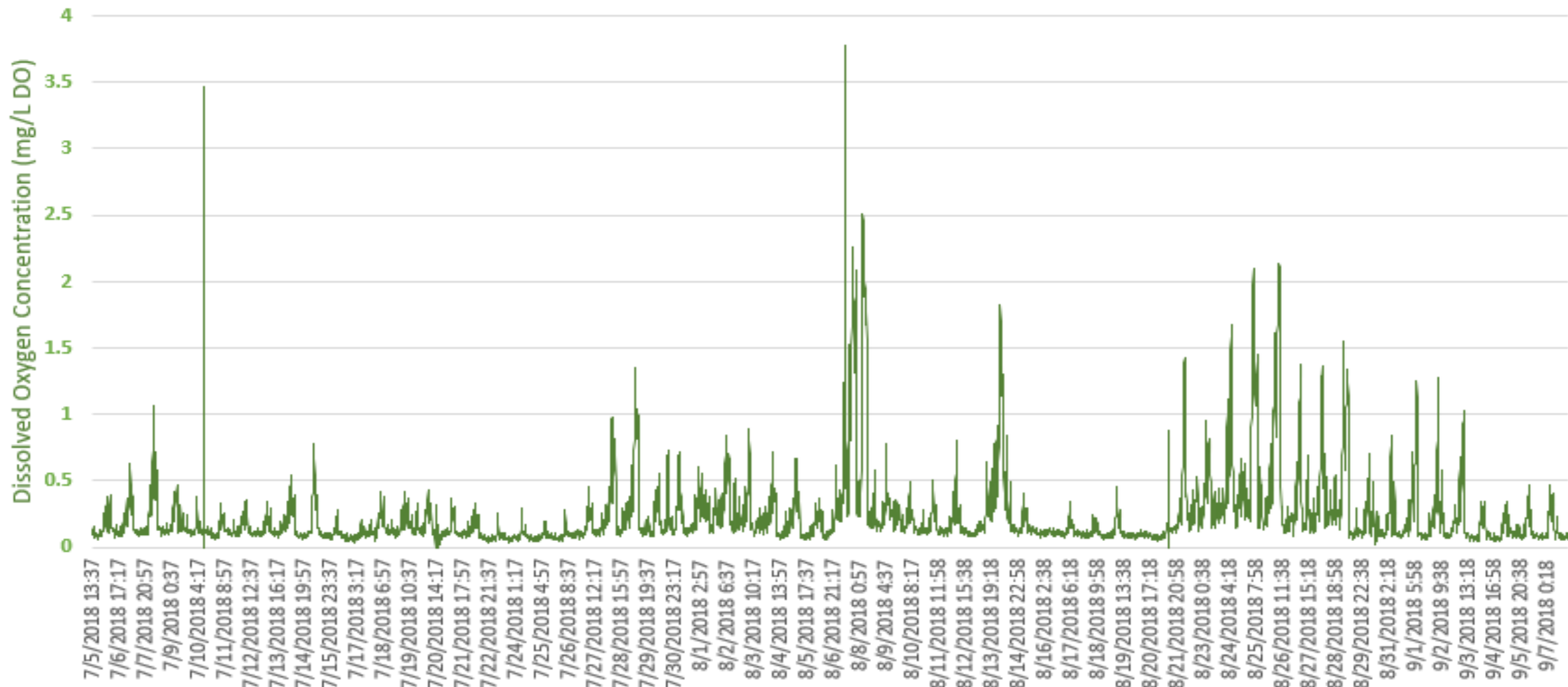
Bradford WWTP
Nutrient Profile
Nitrate Grab Sampling
4/11/2018 - 5/23/2018



Bradford WWTP
Nutrient Profile Grab Sampling
4/11/2018 - 5/23/2018



Bradford WWTP Oxic Tank Dissolved Oxygen July -September, 2018



Axis Title

Tank ▼ Parameter ▼

— oxic - O2

CONTROLLER

19 Apr 2018

12:56



Values: location

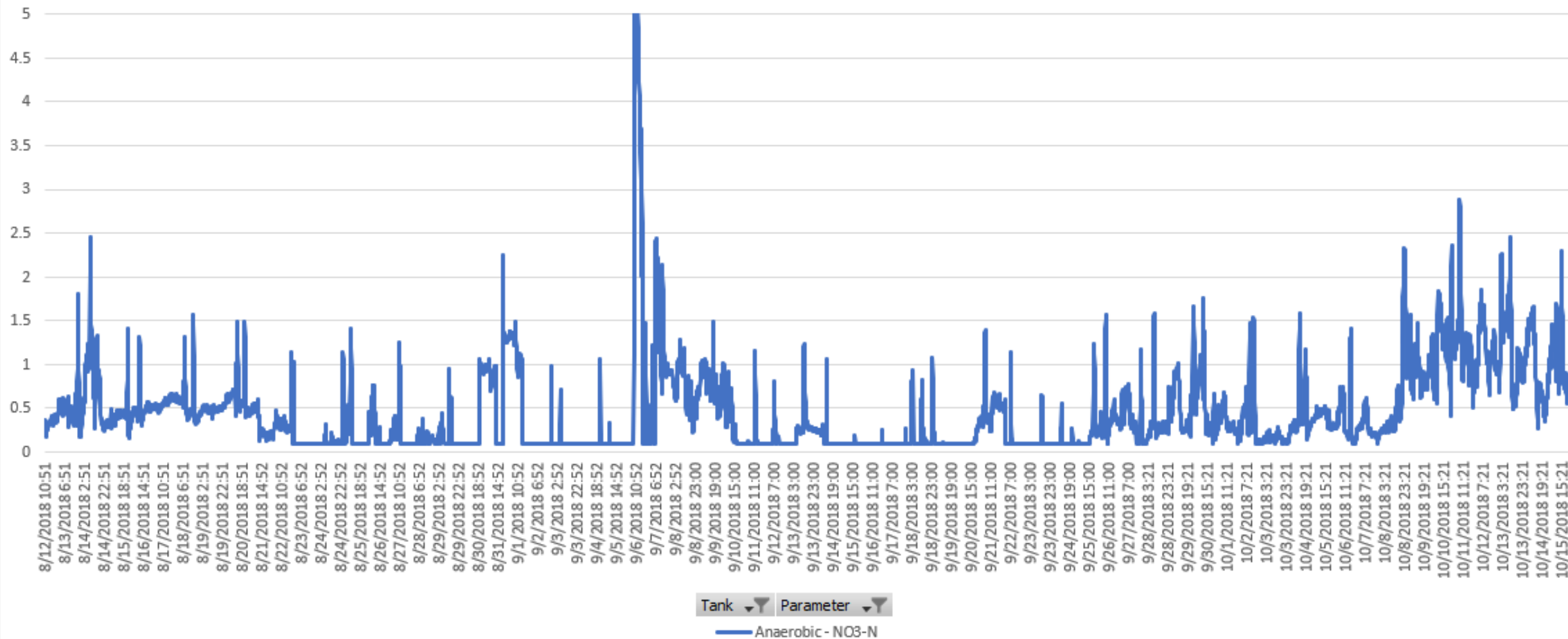
01	3.0*mg/l	NH4-N	10.8 °C	ANX NH3
02	1.9 mg/l	NO3-N	10.8 °C	ANX NO3
03	188 mg/l	Cl	10.8 °C	ANX Cl
04	4.6 mg/l	NH4-N	10.7 °C	ANA NH3
05	2.1*mg/l	NO3-N	10.7 °C	ANA NO3
06	8.7 mg/l	K	10.7 °C	ANA K

Next sensor , Display/Options

Bradford WWTP

Anaerobic Tank Nitrates

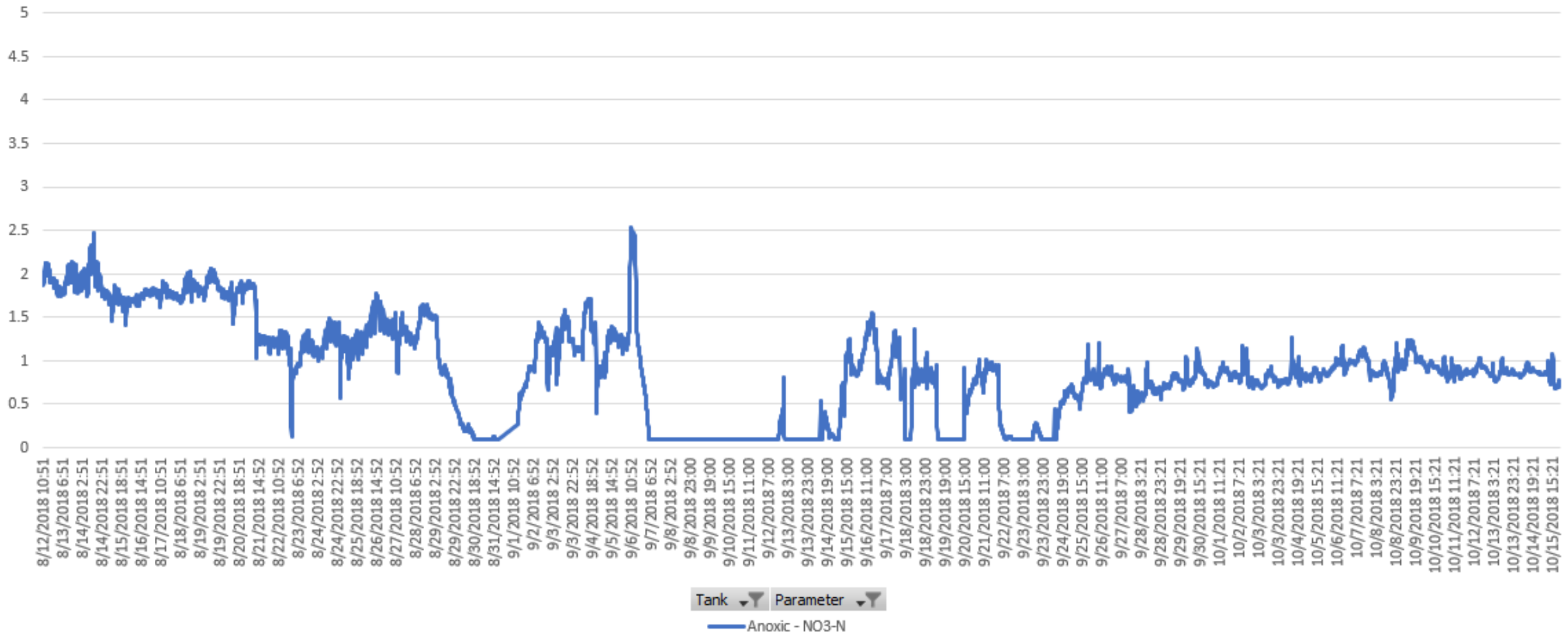
8/12/2018 to 10/15/2018



Bradford WWTP

Anoxic Tank Nitrates

8/12/2018 to 10/15/2018



Troubleshooting BNR Systems in Small Communities

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 month for alum previously.

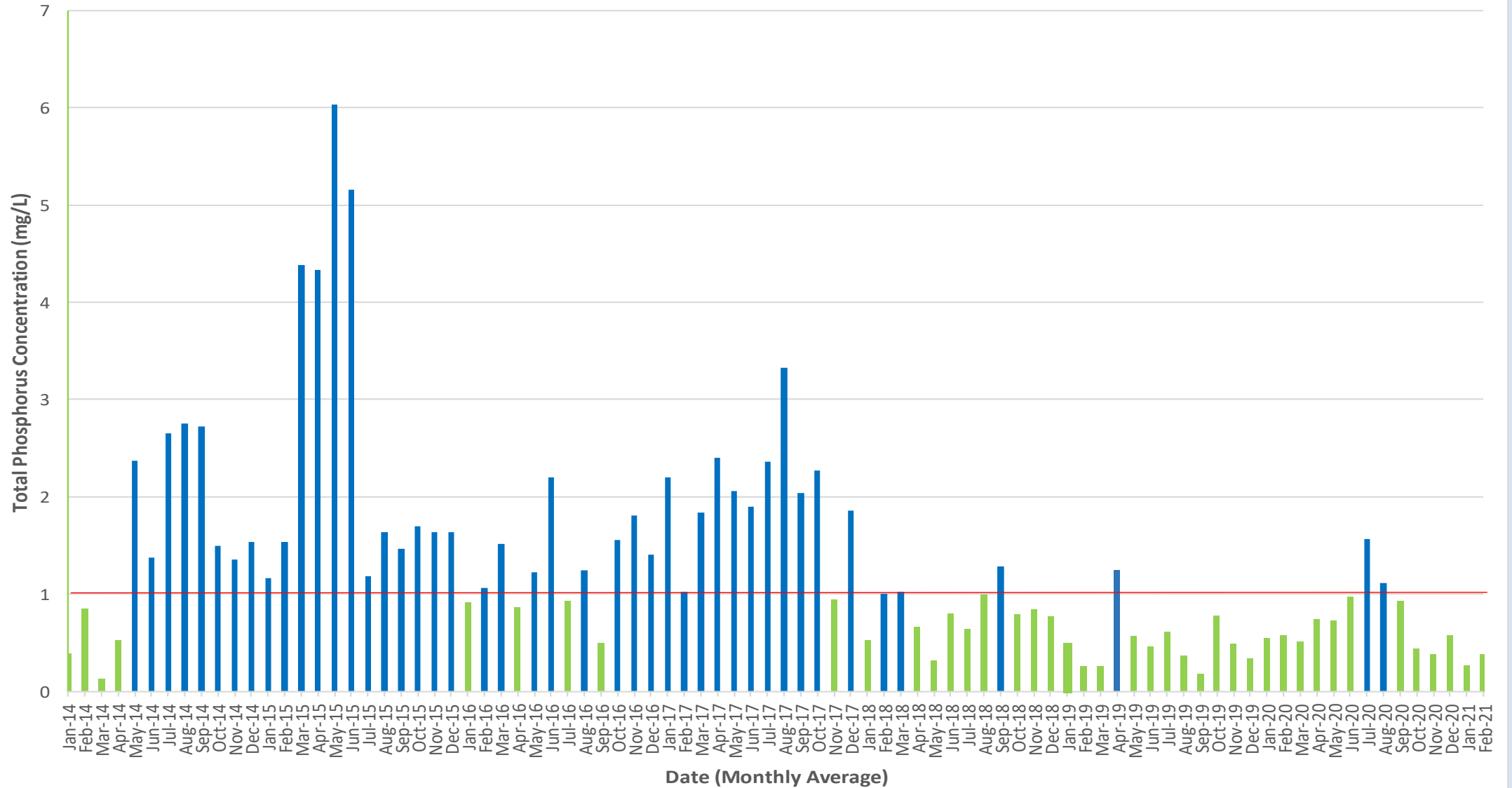
Electricity demand should also be reduced due to mixer turndown



Digester Nutrient Profile

Ammonia Nitrogen	Dilution	Nitrate Nitrogen	Dilution	Orthophosphate	Dilution
Nondetect	(1:4)	504 mg/L	(1:20)	220 mg/L	(1:200)

Bradford Wastewater Treatment Plant Effluent Total Phosphorus Concentration January 2014 - February 2021



Date Range	Monthly Average Reported	Compliant	% Compliant	Noncompliant	% Noncompliant
January 2014 to March 2018	51	10	19.6	41	80.4
April 2018 To February 2021	35	31	88.6	4	11.4

Troubleshooting BNR Systems

Keys to BNR:

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.**

BNR in an SBR?







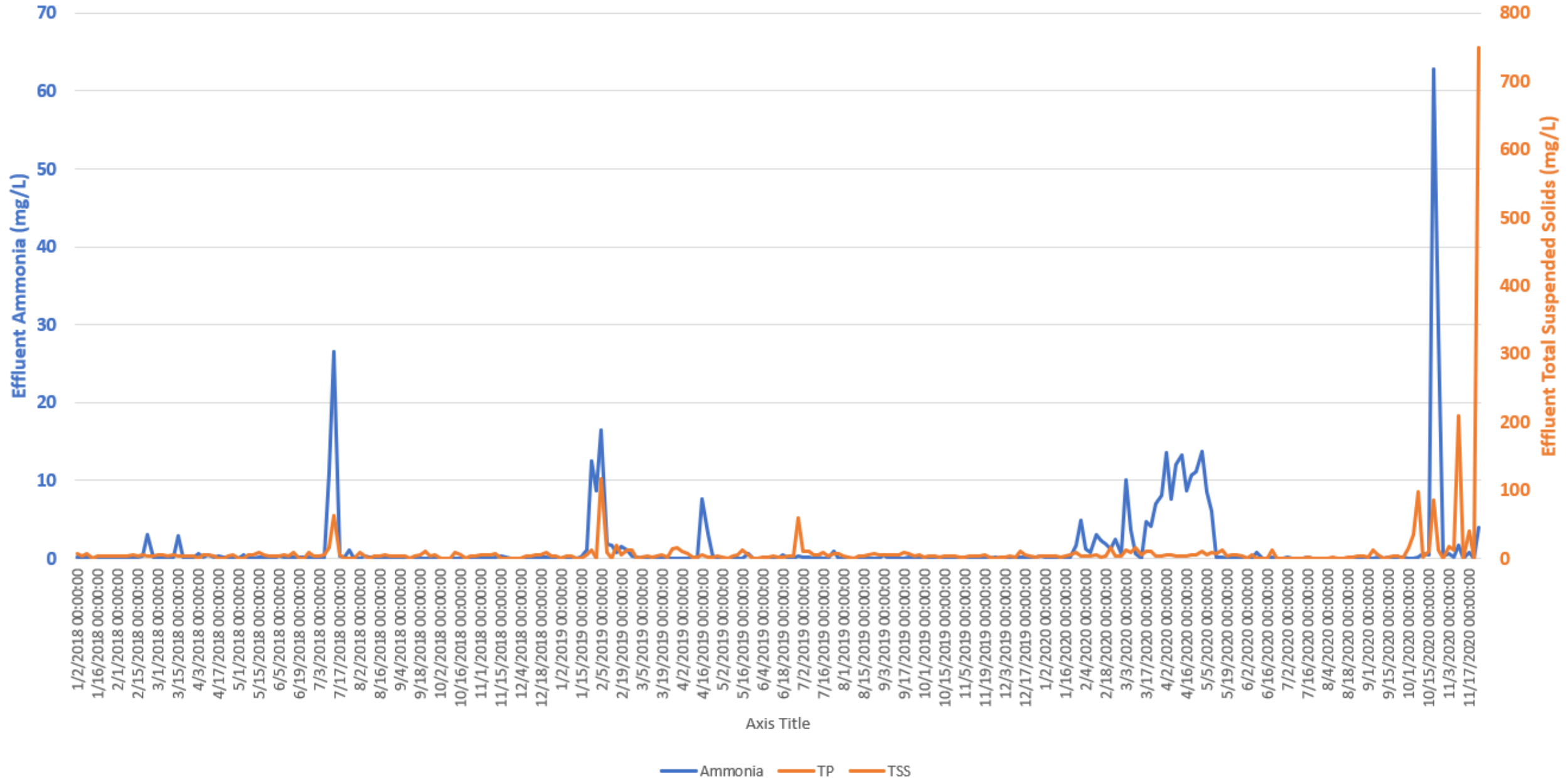
BNR in an SBR

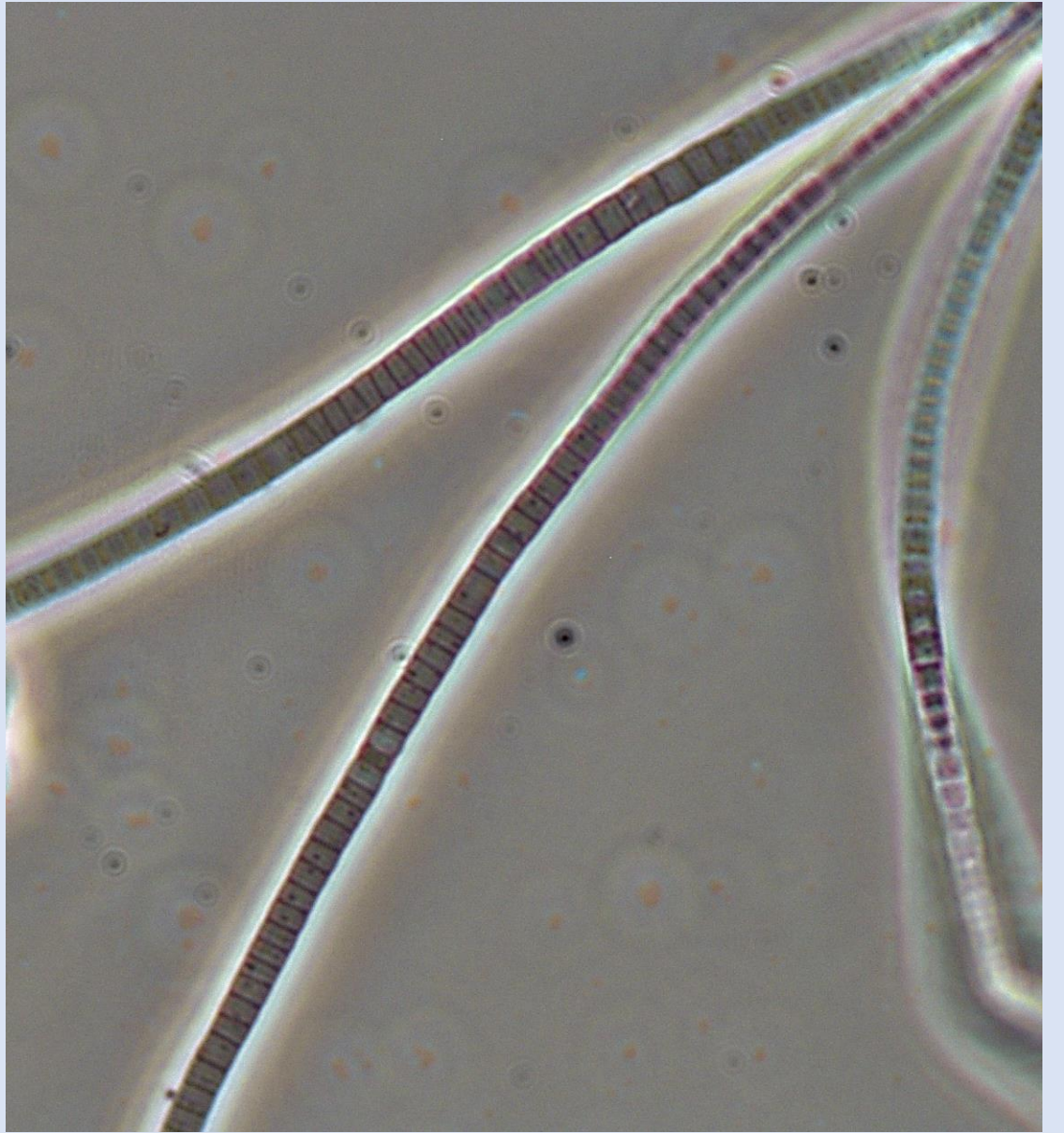
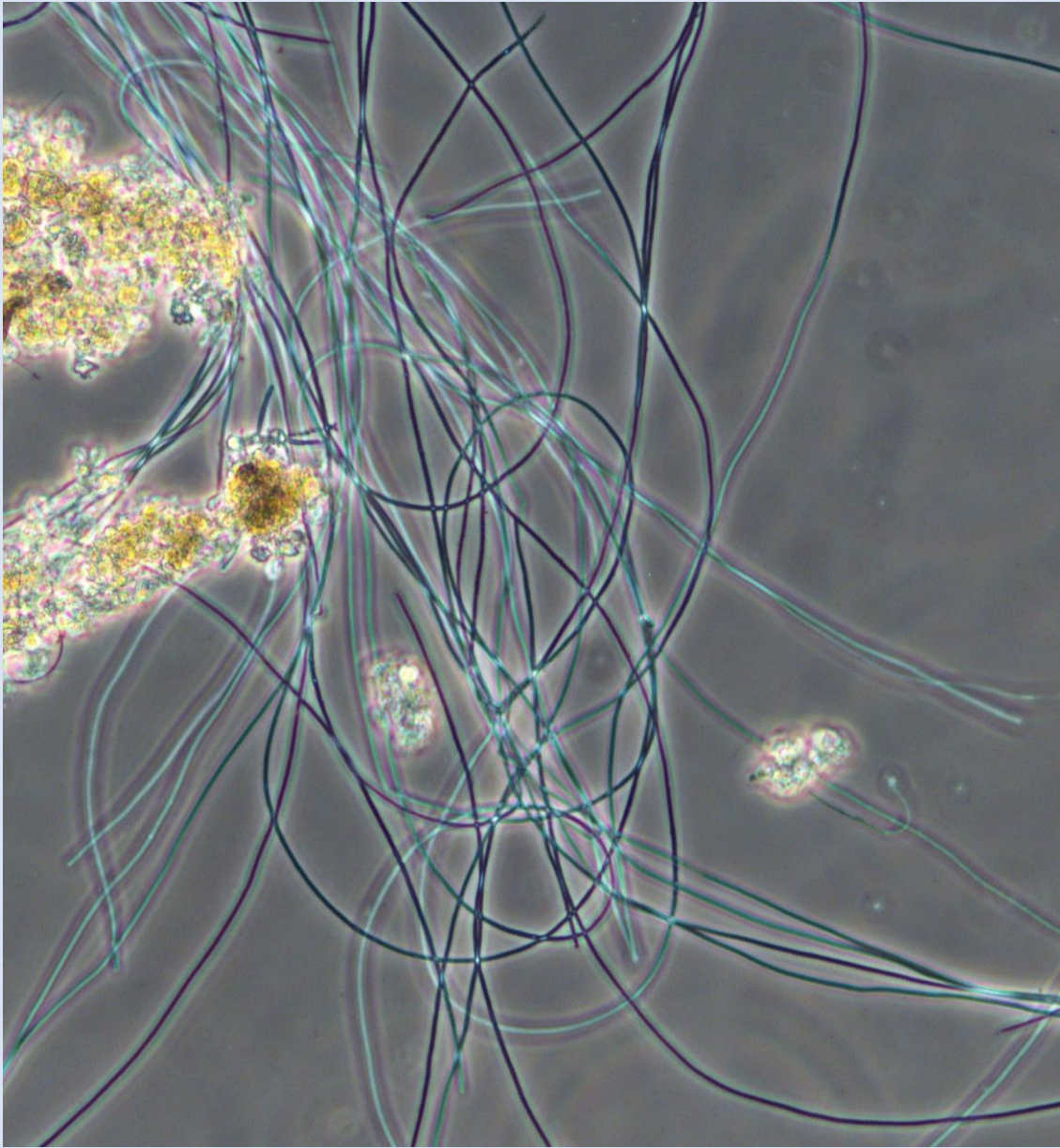
Originally, I was called to diagnose a filament issue.

The SBR had Type O21N, EVERYWHERE.

And it was causing severe noncompliance (11/22/2020)

Effluent Ammonia and Total Suspended Solids 1/1/2018 - 11/24/2020





BNR in an SBR

There was more filament than floc, and solids were being decanted

Type O21N is a septicity filament

So, the solution was to track down the septicity source:

Long, low flow force mains and solids handling are first to check.





BNR in an SBR

First Visit to Walnut Creek (12/9/2020):

I realized that the WWTP was feeding **sodium aluminate** in the influent to the SBR

This was how they were meeting their permit concentrations for
Total Phosphorus

But I suspected that they were inadvertently creating a nutrient imbalance for
phosphorus

The orthophosphate concentration was less than 0.3 mg/L in the mix/fill cycle

And the influent CBOD was typically around 400 mg/L!

BNR in an SBR

The community did have a low flow force main that has septic wastewater discharge to the WWTP

What was the cause of the Type O21N filament?

Was it septicity? Was it nutrient deficiency?

BNR in an SBR

The Plan:

SBRs are complete mix tanks, which is good for a low septic influent.

SBRs can have the cycles adjusted to almost anything as long as the mix/fill and the react/fill cycles match the react, settle and decant cycles.

This SBR was so over designed that they only ran one tank

They could do this because the system was designed to treat 400,000 gpd

But the WWTP only sees around 180,000 gpd.

BNR in an SBR

When we looked at the SBR cycles, we realized that the initial mix-fill cycle was only 5 minutes long

We expanded the mix-fill cycle to 40 minutes to try to stress the phosphorus accumulating bacteria to release OrthoP

We cycled the digester air ON for 3 hours and OFF for 1 hour to try to reduce the Nitrates and OrthoP in dewatering

And on 12/14,

We shut the Sodium Aluminate **OFF**

BNR in an SBR

They could run one tank because they had an influent EQ tank that would store the wastewater during react, settle and decant (actually it could almost store an entire day's flow)

Because the online SBR had so much filament, we switched to the unused tank on 12/15 (with no sodium aluminate added!)

The orthophosphate concentration never missed a beat staying typically below the permit limit of **1.0 mg/L**

But the ammonia crept up slowly settling in at around 10-12 mg/L.

BNR in an SBR

We kept bumping the aeration cycles to try to oxidize the ammonia

But the ammonia didn't budge and remained around 10 mg/L

What is going on here?

BNR in an SBR

Parameter	Dilution (Sample: DI water)	Meter Read	Multiplier	Concentration
EQ Basin	0.2:9.8	0.66	50	33 mg/L
NH3-N (react-fill)	0.2 : 9.8	0.58	50	29 mg/L
NH3-N (post EQ)	0.5:9.5	0.61	20	12.2 mg/L
NO3-N (react)	1 : 0	0.7	1	0.7 mg/L
PO4-P (react)	2.5 : 2.5	0.49	2	0.98 mg/L

Grab samples from 12/16/2020

BNR in an SBR

- Interestingly, the nitrate was almost always less than 1 mg/L as well
- But they didn't have a nitrate limit or a total inorganic nitrogen limit
- To take care of the new ammonia violation, we increased the react/fill and the react cycles.
- But the ammonia didn't come down

BNR in an SBR

- Prior to turning off the sodium aluminate, ammonia was near nondetect
- But that was in the tank with the filaments. We switched tanks to the unused tank to stop losing solids to the creek.
- The other factor was that the tanks were above ground and out of direct sight.
- We didn't have good visual cues, only random cues when we collected samples

BNR in an SBR

What we eventually discovered:

The original tank aeration was on a timed cycle

When we switched tanks, the second tank was programmed to run aeration with a DO probe

We didn't notice when the air was shut down when it reached a high set point

And the influent pump would pump whenever the EQ floats called for pump cycle

BNR in an SBR

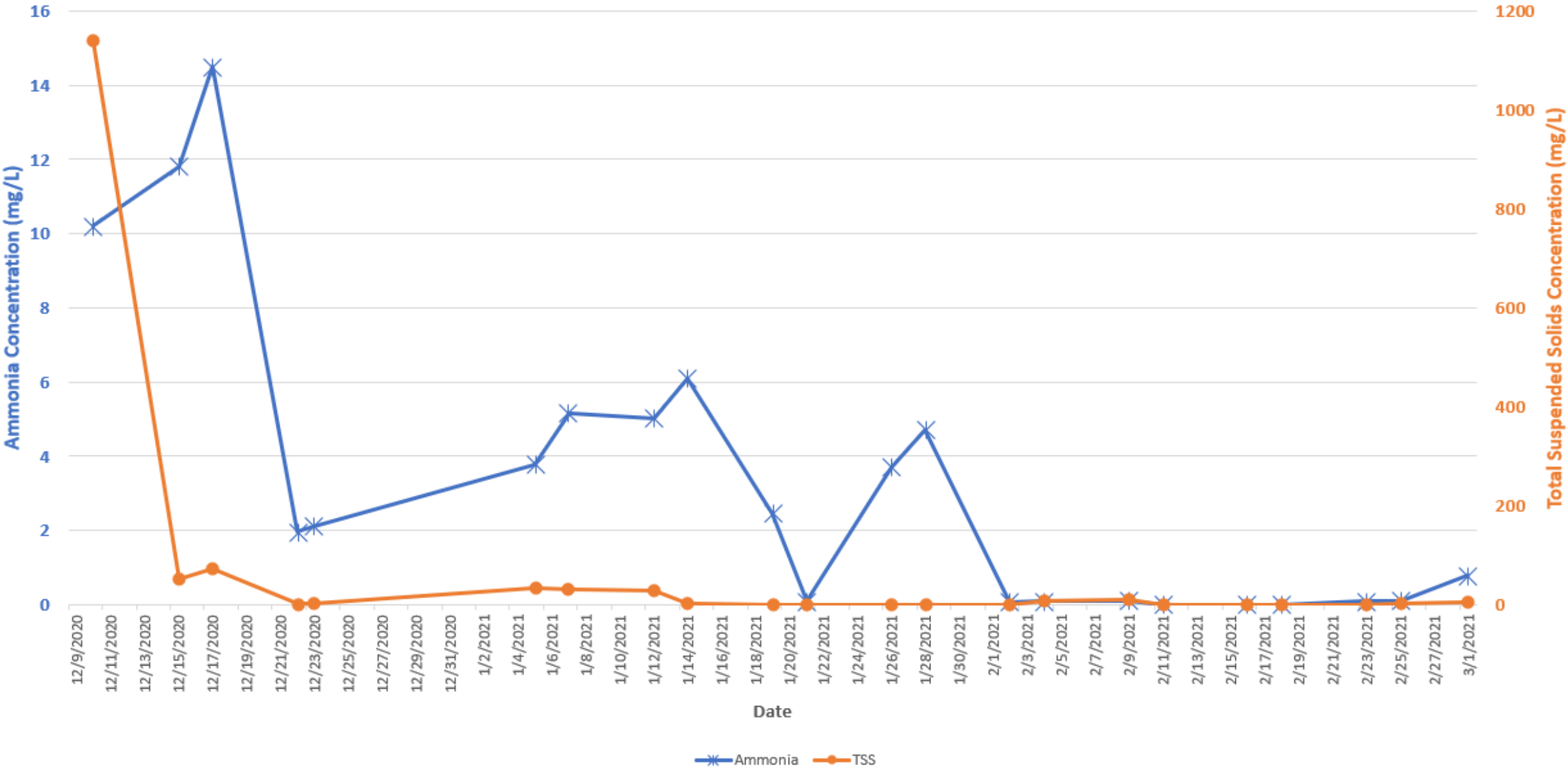
The other thing we discovered much later:

The DO probe was faulty, showing a higher (1-2 mg/L) in the second tank than what my handheld DO probe measured (around 0.5 mg/L)

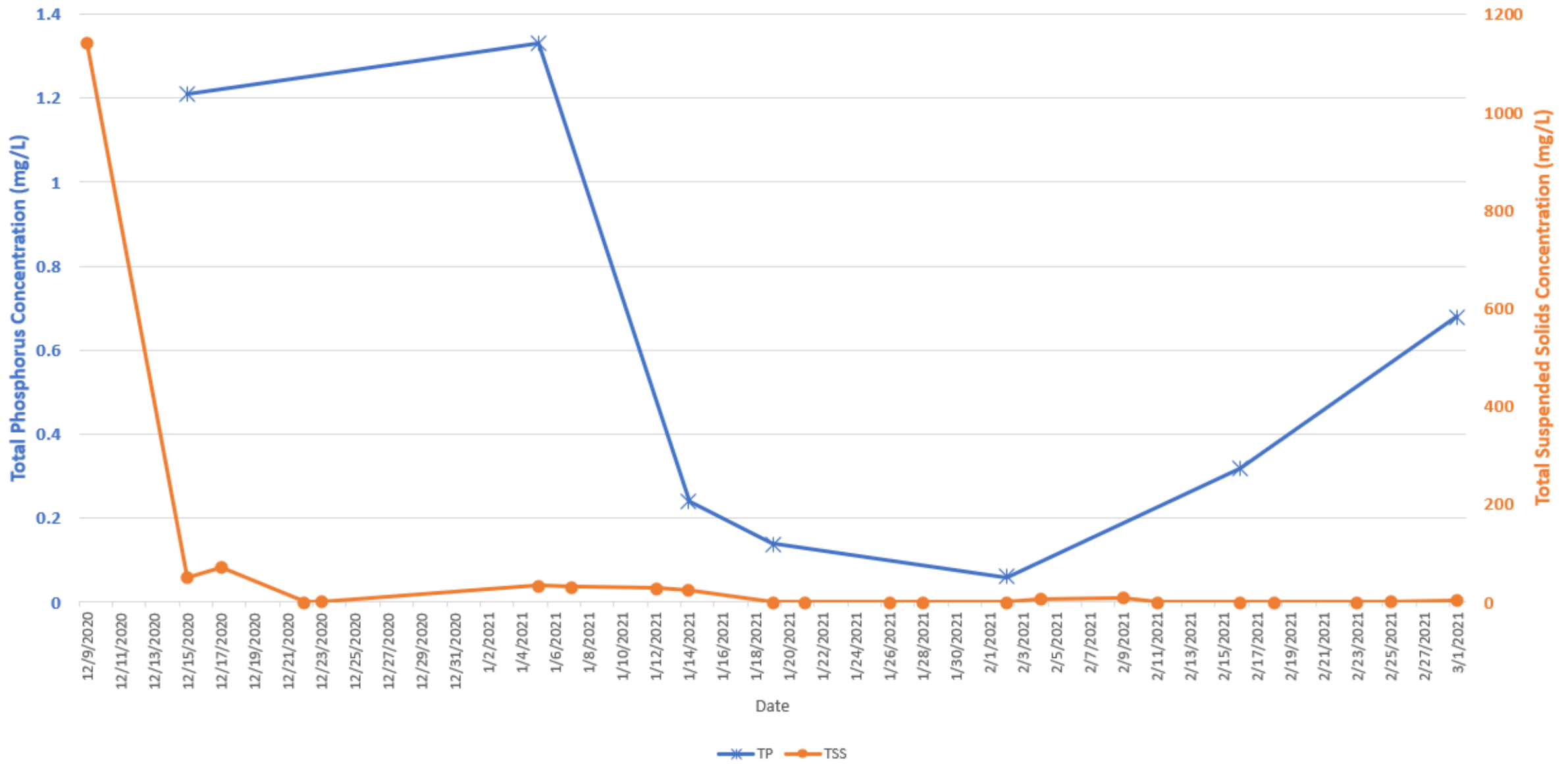
The tank turned out to be DO limited

And a DO limited MLSS will let the ammonia slip into violation

Effluent Ammonia and Total Suspended Solids 12/09/2020 - 3/1/2021



Effluent Total Phosphorus and Total Suspended Solids 12/9/2020 - 3/1/2021



BNR in an SBR

In summary,

Once we solved the low DO issue, the WWTP ran great

And by increasing the Mix/Fill cycle, we eliminated the chemicals...

...which will result in a huge cost savings

Better effluent water at a cheaper cost.

Conventional Activated Sludge Biological Phosphorus Removal

Niles, Ohio

Population: 18,500

6.2 MGD design flow





In 2017, the City upgrades their WWTP from a typical extended aeration system to modern Biological Nutrient Removal system.

It was a needed rebuild of the heart of the WWTP:

- Converted the diffused aeration ditches into 3 – 3 zone BNR tanks

- Constructed 3 big, new clarifiers

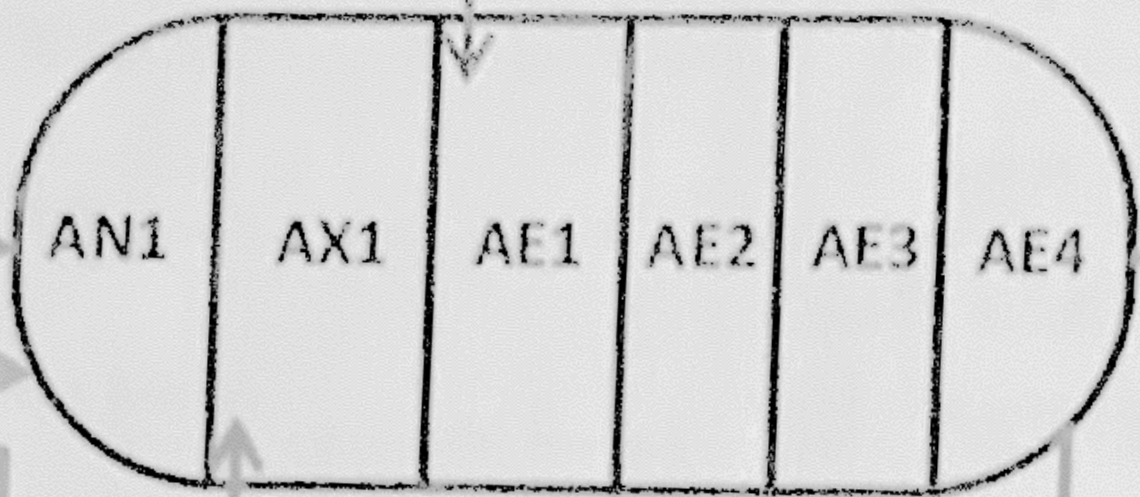
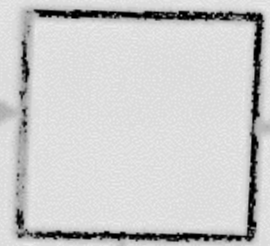
- Converted anaerobic digestion to aerobic digestion

- Constructed a new head works

It was very expensive

Mixed Liquor
Flow
Splitter

Bypass

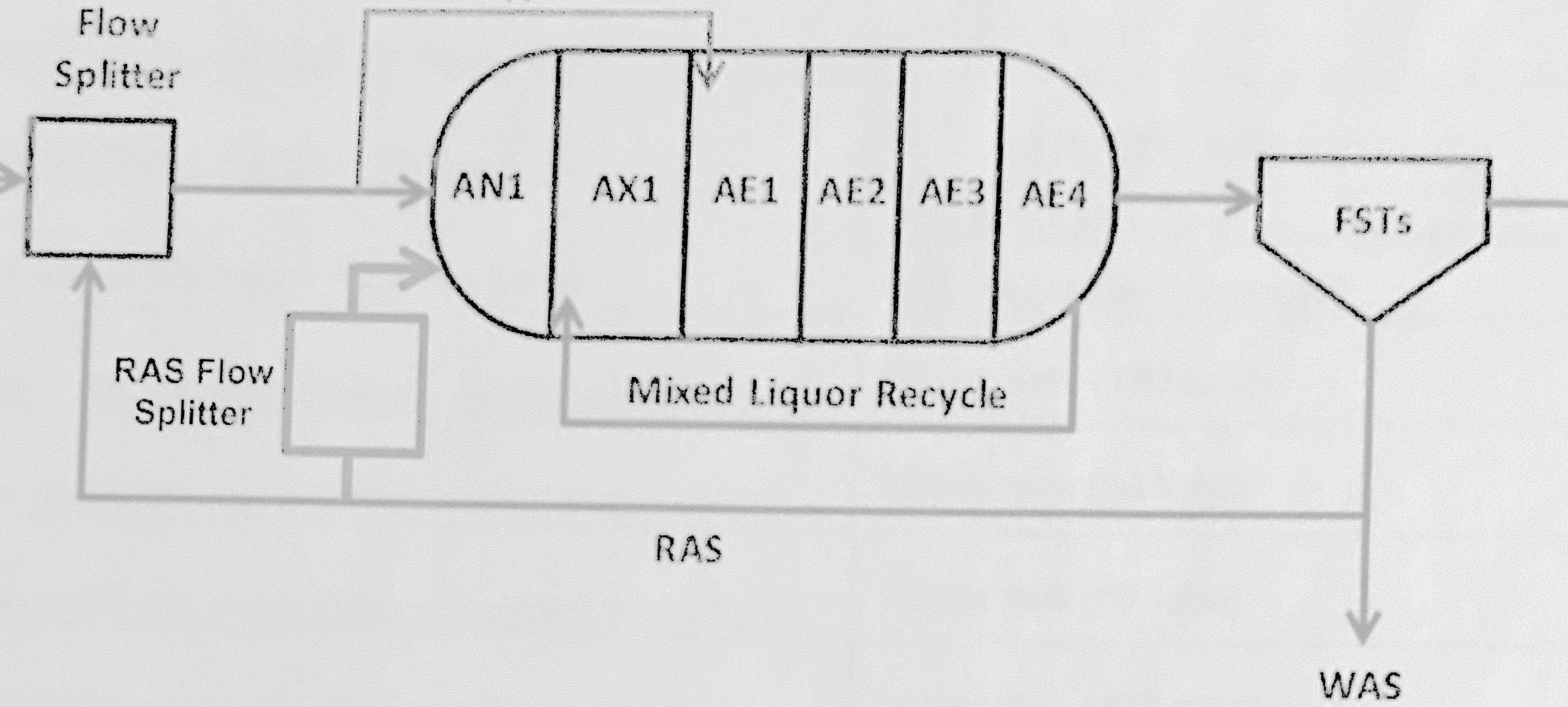
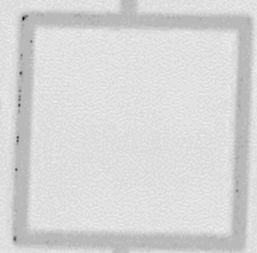


RAS Flow
Splitter

Mixed Liquor Recycle

RAS

WAS











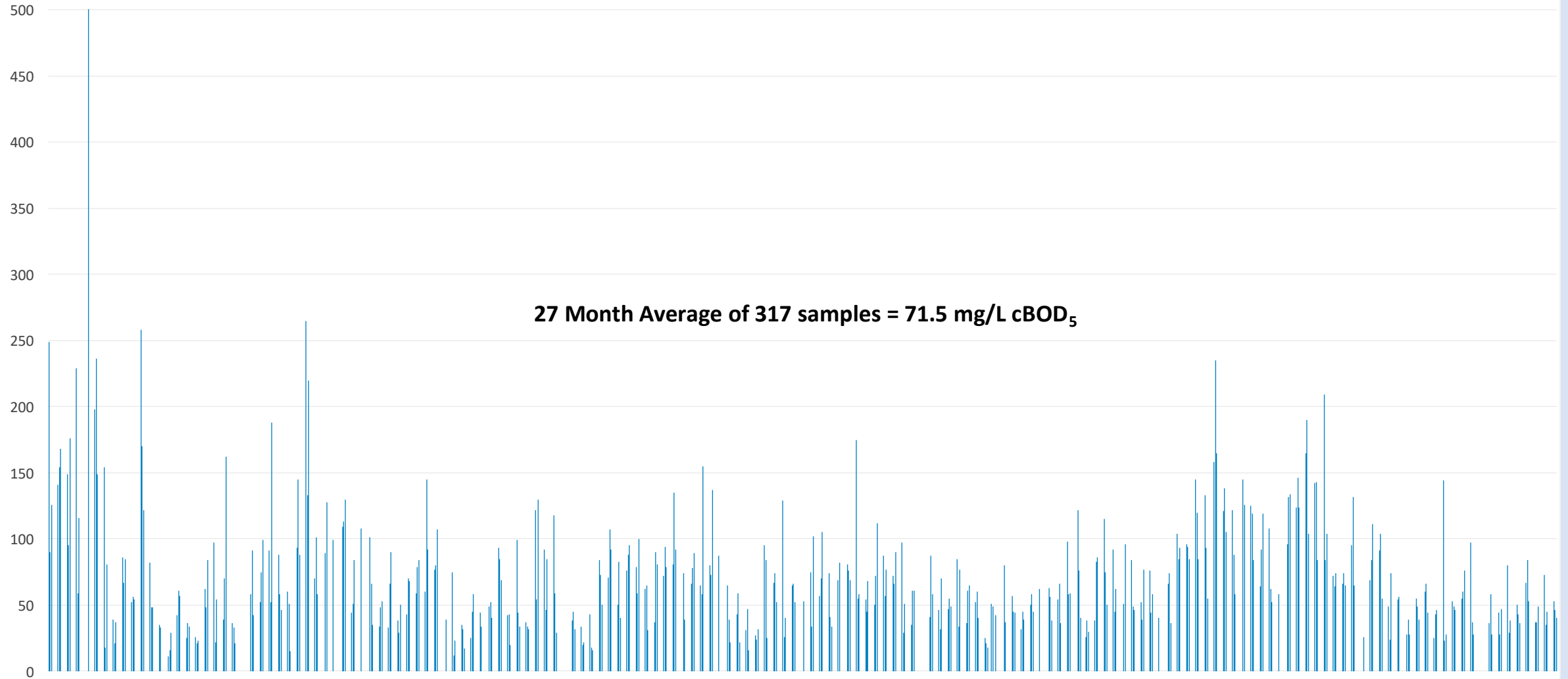


But the design engineers missed one thing:

The WWTP averaged less than 100 mg/L cBOD5 in their influent

There was not enough loading to drive the bacterial reactions that result in effective biological phosphorus removal

Niles WWTP Influent cBOD₅ 1/1/2018 - 3/1/2020



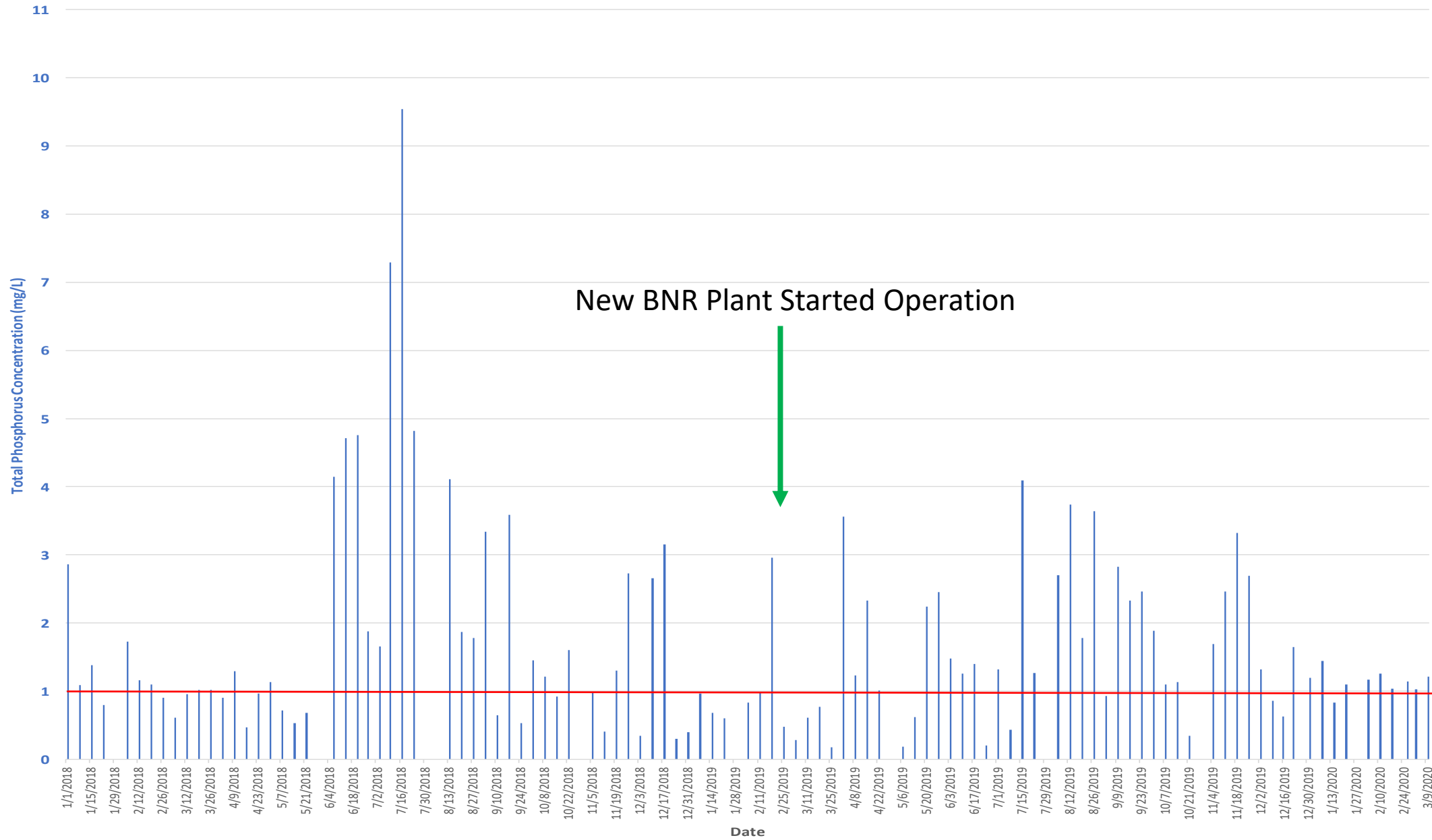
The Construction finished up in 2019.

The one-year SRF Certification Period began.

The only problem was that the new WWTP didn't reliably remove phosphorus

It met it's 1 mg/L monthly limit pretty randomly

Niles Wastewater Treatment Plant Effluent Total Phosphorus Sampling 1/1/2018 - 3/1/2020



Since the new WWTP started up, the treatment plant had only:

13 of 49 samples under 1.0 mg/L PO₄-P

The superintendent called me in late February 2020

I drove up, got a tour of the wwtp and then started to tell him about the success we had in Bradford

And what would be involved to implement it in Niles

Then **COVID-19** arrived on the scene

And Ohio EPA field staff was grounded (including ME) on
3/18/2020

So, we started to troubleshoot noncompliance from a distance,

by Phone

by Text

by Email

The Niles upgrade didn't have VFDs or timers on the mixers

But it was staffed 24/7

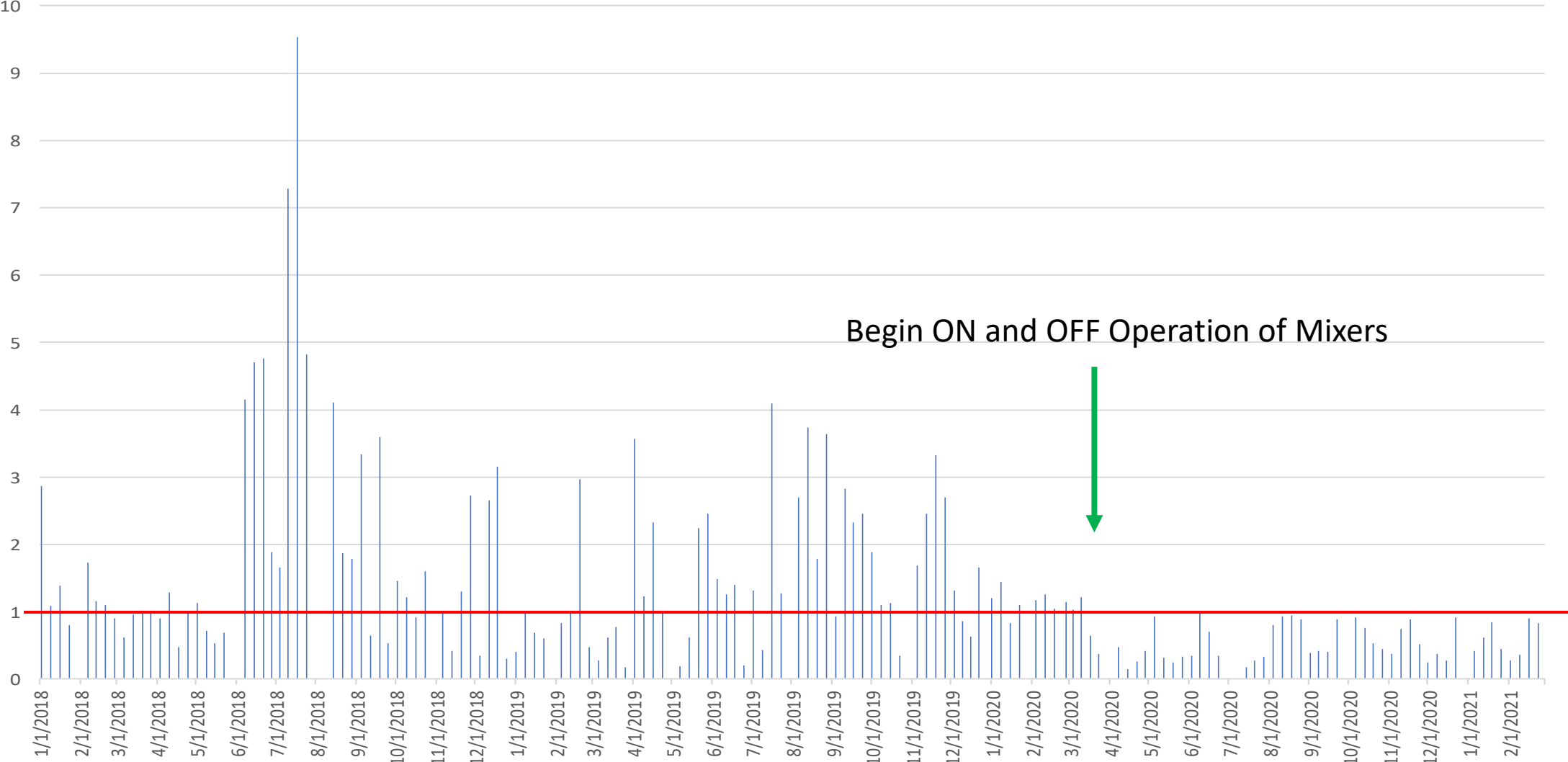
So the superintendent assigned treatment plant staff to:

Turn Mixers **OFF** for 3 hours

Turn them back **ON** for 30 minutes

Just like Bradford

Niles Wastewater Treatment Plant Effluent Total Phosphorus Sampling 1/1/2018 - 2/28/2021



In that last year, the WWTP has been under 1.0 mg/L for every Total Phosphorus Sample that has been collected.

Total Phosphorus compliance is no longer a random event

It works, even with an influent cBOD₅ of 73 mg/L

No chemicals are fed for phosphorus removal, either

(and they did install timers on the mixers...)

Process Control for Phosphorus Removal

Why do Process Control?

Process control procedures will tell you how well the WWTP is performing

Process control methods do not need to be difficult or complex

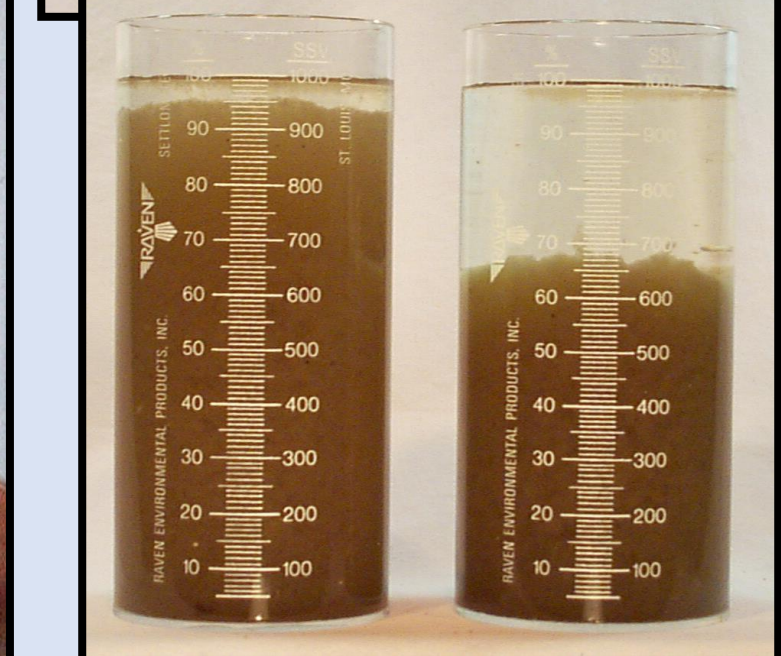
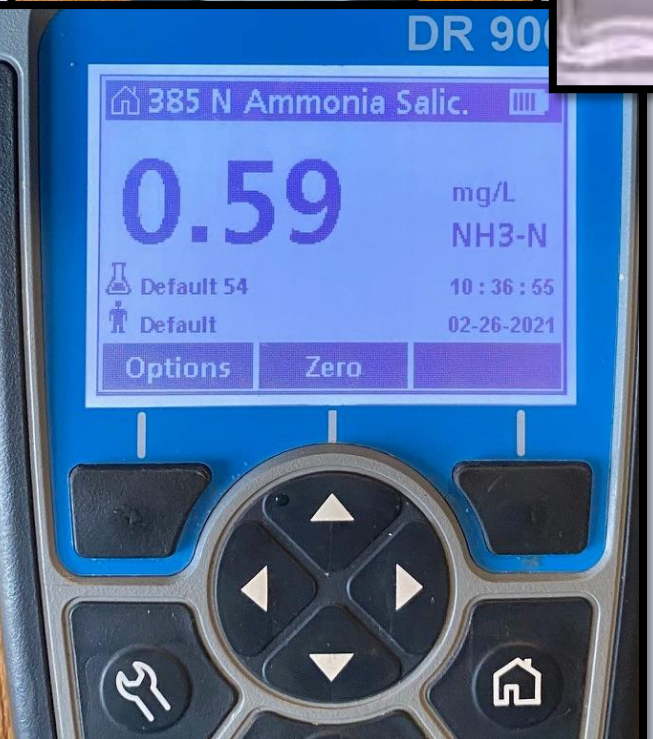
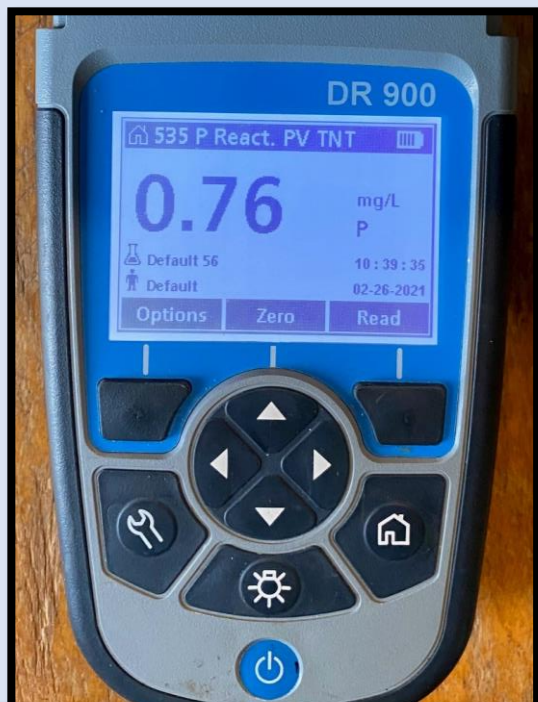
Process control methods should not take all day to get results

Process control should be performed at the WWTP, not sent to a outside lab.

The CAU Process Control Tools

These tools are **cheap, easy, and effective**

- 1) Multiparameter colorimeter
- 2) Dissolved Oxygen Meter
- 3) Alkalinity Test Kit
- 4) Wastewater Centrifuge
- 5) Settleometer
- 6) Core sampler



The CAU Process Control Tools

These tools are **cheap, easy, and effective**

Cheap, because most communities do not have a lot cash

Easy, because if it is difficult, then no one will do it

Effective, because if it is not effective, then why bother?

Why do Process Control?

Effective process control will alert you to when your WWTP begins to move toward noncompliance.

It will give you the data that you need to make the process control decisions that will move the WWTP back toward the middle of the Operational Window and stay in compliance.

Process Control is especially important for effective
Biological Phosphorus Removal

Process Control for Effective BioP Removal

Most failures of BioP Removal that I find are:

Too much nitrate in anaerobic environments

Not enough cBOD to drive the orthophosphate release

Not enough DO to drive the orthophosphate uptake

Process Control for Effective BioP Removal

For effective BNR Process Control:

- 1) Measure nitrate and orthophosphate in the anaerobic environment
- 2) Measure nitrate and orthophosphate in the anoxic environment
- 3) Measure ammonia, nitrate, orthophosphate and DO
in the oxic environment

Questions?

Jon van Dommelen

Ohio EPA – DEFA –CAU

(614) 580-5069

jon.vandommelen@epa.ohio.gov