Dingman-Delaware Valley Middle School STP

Delaware Valley School District
Dingman Township, Pike County

WQM Permits No. 5292402, 5298404

WASTEWATER TREATMENT EVALUATION

Prepared by
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pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION
WASTEWATER TECHNICAL ASSISTANCE PROGRAM

2021

Disclaimers:
The mention of a brand of equipment is in no way an endorsement for any specific company. The Department urges the permittee to research available products and select those which are the most applicable for its situation and compatible with existing equipment.

The goal of the Department's Wastewater Optimization Program is to improve receiving water quality through troubleshooting, training, and monitoring. Permittees may be encouraged to achieve effluent quality above and beyond current permit requirements.

Executive Summary:

Starting in late 2019 and continuing through 2021, staff from USEPA and PADEP provided technical assistance to the operator of the Delaware Valley School District's Dingman Township campus wastewater treatment facility, a Purestream sequencing batch reactor (SBR). The purpose was initially to help resolve issues of excessive nitrate-nitrogen discharges in the treated effluent. Upon further investigation and study, however, consulting staff discovered several physical and operational liabilities that hindered performance, and, working with the operator, identified areas for improvement in the treatment process, including the need for dissolved oxygen control and for influent screening to remove trash and detritus that was damaging pumps and valves. This report summarizes those findings.

Recommendations:

Based on evaluation of the data and observations of the facility, DEP and EPA staff have concurred on the following suggestions for improved process control:

1. Install a dissolved oxygen feedback control system that regulates the bioreactor aeration blower with a variable frequency motor drive. This may require upgrading the blower motor to a higher efficiency model.
2. Have the vendor who provides industrial controls programming add the supplemental carbon (sugar slurry) at the correctly adjusted time in the anoxic, denitrification cycle, after dissolved oxygen residual has depleted to less than 0.5 mg/L.
3. Consider adding additional electronic monitoring and automation of the process, including the use of ORP and pH probes to improve biological nitrogen reduction.
4. Repair voids in the sand mounds and check the drain field pipes for obstructions or collapse that may be creating uneven distribution of treated effluent.
5. Consider adding modern trash screening and removal systems at the headworks of the treatment plant in order to remove plastic and paper trash that damages downstream pumps, valves, and decanters. Fine screening is the best technology for this. Bar racks and comminutors are no longer considered optimal for protecting downstream equipment.[1]
6. Continue adding supplemental organic loading to the influent buffer tank during periods of low loading, especially during long weekends and school holidays. Aside from using expensive, proprietary products, it may be possible to source food manufacturing wastes that can supplement organic loading.
7. Continue to recirculate effluent water to the influent buffer tank to maintain hydraulic loading when it is necessary. At times when the schools are closed, such as weekends and holidays, when flow to the facility is drastically reduced, recirculation can maintain the system and provide diluent for supplemental organic loading.
8. Monitor process alkalinity, and add an alkalinity mixing and liquid slurry feed system, if possible, to supplement alkalinity on an attenuated basis over the course of the day.
9. Consider pump and treat offsite during the summer months when campus activities are minimized. This may prove expensive, but it is likely to be less expensive than the cost of operating the facility with supplemental organic and hydraulic loading for long periods of time.

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[1] Facility staff had consulted with a vendor who recommended installing a small screw-type screening system that will replace the existing comminutor located upstream from an existing screening basket at the flow buffer tank adjacent to SBR #1 in the building. A proposed WQM Permit Amendment is undergoing review and approval. This new screening device will also have a bypass line that would channel potential overflow to the basket screen to prevent overflows should the device become inoperable.

During the evaluation, DEP and EPA staff observed that some process management practices could enhance the operation of the facility.

1. With the facility operator approaching retirement age, the facility owner should consider training additional staff to operate the facility. It was clear during the evaluation that there were times when one operator on staff could have benefitted from assistance with some of the maintenance tasks.
2. The facility has laboratory equipment that ought to be used more frequently to monitor the health and efficiency of the treatment process. While it is often not possible to conduct frequent process monitoring tests, DEP and EPA staff suggest that some process control tests be performed on a weekly or bi-weekly basis. Attachment E, following, includes a list of recommended process monitoring and control tests for a treatment facility of this size.
3. Routine maintenance of epoxy-coated steel tanks is necessary to avert corrosion. The tanks should be cleaned and examined during the idle summer months when it is possible to provide extended time for removing rust, refinishing metal, and performing maintenance on the valves and other moving parts. Check and replace sacrificial anodic devices and system grounding wire annually.
4. Consider alternating treatment units on a semi-annual or annual basis to maintain the idle SBR #2 unit in working condition. It appears that parts from this unit have been cannibalized over the years to keep SBR #1 running. Although the facility has been routinely operated using only one of two SBR bioreactors, the water quality management permit noted that two units are permitted. Both should be maintained in good working order. It may not be possible for the facility owner to drop the second bioreactor unit from the water quality management permit, so it is prudent to repair it.

Background:

The Delaware Valley School District (DVSD) based in Milford, Pike County, Pennsylvania, owns and operates a small-flow wastewater treatment facility located on its elementary and middle school campus in Dingman Township. It is rated for 27,000 gallon per day, with average daily flows of about 10,000 gpd. The system operates under a water quality management permit, #WQM5298404, within the groundwater drainage of Dwarfs Kill Creek in Dingman Township. Because of its groundwater discharge, there is a concentration-based limit on nitrate-nitrogen for a monthly average of ten milligrams per liter (10 mg/L.)

In 2019, the Northeast Regional Office of Pennsylvania Department of Environmental Protection (PADEP) referred the school district to staff of US Environmental Protection Agency Region III Office of Infrastructure and Outreach (EPA) due to ongoing nitrate exceedances from its facility. The treatment facility automated computer program had been modified to include denitrification during a mixed fill cycle; however, the facility was chronically underloaded and lacked sufficient organic loading required for denitrification to be successful.

EPA staff began to work with the facility operator at DVSD to troubleshoot and assist in developing strategies for maintaining wastewater biology through periods of extended cold and limited organic loading. A complication of the process is that when ammonium-nitrogen is discharged to the sand mounds, it is oxidized by soil nitrifying bacteria to nitrate, thereby increasing the potential high concentration of nitrate in groundwater drainage into Dwarfs Kill watershed and residential wells. Working with EPA staff, the operator adjusted SBR timings and cycles to optimize biological nutrient reduction (BNR) under cold and low-loading conditions.

EPA staff then invited instrumentation assistance from PA Dept. of Environmental Protection's Wastewater Technical Assistance Program (WWTAP). In November 2019, DEP staff installed dissolved oxygen (DO) and oxidation / reduction potential (ORP) probes to monitor two useful parameters for biological nitrification and denitrification. DEP's initial concern was that the dissolved oxygen residual in the SBR remained high into the denitrification cycle, preventing anoxic conditions necessary for facultative, heterotrophic bacteria to consume nitrate. The operator attempted minor process adjustments in aeration time and the aeration blowers' check valves. He also set up a day tank with a metering pump to add dissolved table sugar as a supplemental carbon source, but initially, the metering pump was not limited to the SBR's anoxic treatment cycle.

The Covid pandemic shut down the project in early 2020 when the two schools closed prematurely, and quarantines began. DEP and EPA staff were unable to retrieve equipment until late August of 2020. When the schools reopened the following academic year, DEP returned with more monitoring equipment, including nitrate and ammonium probes to measure nutrient nitrogen and a pH probe to monitor mixed liquor pH during the aeration cycle, when nitrification acidifies the mixed liquor. On a weekly basis, the operator downloaded data and forwarded it to EPA and DEP for graphical analysis, review, and recommendations.

Attachments following this report include a list of the principal participants in the study as Attachment A. Probe locations and facility flows are diagrammed in Attachment B. Graphs of operational data follow in Attachment C, while record photographs comprise Attachment D. Attachment E summarizes recommended process monitoring tests for small-flow facilities. A brief discussion of biological nitrogen removal follows as Attachment F. Because alkalinity adjustment is so important, Attachment G presents a method for calculating alkalinity demand based on influent nitrogen loading. Attachment H includes information on continuous monitoring probes recommended for BNR.

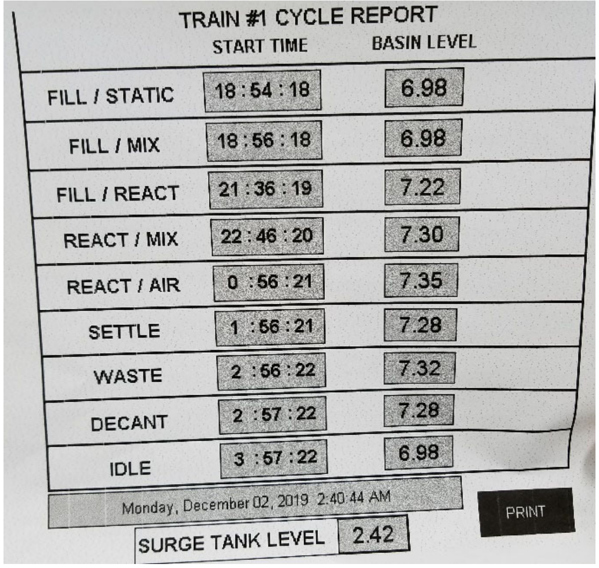
Treatment Process:

DDVSD's Purestream package plant SBR is a two-stage, dual train treatment unit utilizing activated sludge under periods of aeration and anoxic mixing to remove pollutants from domestic sewage and institutional cooking and cleaning. The operator reports the average hydraulic flow is between 10,000 and 12,000 gpd, depending on use of two schools, the Dingman-Delaware-Middle School and the Dingman-Delaware Primary School. This facility treats only wastewater generated on-site by the two schools, their support services, and the offices associated with them. The influent wastewater is characterized by low-to-moderate organic concentration and relatively high ammonia-nitrogen concentration. The original design values for construction were:

Total Suspended Solids:	400 mg/L
Biological Oxygen Demand (5-day):	400 mg/L
Ammonia-Nitrogen:	90 mg/L

Because the historical average hydraulic and organic loading have been relatively light, only one of the two trains is in active service, averaging ten thousand gallons per day. The other unit is used for peak use periods and for extra storage capacity, although it appears to have been idle for considerable time and is likely to be in disrepair.

The Purestream package plant has a small surge tank to store incoming wastewater and attenuate flow into the biological reactor, but a larger flow equalization tank was added some years ago, with a comminutor used to shred rags and detritus prior to treatment. Influent to the surge tank also passes through a modest bar screen. Subsequent treatment may include addition of coagulants to aid in sludge settling. There is an aerated sludge holding tank for waste sludge, and conveyance to a distribution field where there are sand mounds. There is evidence of older, disused underground storage and distribution. The SBR process is automated in part to regulate the duration of various treatment cycles, and the operator can adjust aeration through addition or deletion of weights to the rotary-lobe blower check valves. The decant and sludge wasting pumps are electromechanical.



TRAIN #1 CYCLE REPORT

	START TIME	BASIN LEVEL
FILL / STATIC	18 : 54 : 18	6.98
FILL / MIX	18 : 56 : 18	6.98
FILL / REACT	21 : 36 : 19	7.22
REACT / MIX	22 : 46 : 20	7.30
REACT / AIR	0 : 56 : 21	7.35
SETTLE	1 : 56 : 21	7.28
WASTE	2 : 56 : 22	7.32
DECANT	2 : 57 : 22	7.28
IDLE	3 : 57 : 22	6.98

Monday, December 02, 2019 2:40:44 AM

SURGE TANK LEVEL 2.42

Treated effluent is pumped to elevated sand mounds adjacent to the building housing the SBRs. The original plans for the site showed up to six sand mounds could be accommodated. Originally, four were constructed, and another was added seven years later in 1999.

An example of the SBR timing is displayed at the left. The working bioreactor has about three batches per day.

Wastewater Treatment Evaluation:

The waste stream is characterized by high ammonium content and modest, even light, organic carbon loading. In December 2020, ammonium nitrogen in the wastewater was 66.8 mg/L in concentration, while BOD averaged 102 mg/L. The ratio of ammonia to total Kjeldahl nitrogen (TKN) was 94%, considerably higher than the average 70% for purely residential waste.[2] Also, the influent loading varied according to the academic calendar, and during weekends and holidays, very little to no waste is generated save, perhaps, from janitorial services. This creates a “feast or famine” loading condition that is not particularly conducive to biological nutrient reduction (BNR).

Due to this inconsistent organic loading, the evaluators found that insufficient carbon may be available to drive denitrification after completion of aerobic processes. To remedy this, the operator constructed a feed system that adds dissolved sugar to the bioreactor at the peak of the denitrification cycle. This system was to be controlled by the Purestream’s SCADA program, but it took a long time for the programming changes to be sub-contracted.

Treated effluent is returned to groundwater in leaching fields. Biological nutrient removal (BNR) for nitrate reduction may be easily achieved by cycling activated sludge aeration, controlling maximum dissolved oxygen residual in the mixed liquor, and meeting the alkalinity demand of the nitrification process using a variety of compounds like sodium bicarbonate and soda ash. For periodically underloaded facilities such as DDVSD’s STP, addition of supplemental organic carbon is necessary to promote BNR.

The denitrification cycle of treatment has been hindered by excessive dissolved oxygen residual concentrations. This could be fixed by installing variable frequency drives (VFD) on the rotary lobe blowers and using a dissolved oxygen probe in the SBR to control the VFD. This is a recommended process control improvement.

Organic loading used to maintain healthy biomass over routine weekends and holidays included a recommended mixture of dry dog food that has been predigested to render it more bioavailable. Per recommendations, the operator pre-digested the mixture overnight before adding it to the process. These small batches were added to the influent buffer tank on Fridays. EPA staff also

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[2] High ammonia waste is typically found in wastewater from schools. TSS typically comes from food processing operations in the schools, and other solids contributions are lower than found in average domestic waste.

recommended that the operator recirculate process effluent water during the weekends and holidays to reduce SBR idle-time and maintain hydraulic loading.

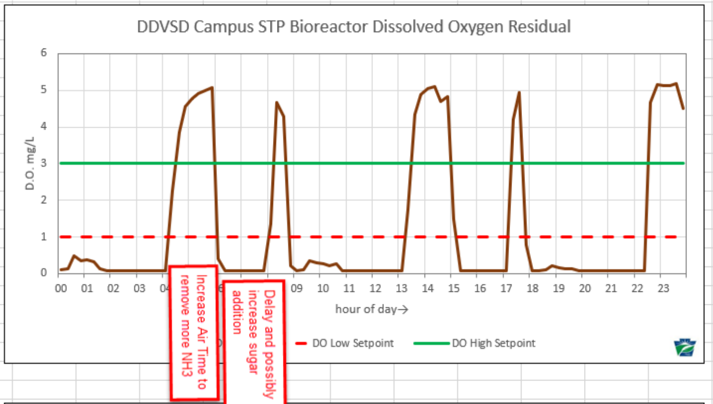
Pre-digestion involved acidifying the batches to break down complex fats, oils, and greases (FOG) and complex carbohydrates and proteins in the dry dog food kibble to make it more bioavailable as soluble BOD_5. Accumulated FOG in the bioreactor would otherwise promote the growth of filamentous bacteria that could hinder sludge settleability during the settling and decant phase of the SBR cycle. A small amount of home laundry detergent was added to the batch as a source of enzymes to further break down complex food into simpler molecules for the bacteria. Prior to adding the batch to the influent wastewater, the pH was neutralized using a high pH base. These batches were made up on a trial and error basis, as there was no dosing literature available. Besides using dog food, some sources have recommended using rabbit or fish feed; others have recommended sourcing food-manufacturing waste to supplement organic loading, but finding such a food manufacturer nearby, with an acceptable type of waste, was not possible.

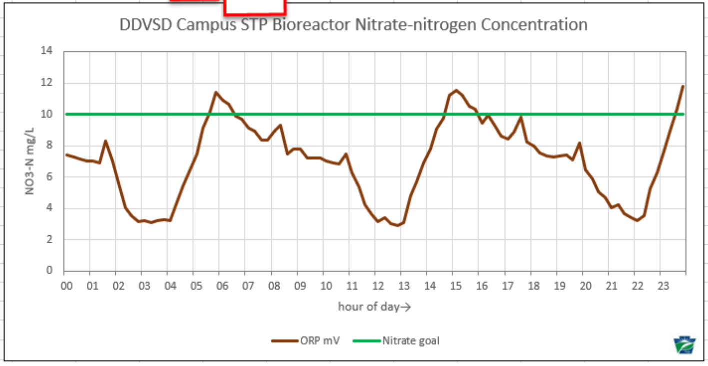
Addition of urea-nitrogen fertilizer to the raw wastewater buffer tank on weekends and school holidays was recommended to help maintain the nitrifying bacteria when growth was hindered by lack of sustained organic loading.

The emergence of the Covid-19 pandemic in February 2020 led to the schools being closed for the remainder of the academic year. By summer, ultimately, the operator had shut down the Purestream treatment system and the facility moved to a pump-and-treat-offsite strategy to maintain permit compliance. During the summer, the facility had little organic loading, but the use of sanitizers and bactericides in the schools had increased. The operator shut down the SBR and had contracted with septic haulers to transport wastewater off-site for treatment.

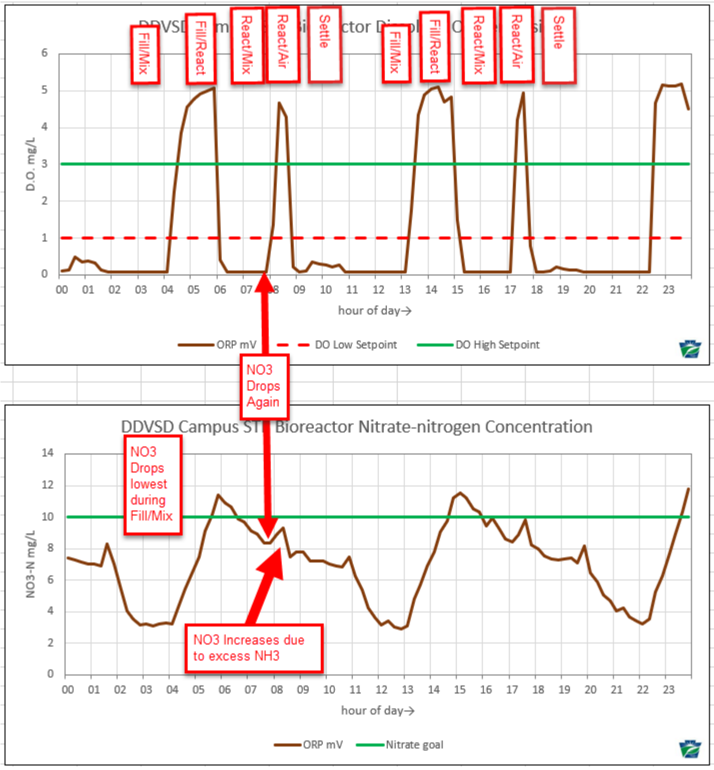
Schools reopened on a limited basis at the beginning of the new academic year in September 2020, and instrumentation was reinstalled. This time, at the request of new DEP staff, ammonium and nitrate probes were installed to monitor nitrogen, and pH was also added for monitoring production of acid waste during nitrification, showing increased need for alkalinity addition. Selected graphs for these measurements follow in Attachment C. Monitoring continued through the autumn semester.

The graph set at the right displays a 24-hour monitoring period for SBR 1 after increasing aeration time to oxidize more ammonium. The lower graph displays the concurrent increase in nitrate production, followed by the depletion of nitrate during the anoxic denitrification cycle.





The graph set on the following page shows the same data set with the SBR cycles labeled. It was found that denitrification is optimal during the fill-mix cycle, when organic carbon in the wastewater is available to the bacteria that utilize nitrate as their oxygen course when dissolved oxygen isn't available. A small increase in nitrate concentration at the start of the react/aeration cycle occurs when the ammonium in that newly introduced raw wastewater is oxidized.



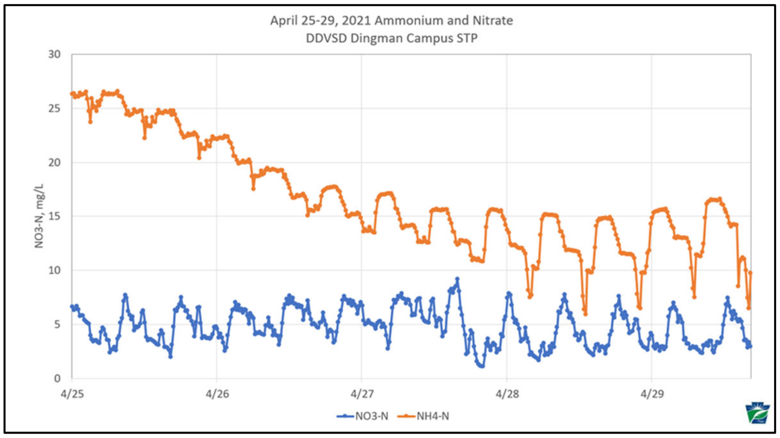
Use of the instrumentation allowed the operator to adjust cycle timing to optimize both nitrification and denitrification. It is important to remember that any untreated ammonia that passes on to the sand mounds will be oxidized to nitrate there without the full benefit of denitrification to reduce the concentration of nitrate entering the groundwater supply.

One issue that arose during the evaluation was that significant amounts of trash and detritus entered the surge tank following passage through a comminutor upstream. The material entering secondary treatment tended to accumulate in the tanks and cling to diffusers, valves, pumps, and instrumentation to a degree that damaged many submersible pumps over the years and contributed to overall wear and tear on the facility.

EPA staff recommended to the operator a consultation by a vendor of wastewater equipment to propose replacing the comminutor with a more modern technology that continually screens the wastewater and removes trash rather than simply grinding it up and sending it forward.

In the time since the evaluation ended, the operator and the vendor proposed and contracted for installation of a new screening system. This will significantly reduce unwanted rags and plastics from fouling the activated sludge treatment and eliminate the potential for microplastics to foul the drain fields and their effluent distribution pipes. In 2020, the facility engineer submitted a Part II NPDES Permit amendment application for this, and it was approved by the Department in 2022.

In late April 2021, the operator hired a contractor to modify the SBR control program to add sugar slurry at the optimal time for denitrification, and during the last days of the month, the facility did achieve denitrification on a limited basis. Unfortunately, following the summer recess of the schools



Reduction of both ammonium and nitrate in the bioreactor suggests successful biological nitrogen removal has occurred in the presence of anoxic conditions, alkalinity, and supplemental carbon addition.

some weeks later, the facility's organic loading dropped considerably, and the treatment process became less efficient. However, the facility was able to briefly achieve successful BNR by a combination of adjustments to the SBR timing, alkalinity supplement-ation, and organic carbon supple -mentation. It is believed that instrumentation to control aeration, recirculation of effluent during slack times along with adding supplemental organic loading, alkalinity control, and the use of sugar slurry addition during denitrification will allow the operator to replicate these treatment conditions on a regular basis.

Thus, the next step would be to add variable frequency drives (VFD) to the aeration blowers in order to regulate the dissolved oxygen residual in the bioreactor tank. Activated sludge treatment requires DO residuals of 1.5 mg/L to 3.5 mg/L to effectively treat organic waste and to oxidize ammonia. Over-aeration of the activated sludge makes removal of the oxidized nitrogen more difficult, because it prevents anoxic denitrification from occurring during the mixed fill cycle of the SBR. Biological denitrification will occur only when facultative bacteria have no dissolved oxygen to use for respiration. Anoxic conditions force the bacteria to take oxygen from dissolved nitrate. At the end of this process, molecular nitrogen gas is released into the air. That means there will be less nitrate entering the groundwater and potentially causing harm to users of well water. Biological Nutrient Removal is discussed in more detail in Attachment F, following.

The facility's positive displacement, or rotary lobe, blowers are ideal for using VFDs on their motors. A dissolved oxygen probe placed in the working bioreactor would signal the VFD to increase or decrease power to the blowers, regulating the DO residual within optimal limits. Adding this technology to the treatment system should be the next process control project, after the headworks screening upgrade has been completed.

Process Monitoring and Control:

Attachment E, following, contains information on recommended process monitoring tests that the current operators should pursue to achieve operational efficiencies. The operator with whom EPA and DEP had worked did conduct regular testing for mixed liquor settleability, sludge volume by percent, microscopy, and nutrient residual testing. Once per month or more often as needed, he sent mixed liquor samples to a commercial laboratory for mixed liquor suspended solids and volatile suspended solids testing, using the test results to guide setting wasting rates and to calibrate his sludge solids centrifuge test. (weight-to-concentration ratio) This process monitoring testing is essential to operating an activated sludge process, and it is important for operators to supplement their training on the subject. The end goal of regular process monitoring is to achieve steady-state conditions in the facility, operating according to the facility's recommended process control goals, food-to-mass ratio, mean cell residence time, or solids retention time.

Condition of Physical Plant:

Overall, the treatment facility is operational enough to meet the demands of its service area. During the evaluation, though, general deterioration of the Pure Stream steel tanks was noted, where the epoxy finish was damaged or missing in places, resulting in corrosion that could affect the service life of the tanks. These tanks are installed with supplemental sacrificial anodes meant to reduce corrosion. Such anodes do not last indefinitely and must be renewed to assure continued integrity of the tanks. If this has not been recently investigated, it would be useful to do so. Additionally, corrosion and rust on the tanks should be remediated to the bare metal, and that metal should be protected by refinishing it with the manufacturer's recommended coatings.

The second of two bioreactor spaces has been used for overflow space, but the unit appears to have been salvaged for replacement parts over time and may no longer be fully functional. Attention should be paid to refurbishing these facilities and then alternating the use of bioreactors, if necessary, to prevent loss of function. The built-in sand filter units apparently do not work and exist merely as “a wide spot in the line.” A regular program of preventative maintenance is recommended to assure the idle or standby processes are ready for use when pressed into service.

Earlier compliance enforcement inspection reports by the Department have noted that the drain fields may have voids. If the drain fields have not already been serviced, it is recommended that this work be completed, not only to fill voids but also to remove any detritus that may have become lodged in the pipes where it impairs proper functioning of the drain fields.

It is recommended that the facility’s consulting engineer evaluate the physical plant with an eye to assuring its continued operation in future years, improving the treatment process where necessary either because of evolving regulations or the need to optimize treatment to achieve better treatment, energy, and cost efficiencies.

Acknowlegements:

The Department recognizes and appreciates the teamwork of facility operator, Frank Navarro, and EPA Region 3 Infrastructure and Assistance staff, Walter Higgins, in this wastewater treatment evaluation field work performed while bracketed by the international Covid-19 pandemic. Their assistance and insight were valuable in understanding the facility’s needs and requirements, as were their diligence in continuing to work through the epidemic.

LIST OF ATTACHMENTS

Attachment A lists the primary participants in this study.

Attachment B shows the original treatment schematic for the treatment facility

Attachment C consists of graphs of data recorded by the continuous immersion probes

Attachment D contains some record photographs of the project.

Attachment E tabulates the water quality management permit limits for the facility

Attachment F discusses recommended process monitoring tests and their frequency

Attachment G is a discussion of biological nutrient removal

Attachment H is a method for calculating supplemental alkalinity dosing

Attachment I estimates the current costs for equipment like that employed during the study.

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ATTACHMENT A: EVALUATION TEAM

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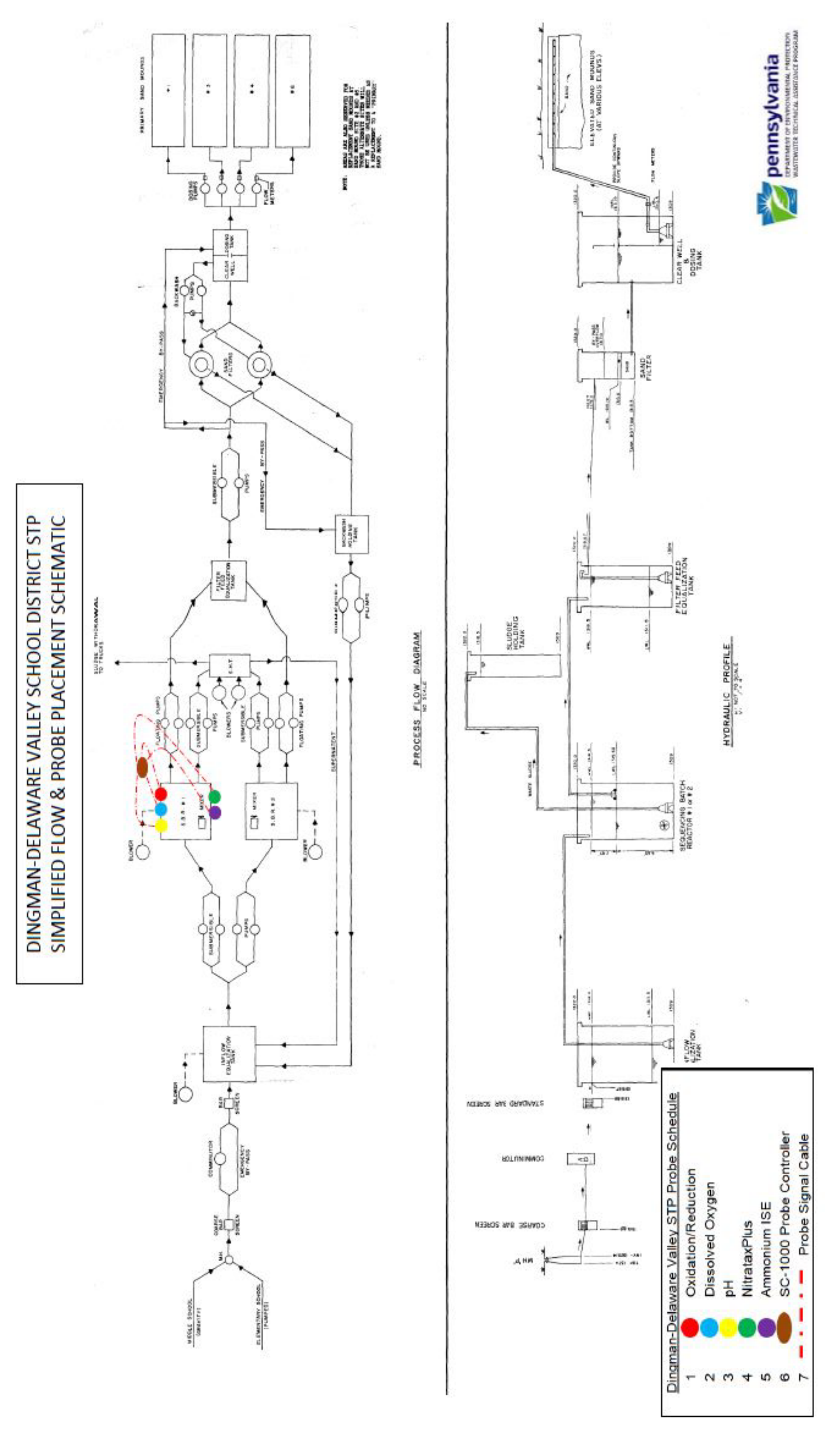
ATTACHMENT B: EQUIPMENT PLACEMENT SCHEMATIC

This diagram shows the treatment process and equipment placement.



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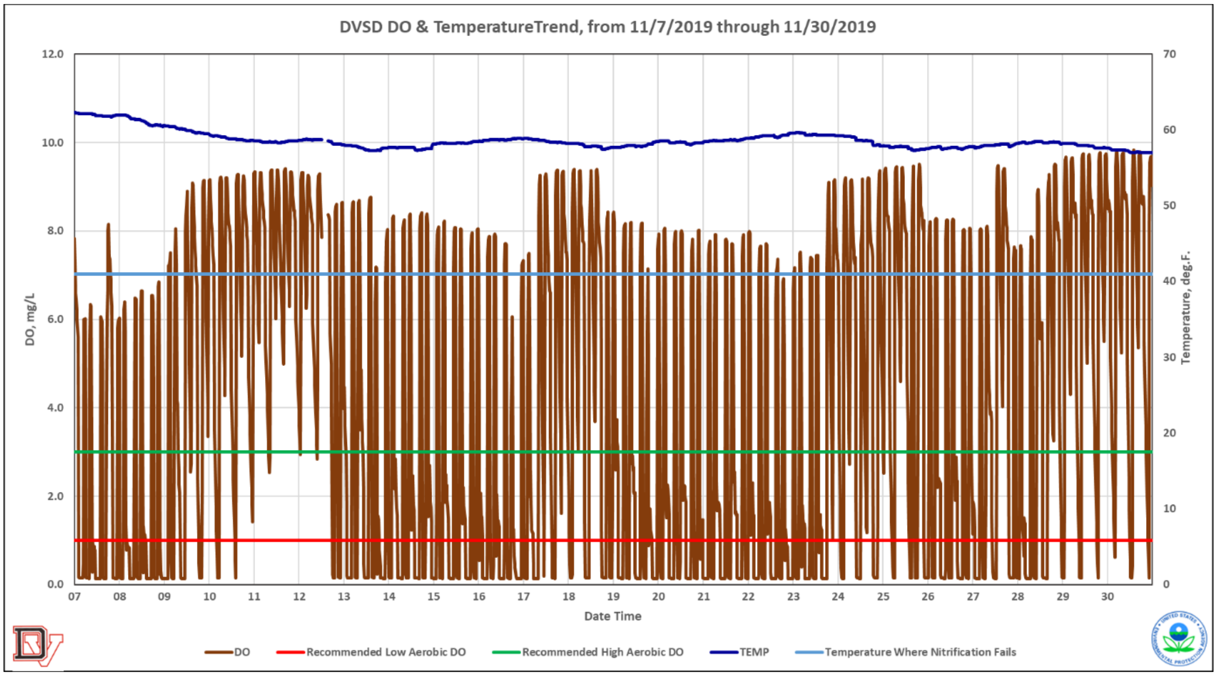
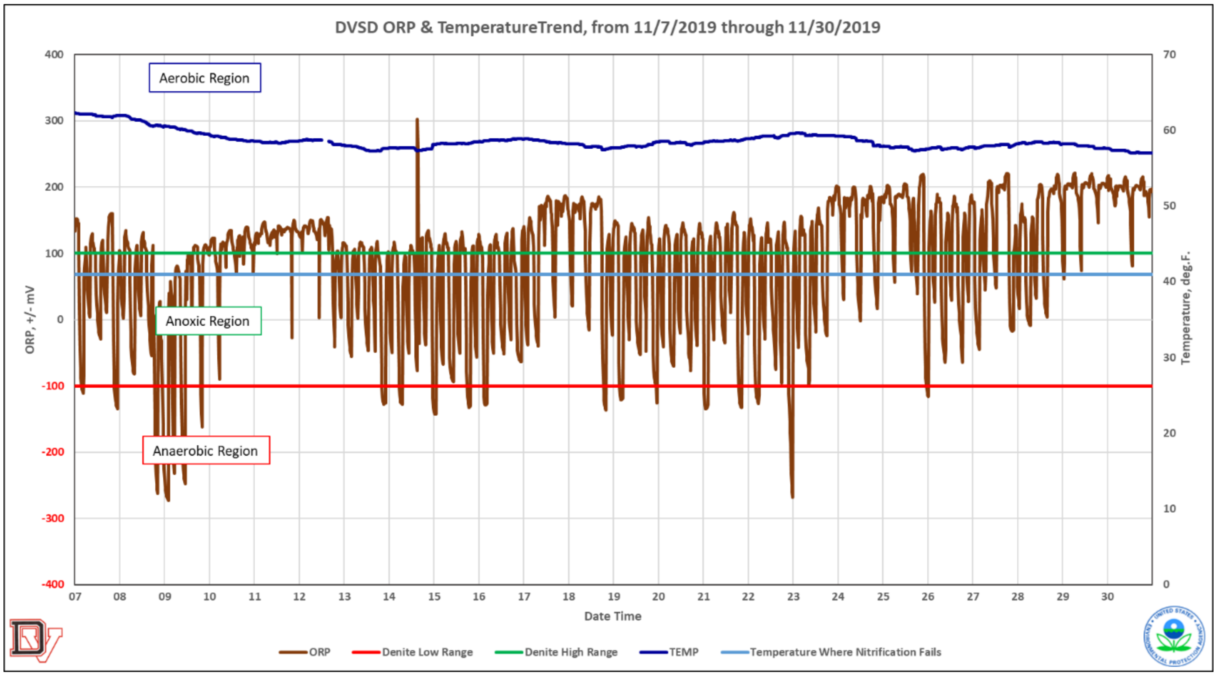
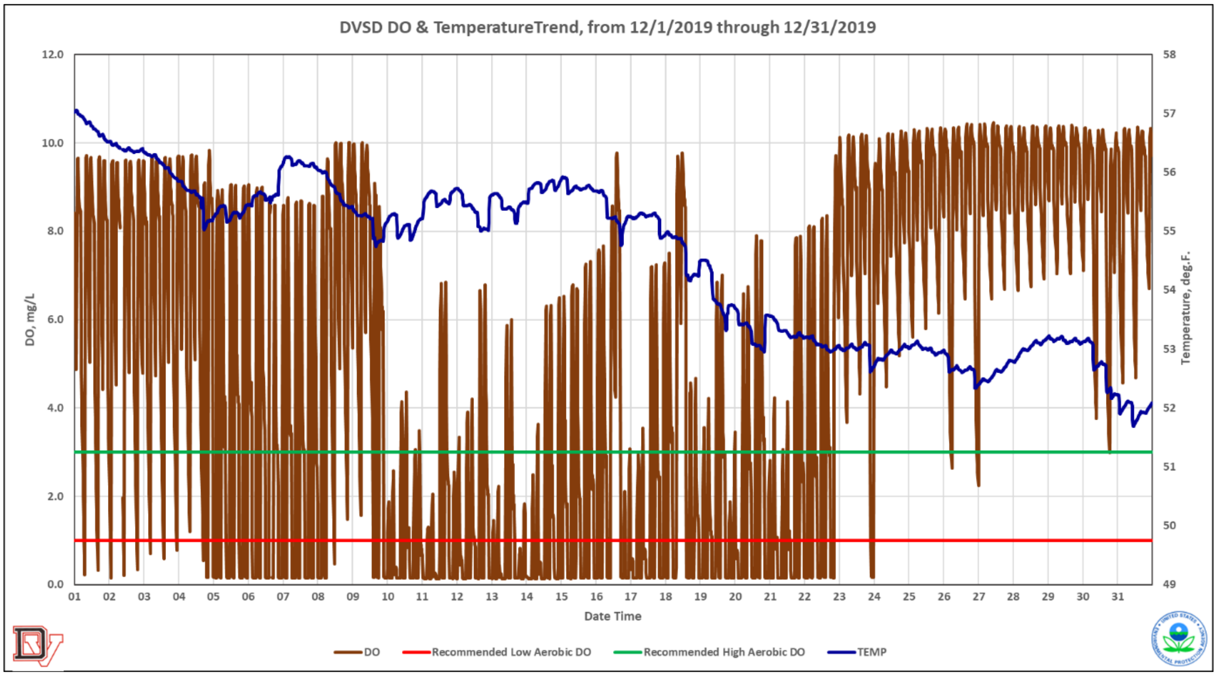
ATTACHMENT C: OPERATIONAL DATA

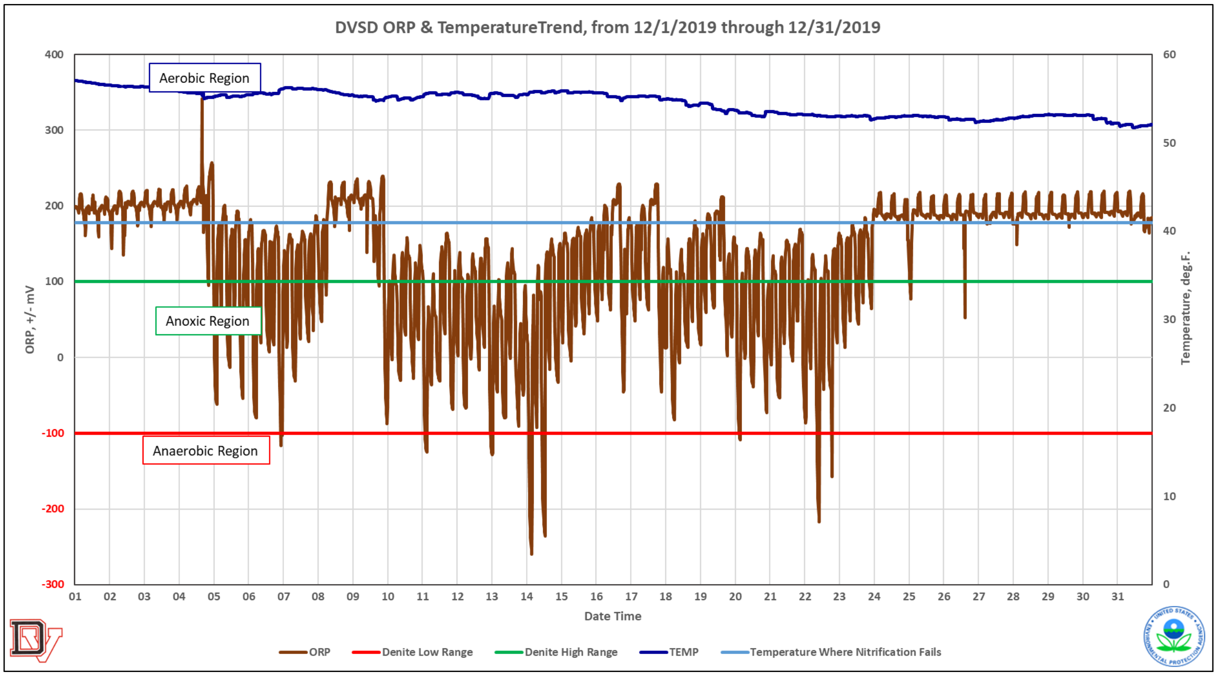


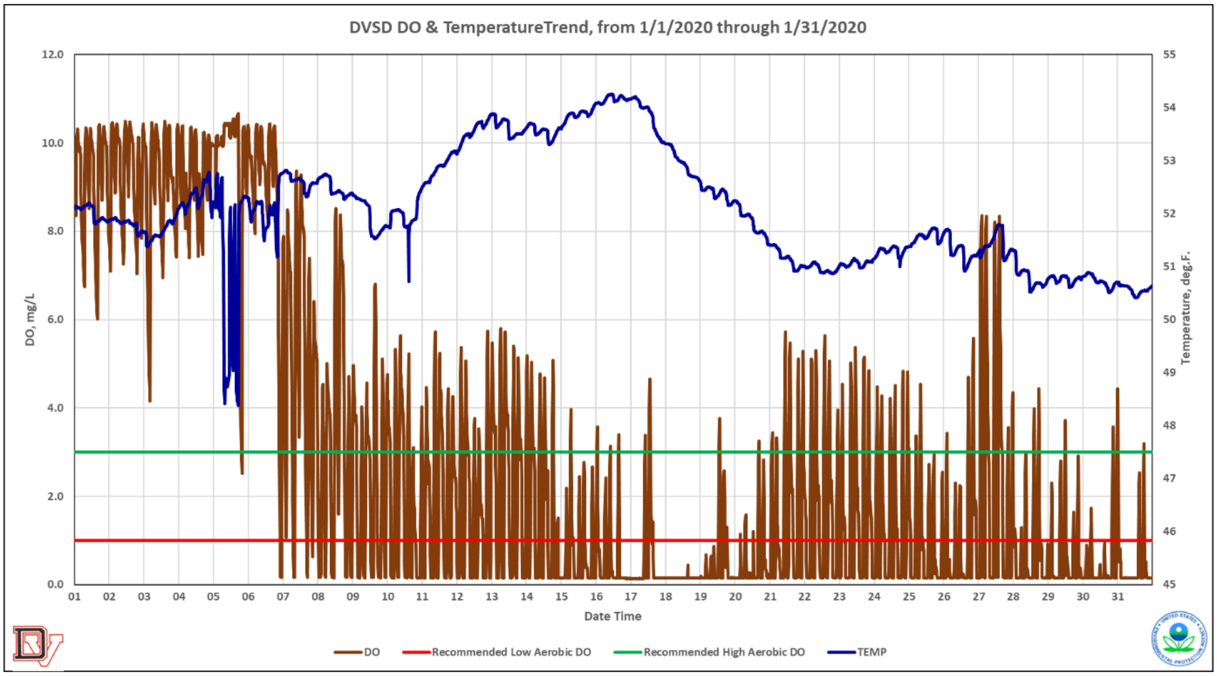
Bioreactor Dissolved Oxygen residual of mixed liquor in bioreactor, November 2019: Note suggested D.O. maximum concentration is often exceeded. Installing DO controls on the aeration system would limit DO residual to manageable levels while simultaneously saving energy consumption.

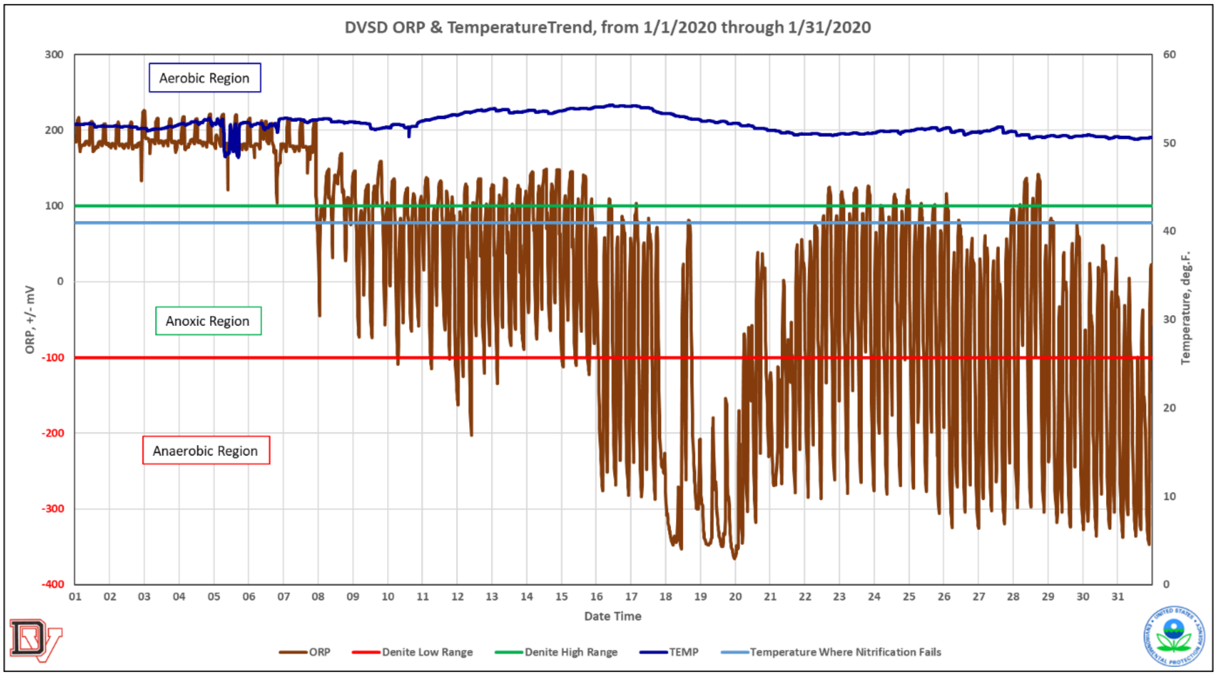


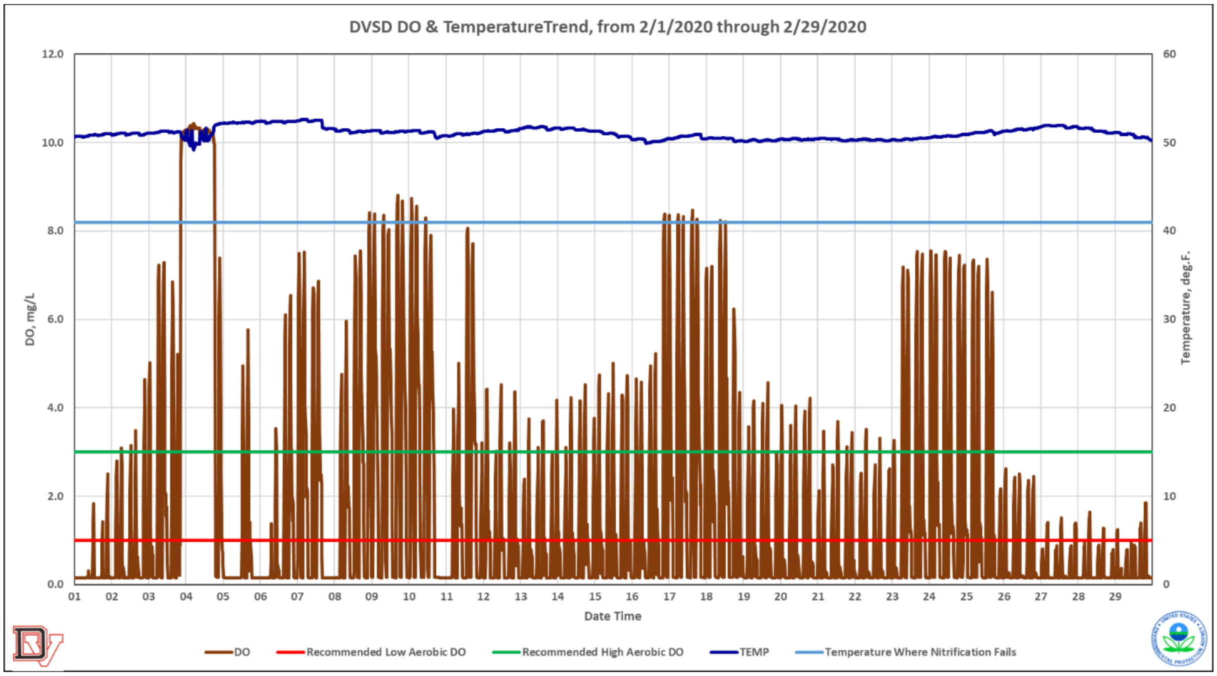
Oxidation/Reduction Potential (ORP), November 2019, history shows generally good anoxic ranges (between the green and red limits) where denitrification is optimal. ORP should be above 100 mV for good nitrification and between 100 mV and -100 mV for nitrate reduction. In the anaerobic region, sulfur-reducing bacteria and other bacteria form noxious odors and organic intermediates that degrade effluent quality.


DVSD DO & TemperatureTrend, from 12/1/2019 through 12/31/2019
DO, mg/L
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Temperature, deg.F.
58
57
56
55
54
53
52
51
50
49
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date Time
DO
Recommended Low Aerobic DO
Recommended High Aerobic DO
TEMP

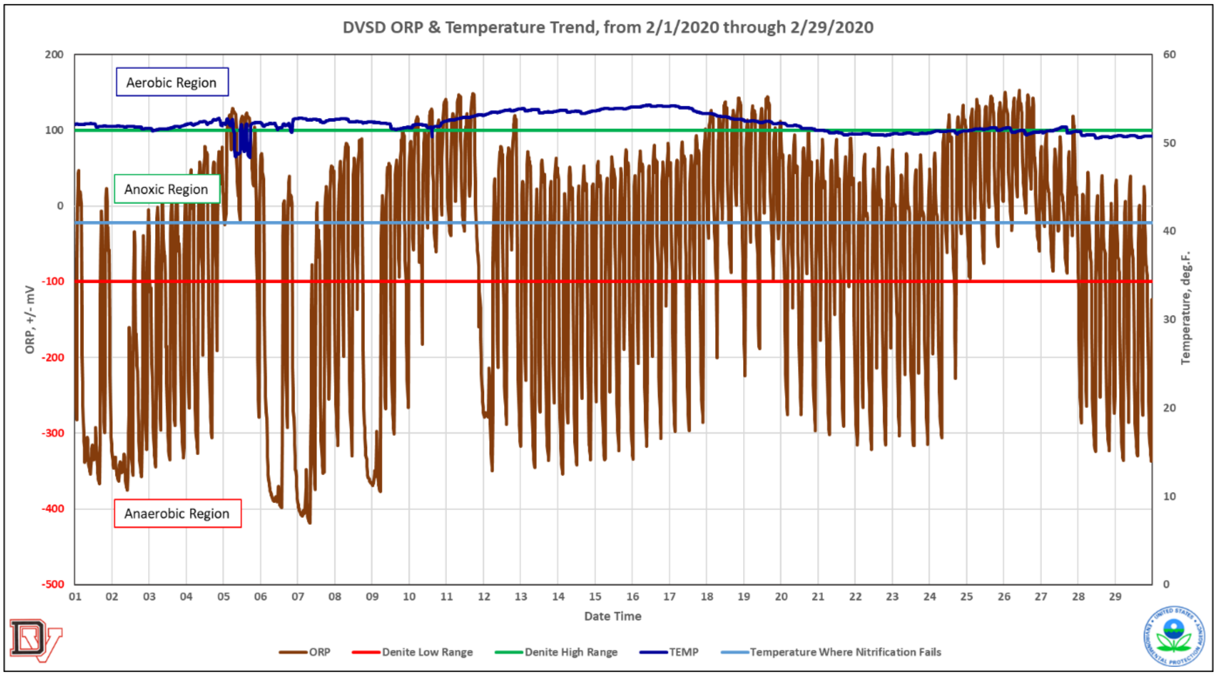

DVSD ORP & TemperatureTrend, from 12/1/2019 through 12/31/2019
ORP, +/- mV
400
300
200
100
0
-100
-200
-300
Temperature, deg.F.
60
50
40
30
20
10
0
Aerobic Region
Anoxic Region
Anaerobic Region
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date Time
ORP
Denite Low Range
Denite High Range
TEMP
Temperature Where Nitrification Fails


DVSD DO & TemperatureTrend, from 1/1/2020 through 1/31/2020
DO, mg/L
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Temperature, deg.F.
55
54
53
52
51
50
49
48
47
46
45
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date Time
DO
Recommended Low Aerobic DO
Recommended High Aerobic DO
TEMP

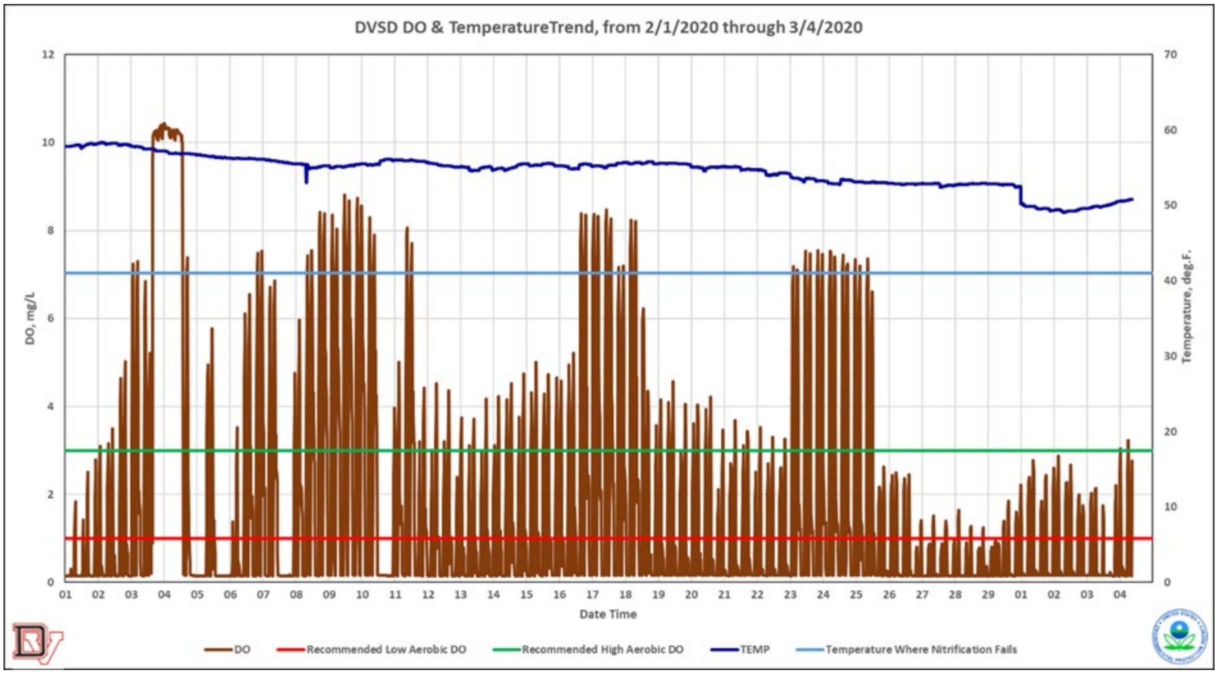

DVSD ORP & TemperatureTrend, from 1/1/2020 through 1/31/2020
Aerobic Region
Anoxic Region
Anaerobic Region
ORP, +/- mV
300
200
100
0
-100
-200
-300
-400
Temperature, deg.F.
60
50
40
30
20
10
0
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Date Time
ORP
Denite Low Range
Denite High Range
TEMP
Temperature Where Nitrification Fails



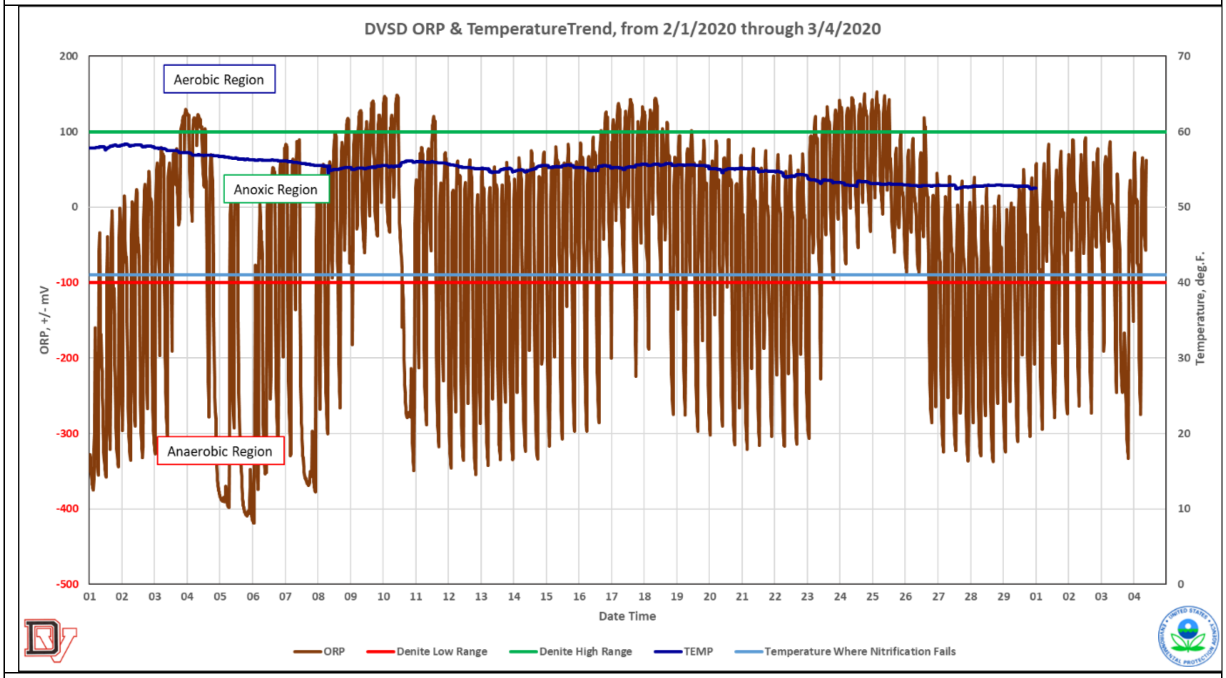
DVSD DO & TemperatureTrend, from 2/1/2020 through 2/29/2020



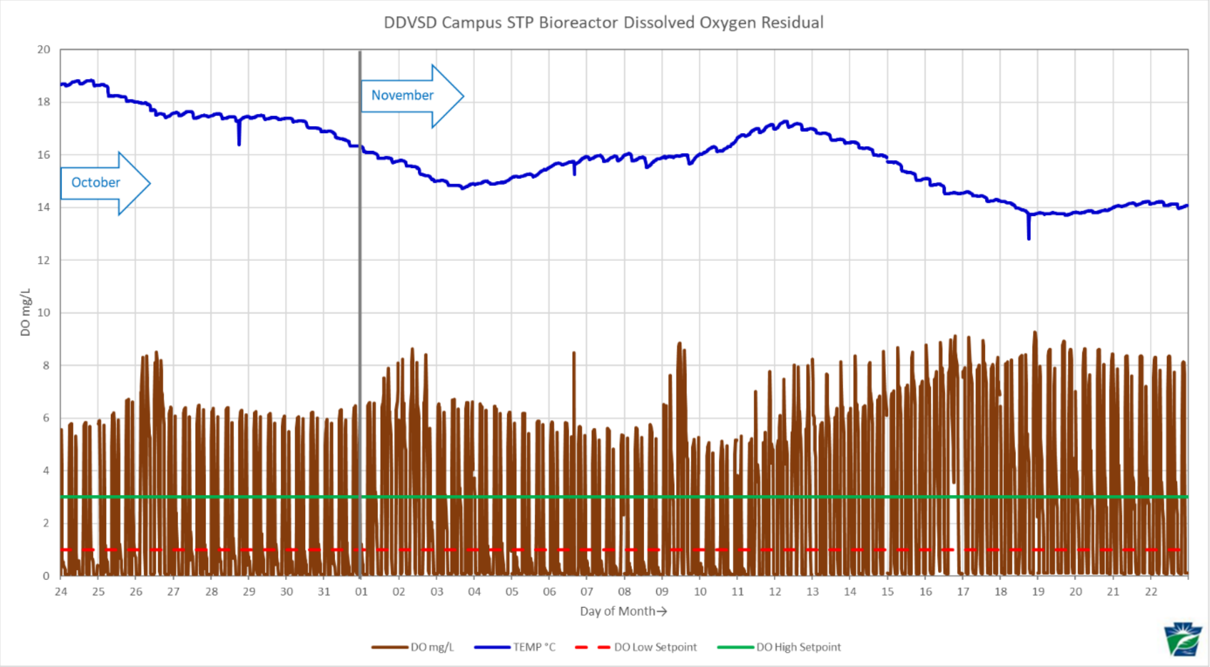
DVSD ORP & Temperature Trend, from 2/1/2020 through 2/29/2020



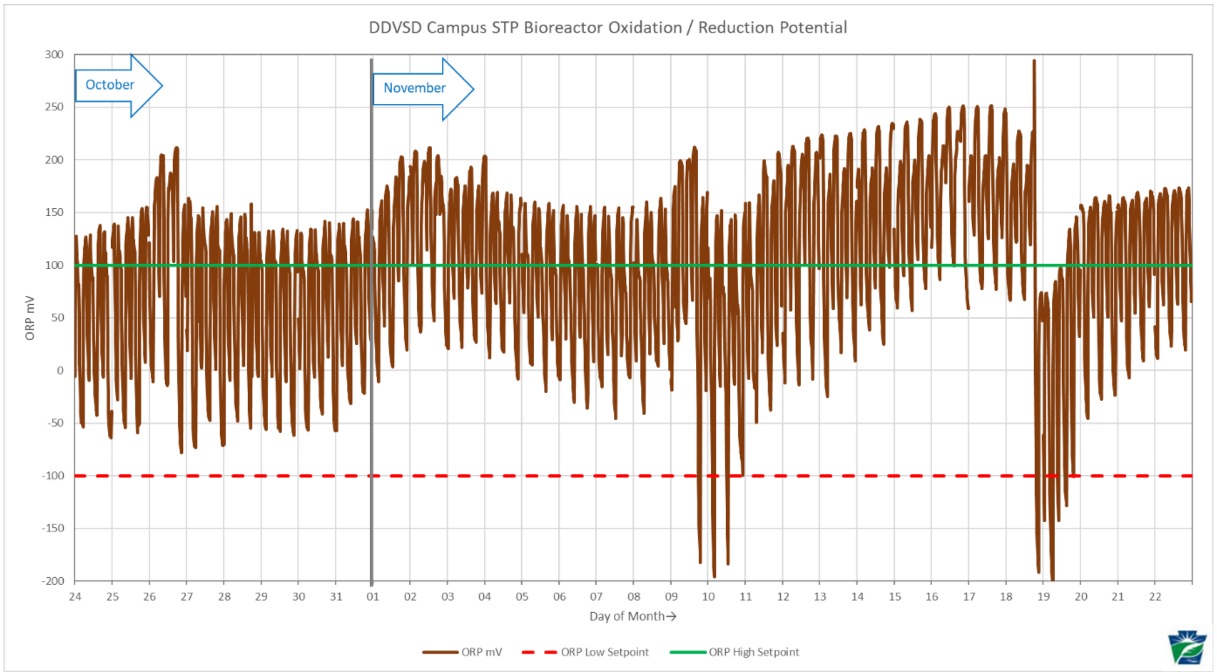
D.O. and Temperature from 2/1/20 to 3/4/20, to the beginning of Covid-19 quarantine.



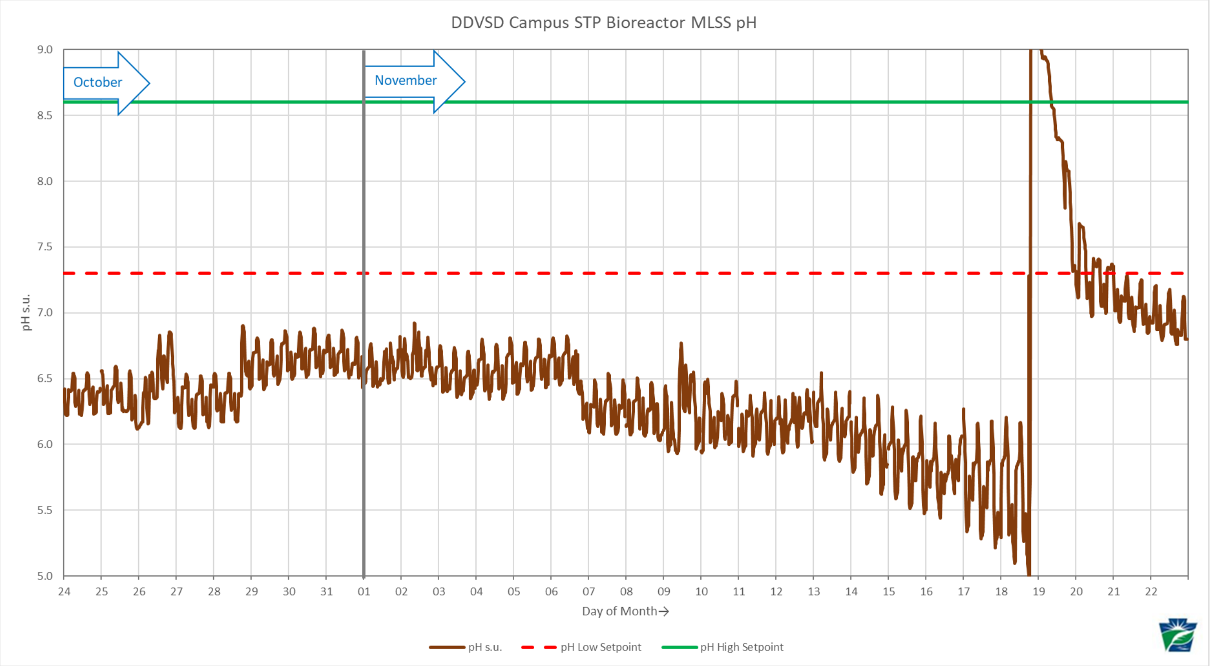
ORP and Temperature from 2/1/20 to 3/4/20, to the beginning of Covid-19 quarantine.



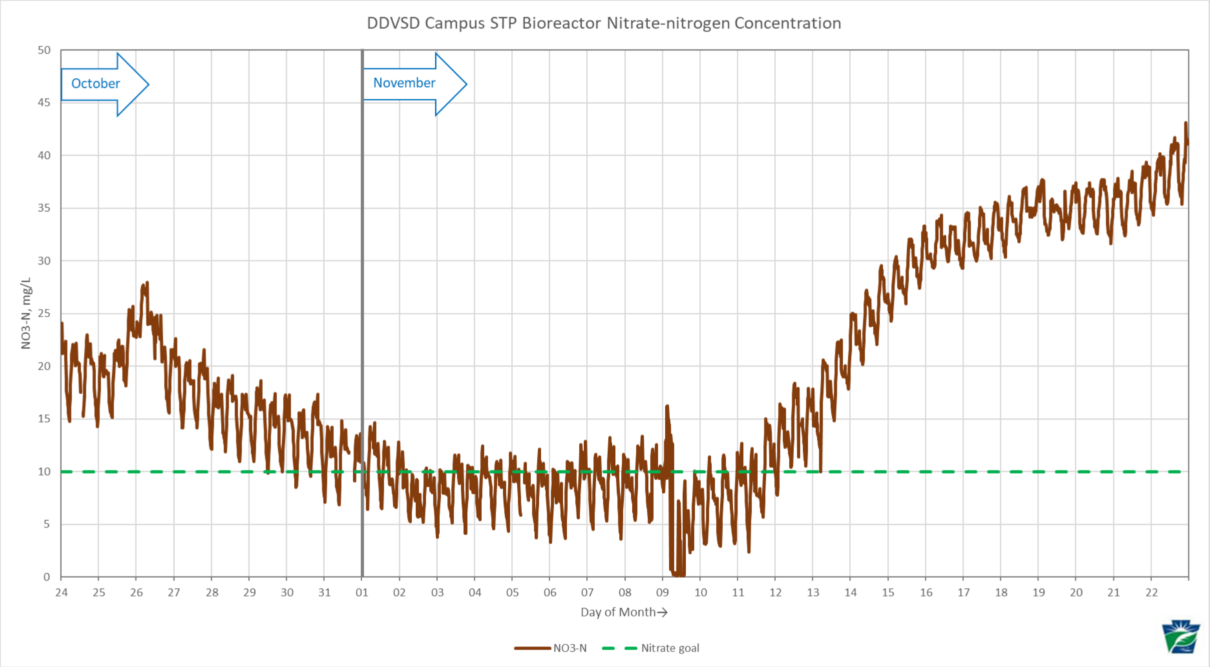
2020 October and November Bioreactor Dissolved Oxygen Residual & Temperature



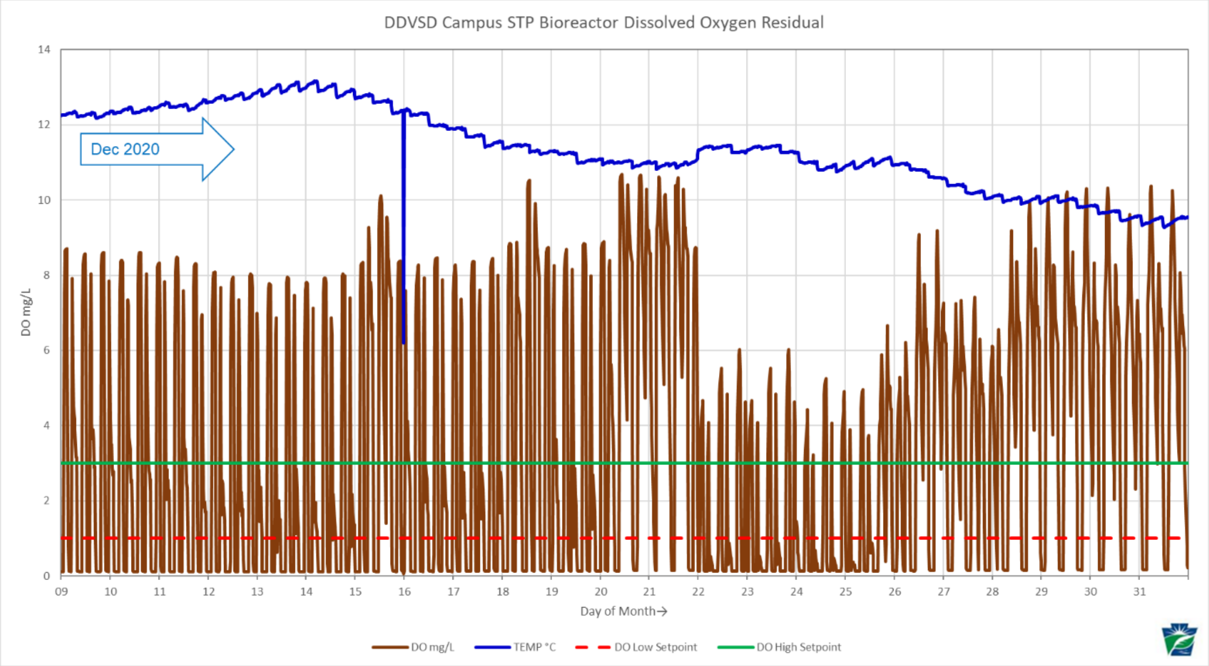
2020 October and November Bioreactor Oxidation/Reduction Potential



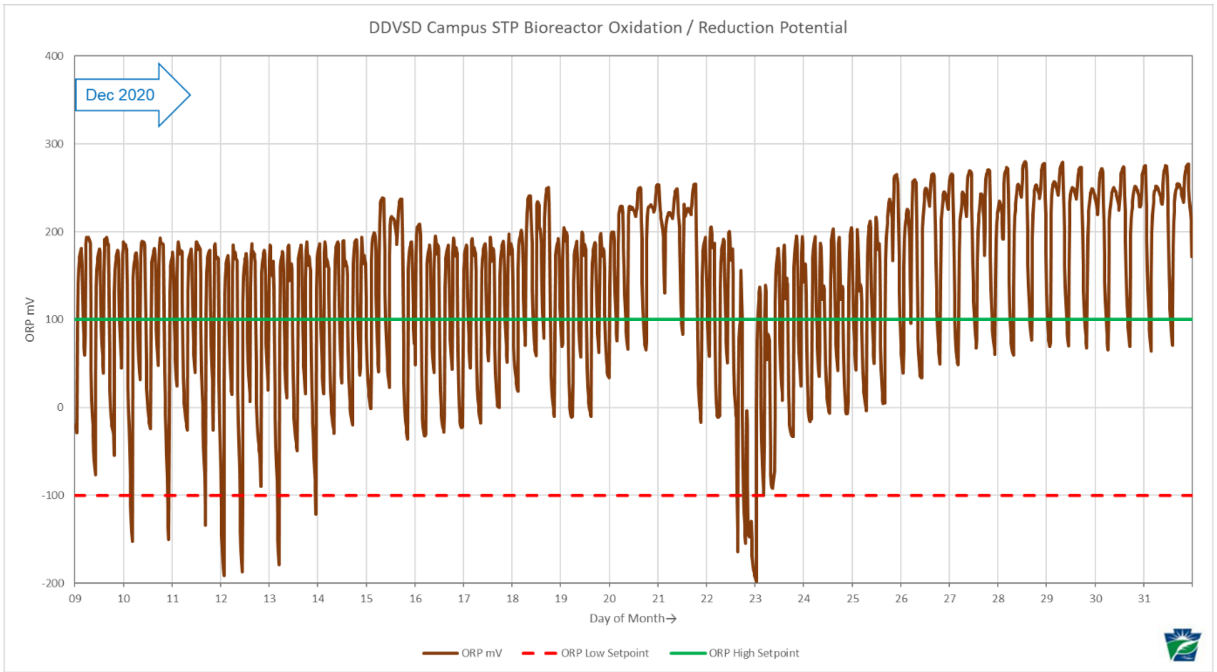
2020 October and November Bioreactor pH



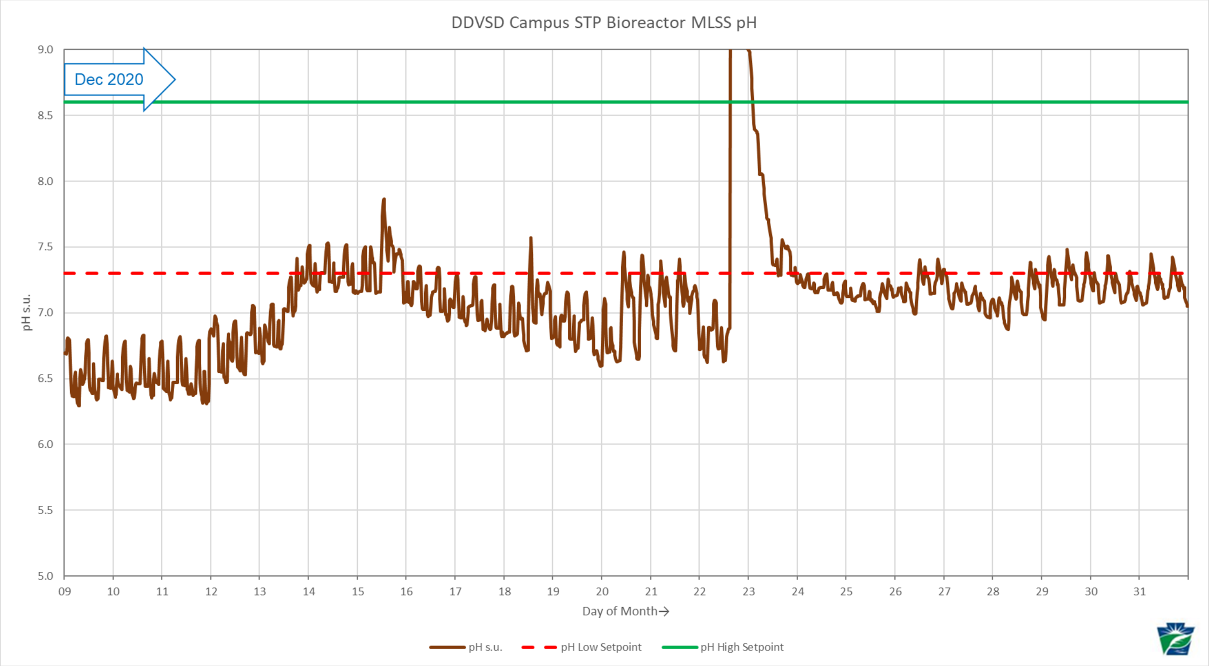
2020 October and November Bioreactor Nitrate-nitrogen Concentration



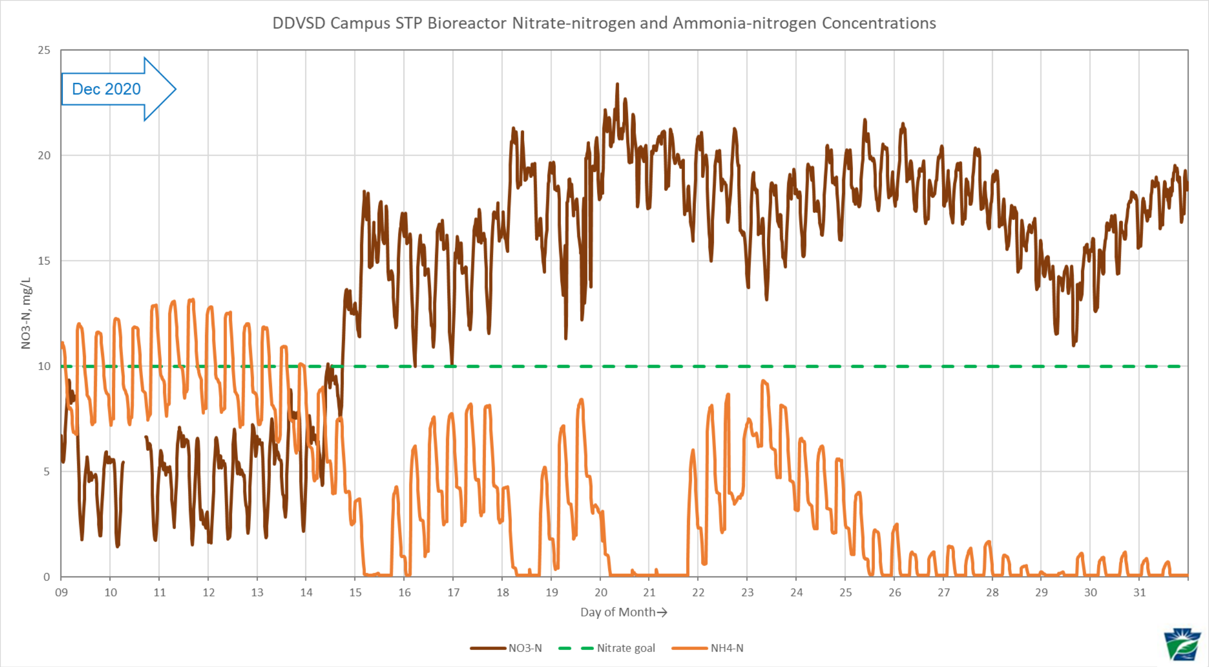
2020 December Bioreactor Dissolved Oxygen Residual and Temperature



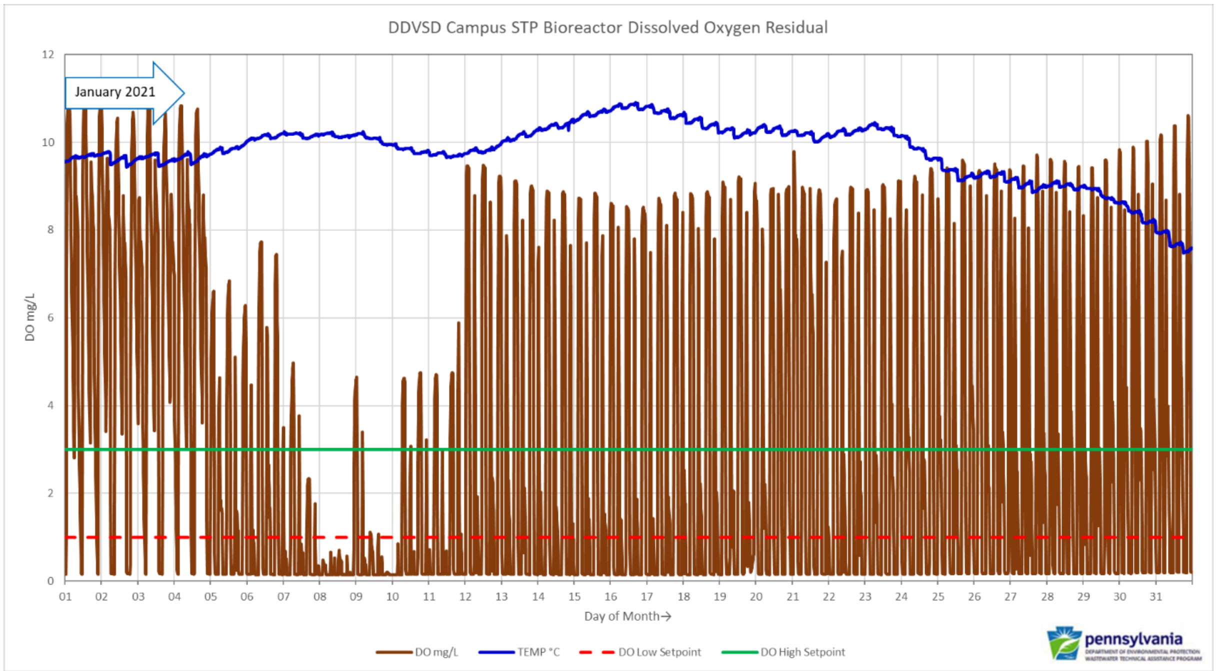
2020 December Bioreactor Oxygen / Reduction Potential



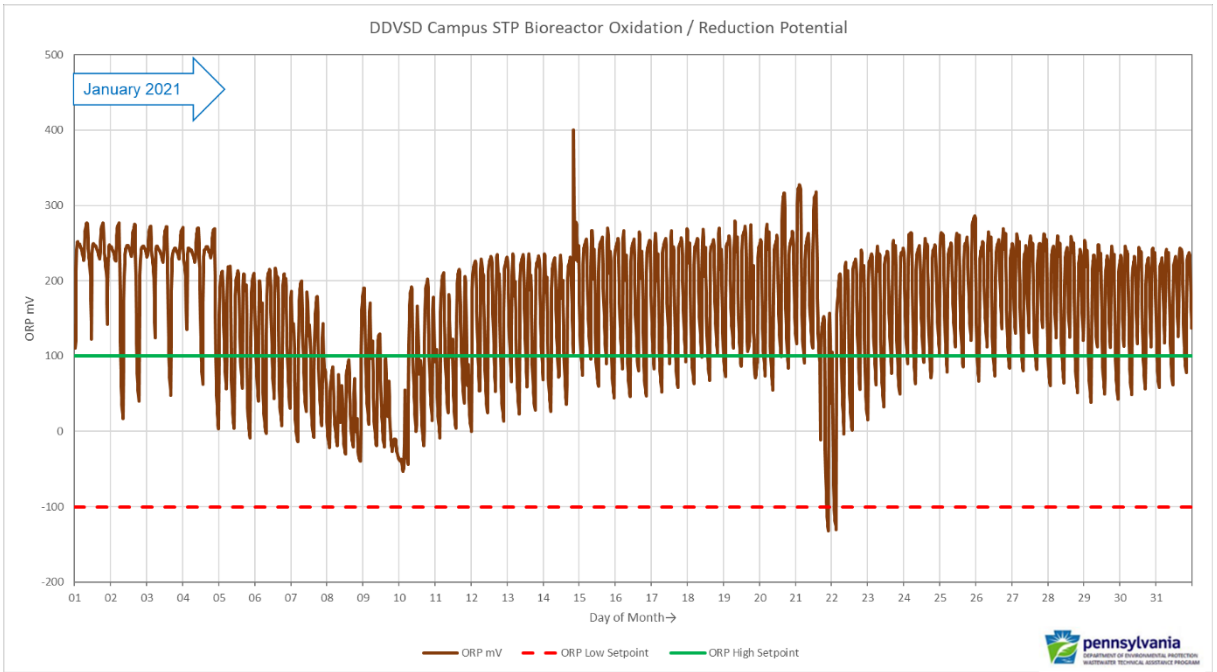
2020 December Bioreactor pH



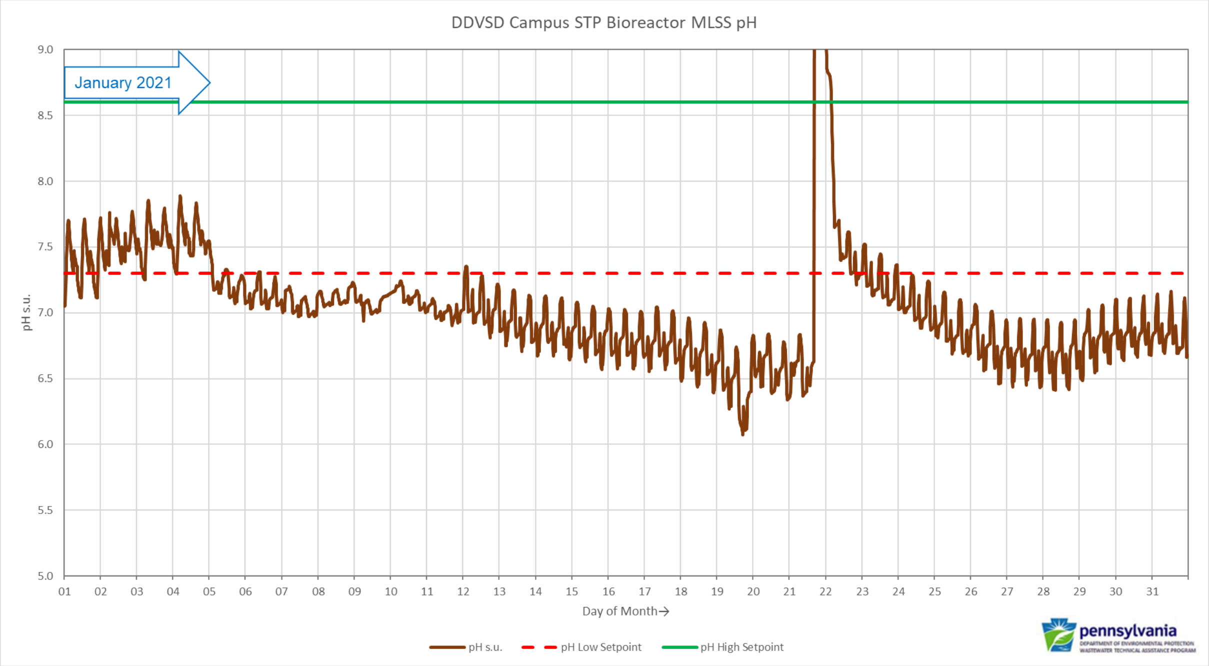
2020 December Bioreactor Nitrate-nitrogen and Ammonia-nitrogen Concentrations



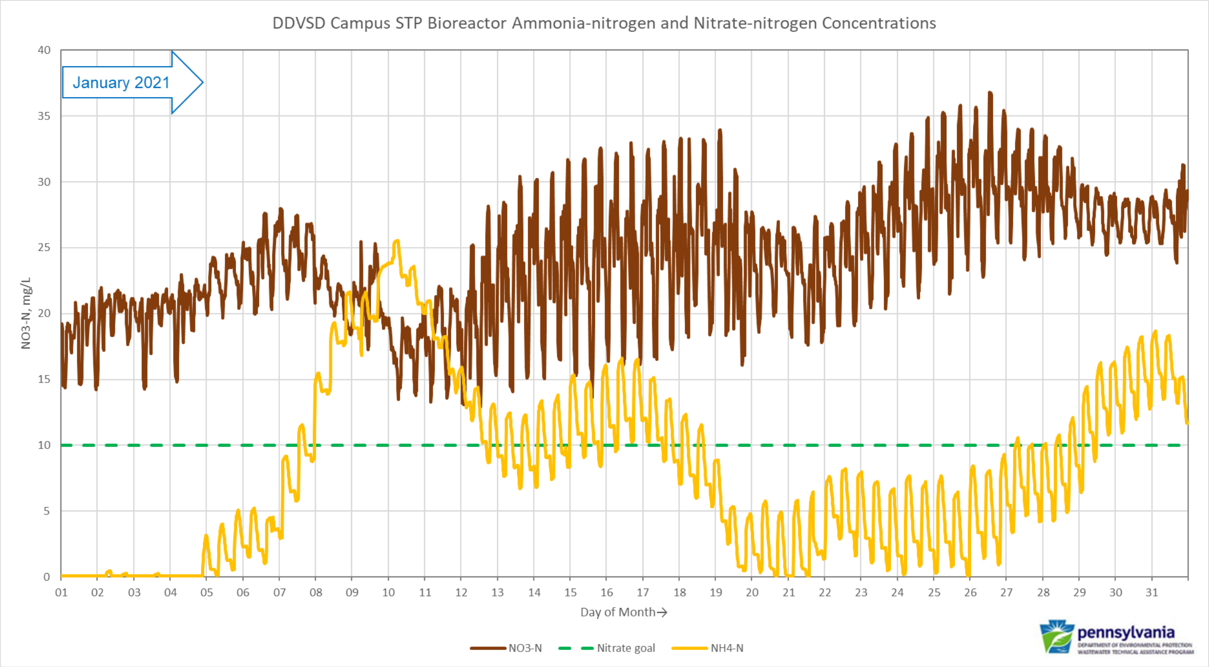
January 2021 Bioreactor Dissolved Oxygen Residual and Temperature



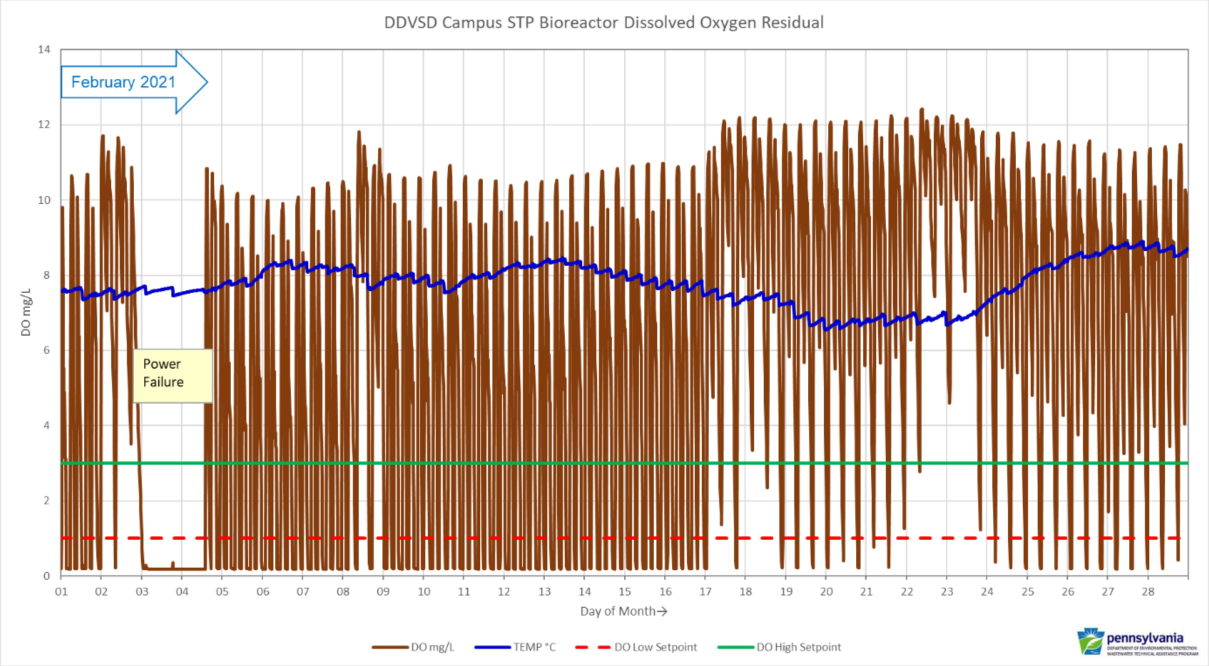
2021 January Bioreactor Oxygen / Reduction Potential



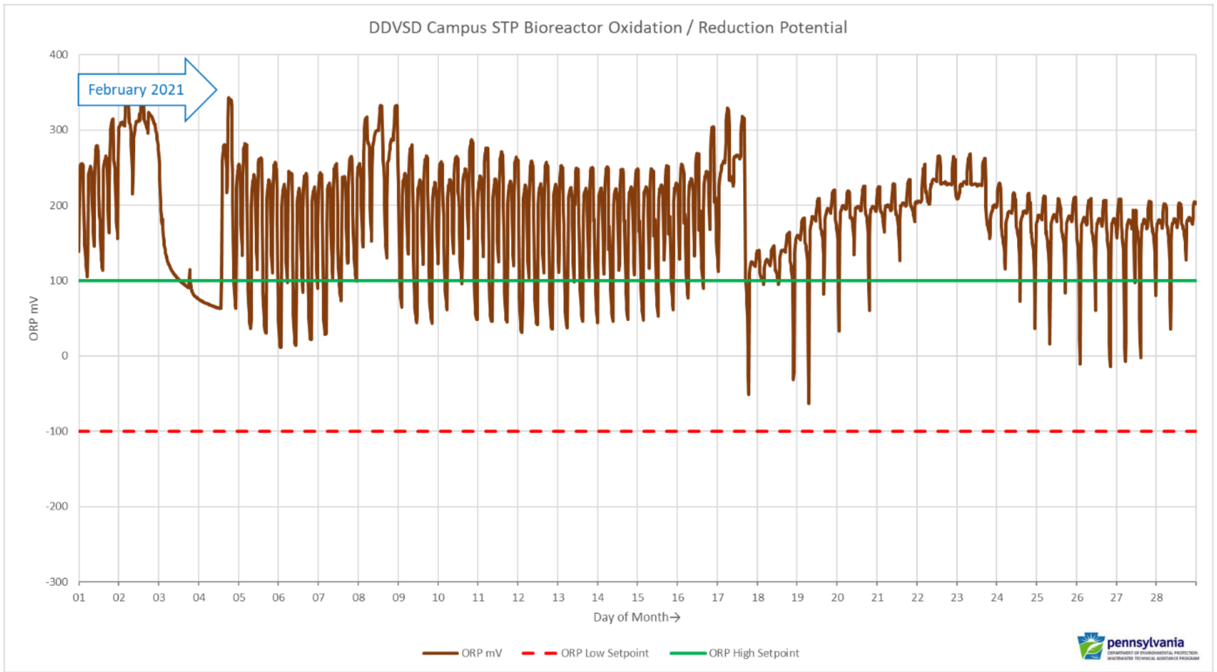
2021 January Bioreactor pH



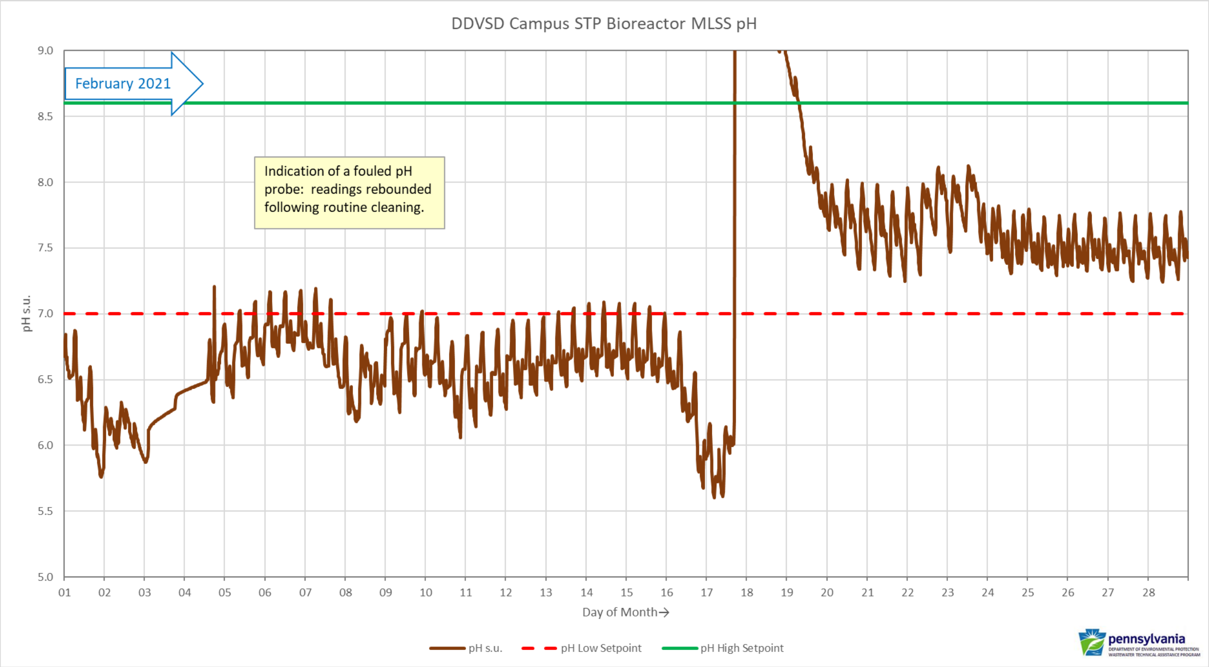
2021 January Bioreactor Nitrate-nitrogen and Ammonia-nitrogen Concentrations



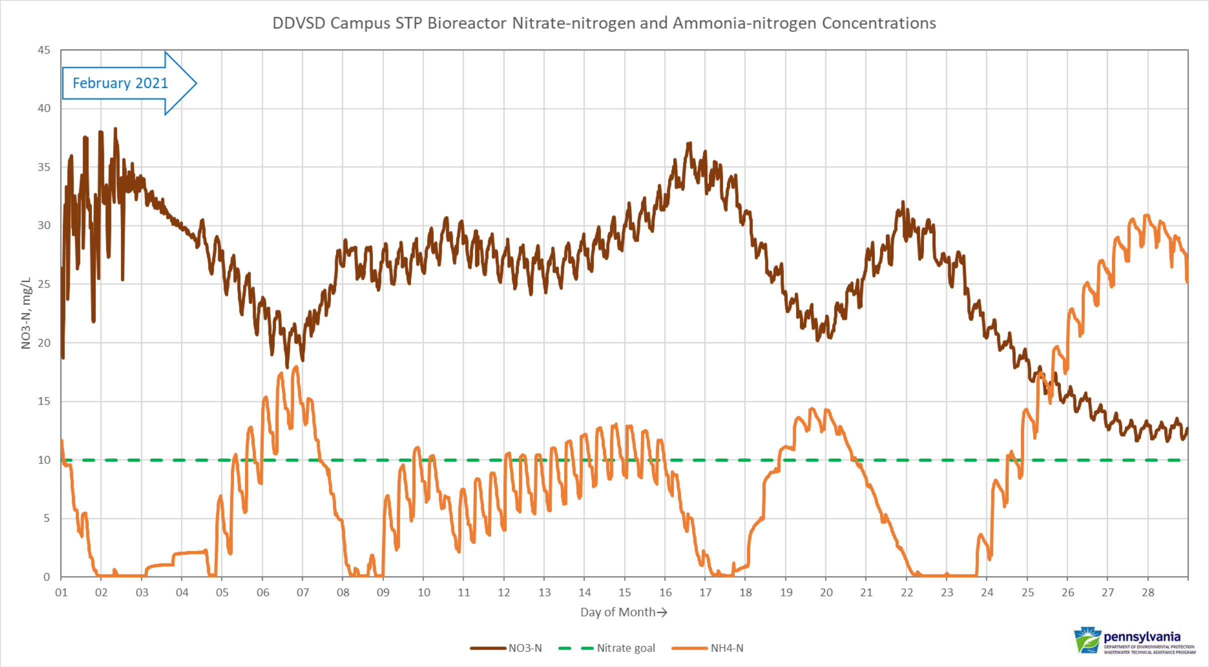
2021 February Bioreactor Dissolved Oxygen Residual and Temperature



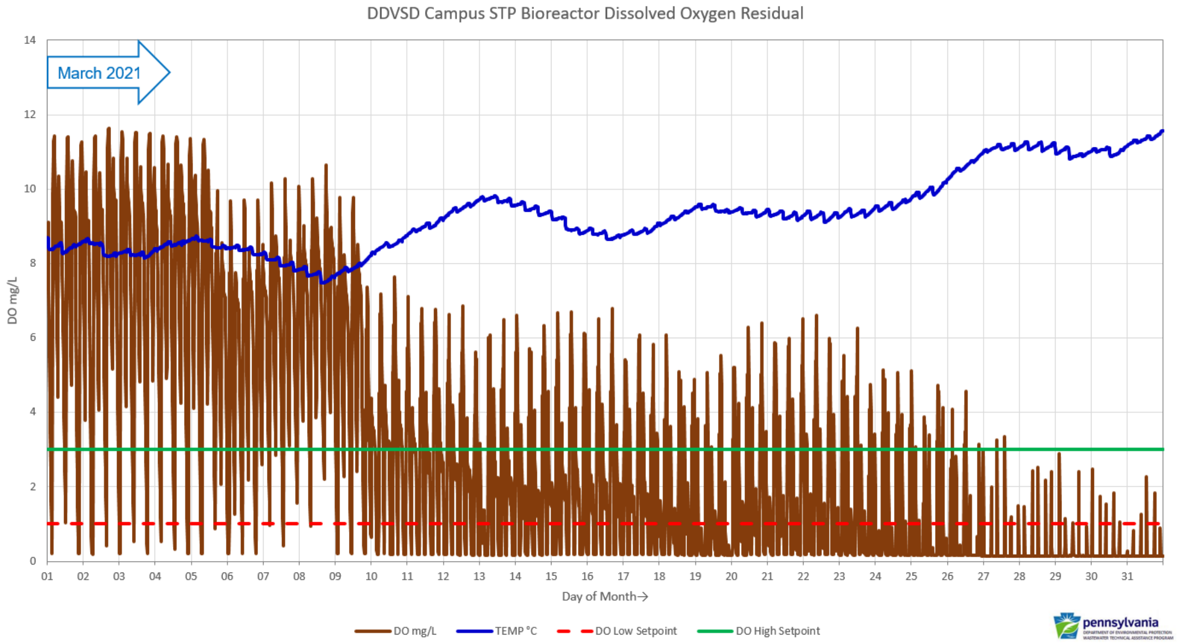
2021 February Bioreactor Oxidation / Reduction Potential



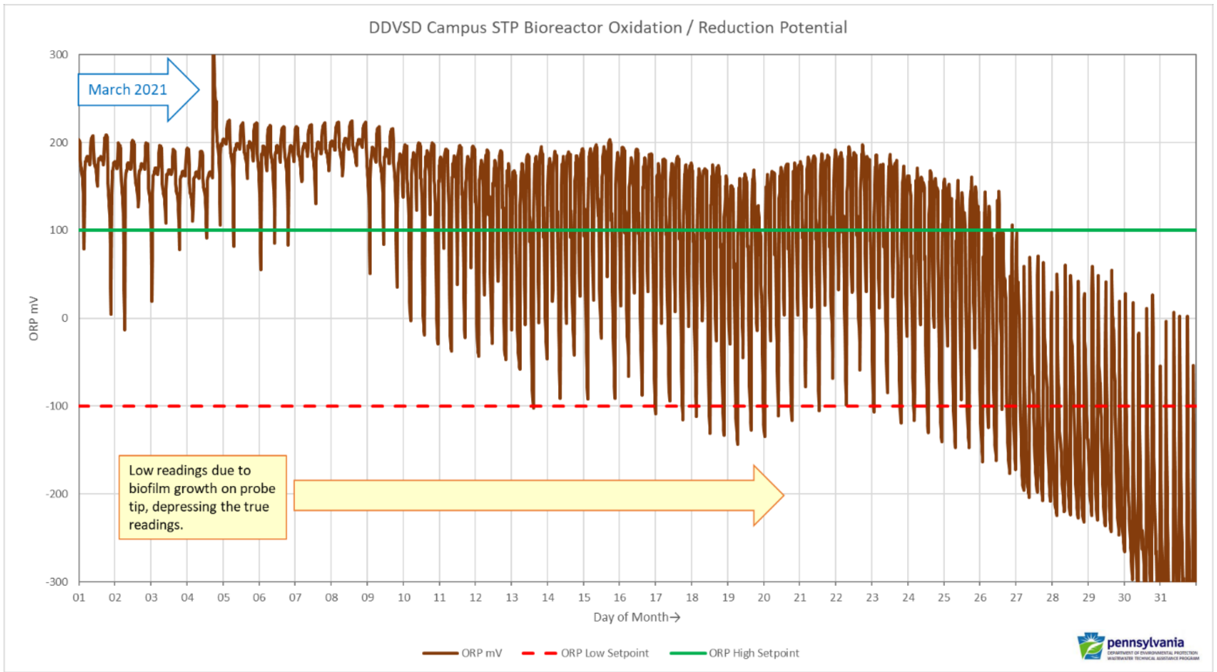
2021 February Bioreactor pH



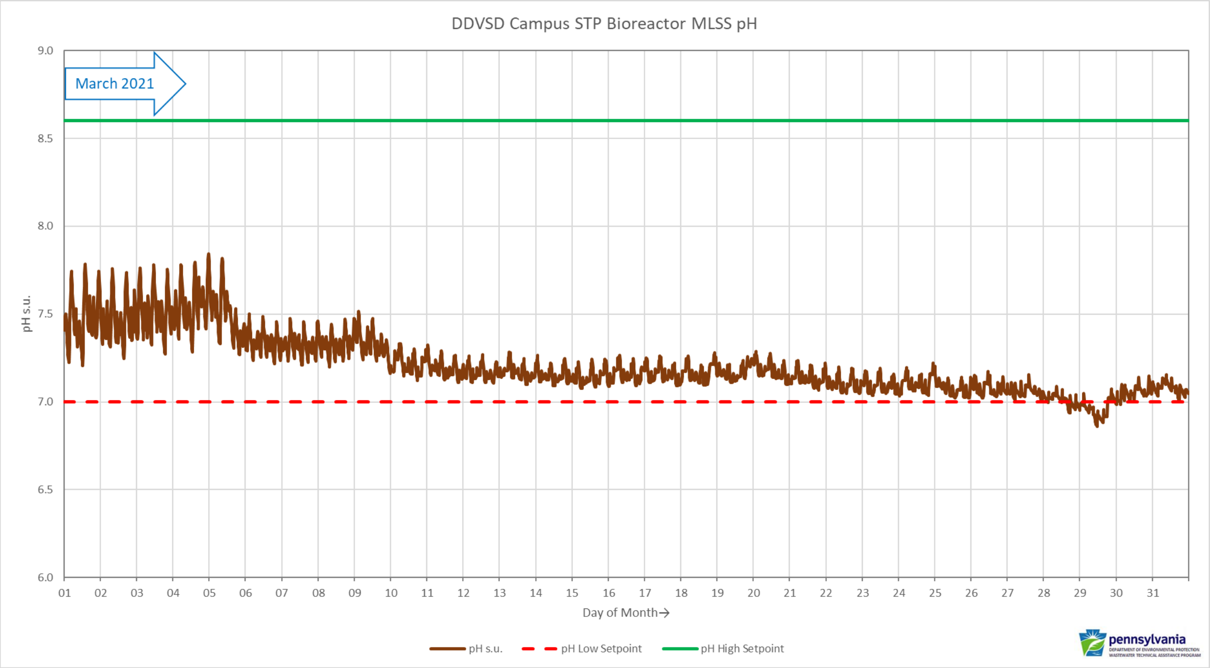
2021 February Bioreactor Nitrate-nitrogen and Ammonia-nitrogen Concentrations



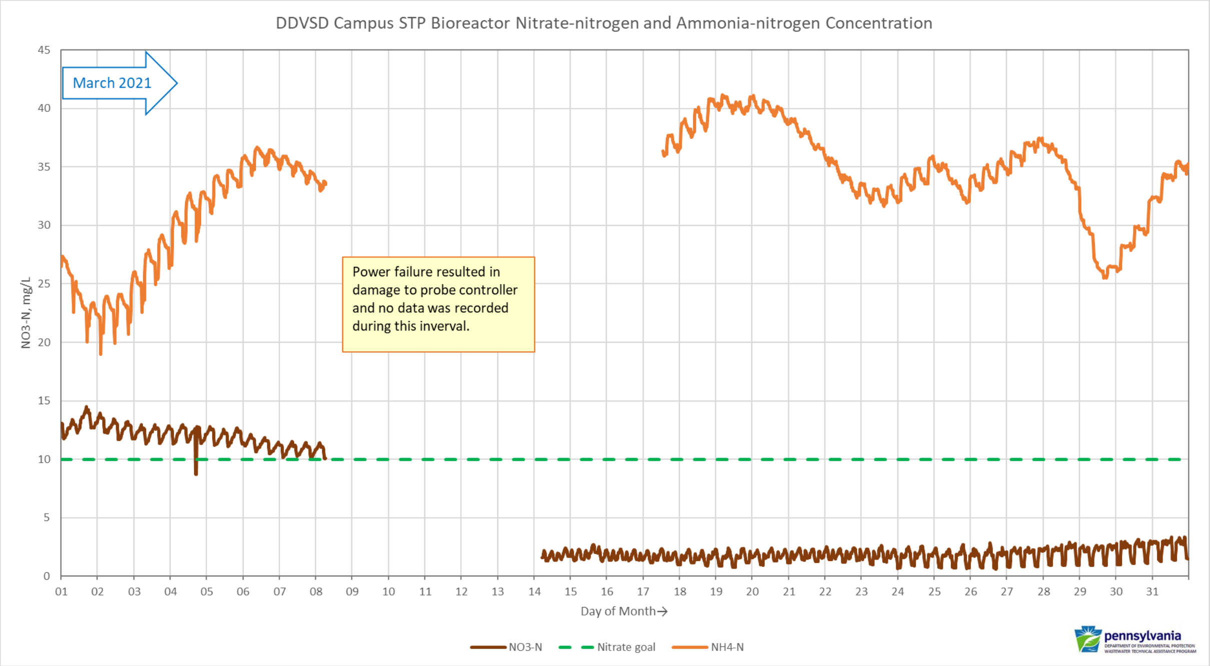
Bioreactor D.O. in March 2021: efforts to throttle D.O. were progressing.



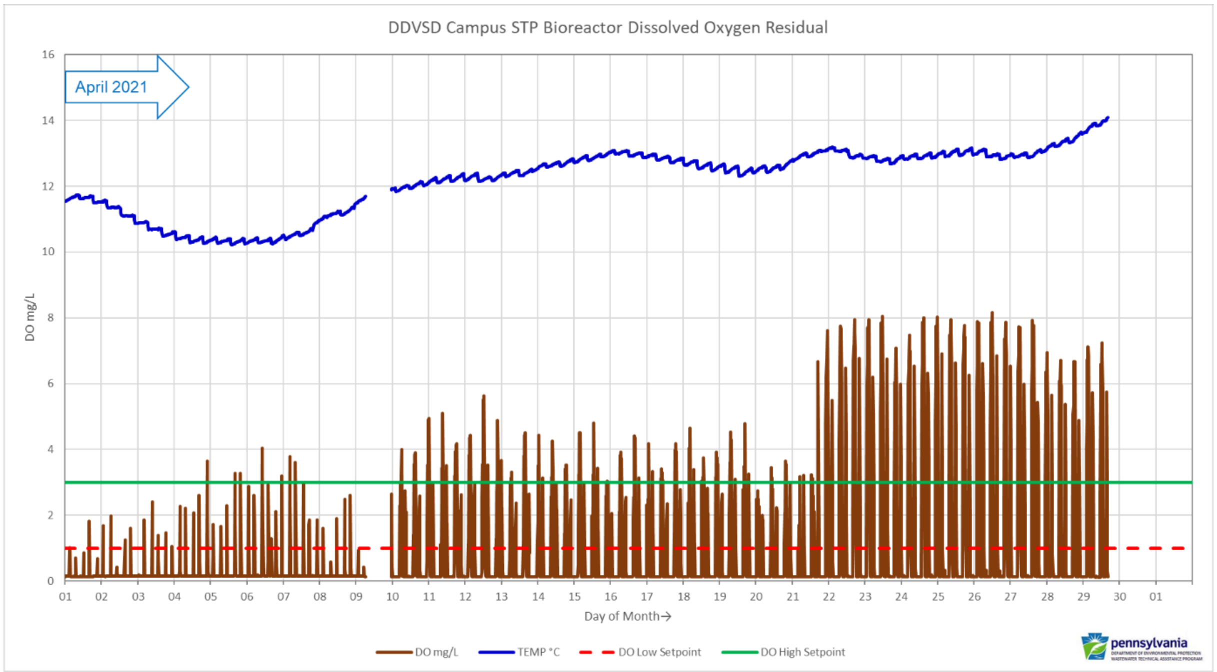
2021 March Bioreactor Oxidation / Reduction Potential



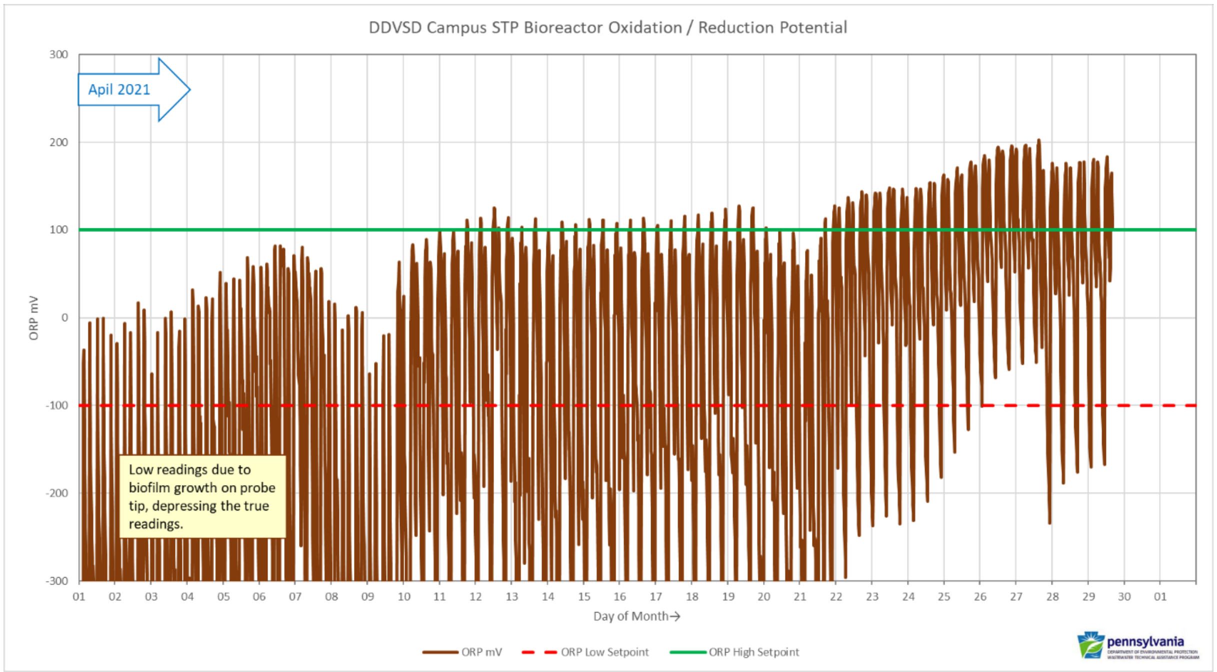
2021 March Bioreactor pH is adequately buffered using alkalinity supplementation.



2021 March Bioreactor Nitrate-nitrogen and Ammonia-nitrogen concentrations: The facility was not nitrifying ammonia at this time, so nitrate was not being produced, and very little dentification was occurring.

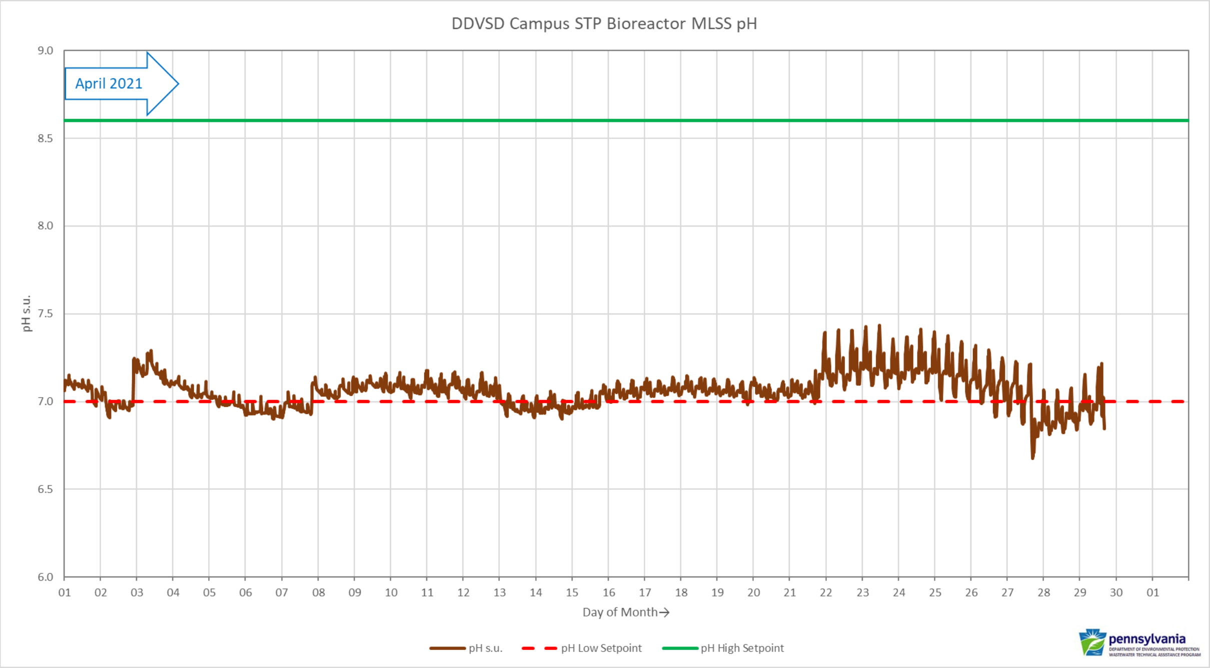


2021 April Bioreactor Dissolved Oxygen Residual and Temperature

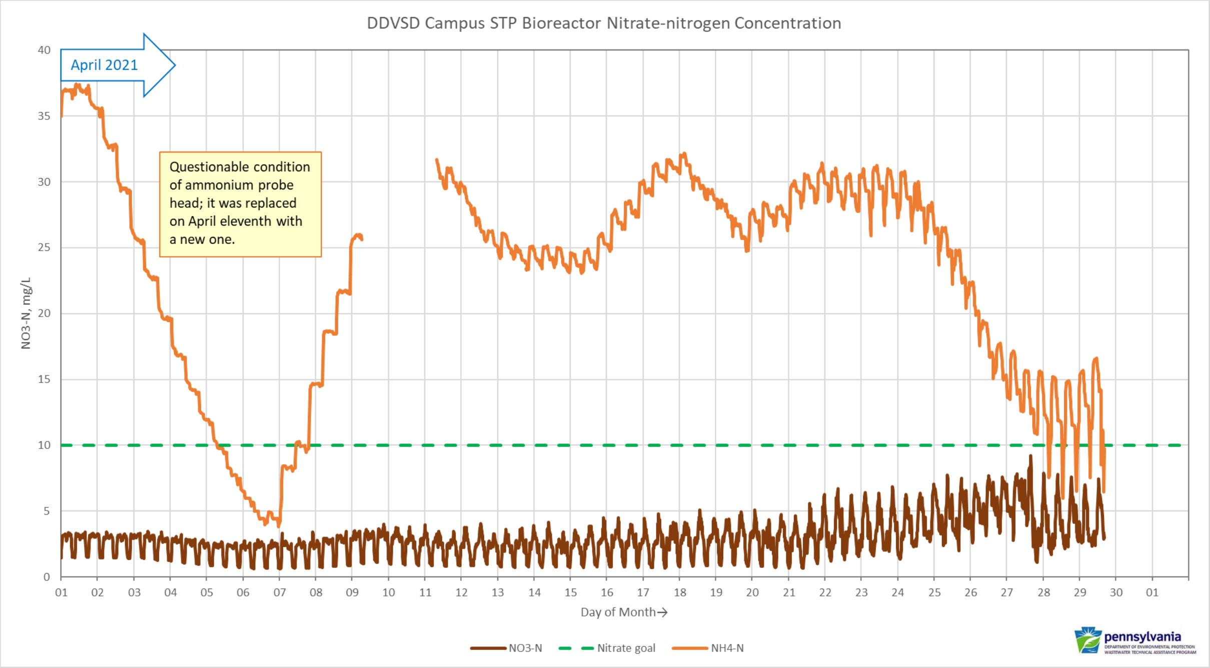


Low readings due to biofilm growth on probe tip, depressing the true readings.

2021 April Bioreactor Oxidation / Reduction Potential

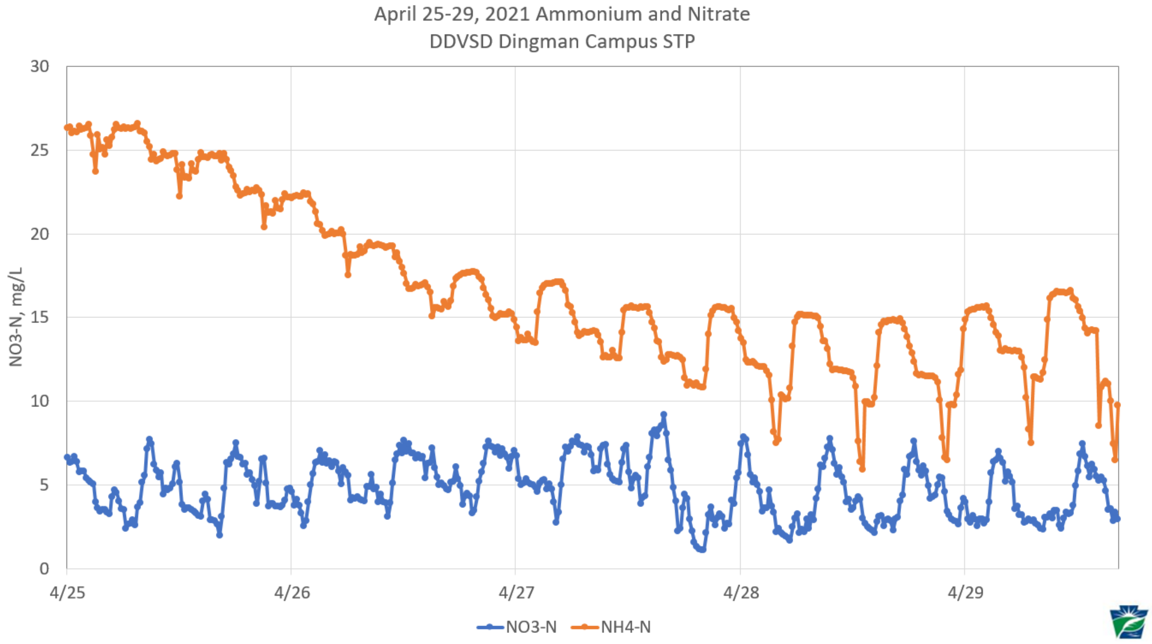


2021 April Bioreactor pH had been buffered by alkalinity supplement to achieve desired range.

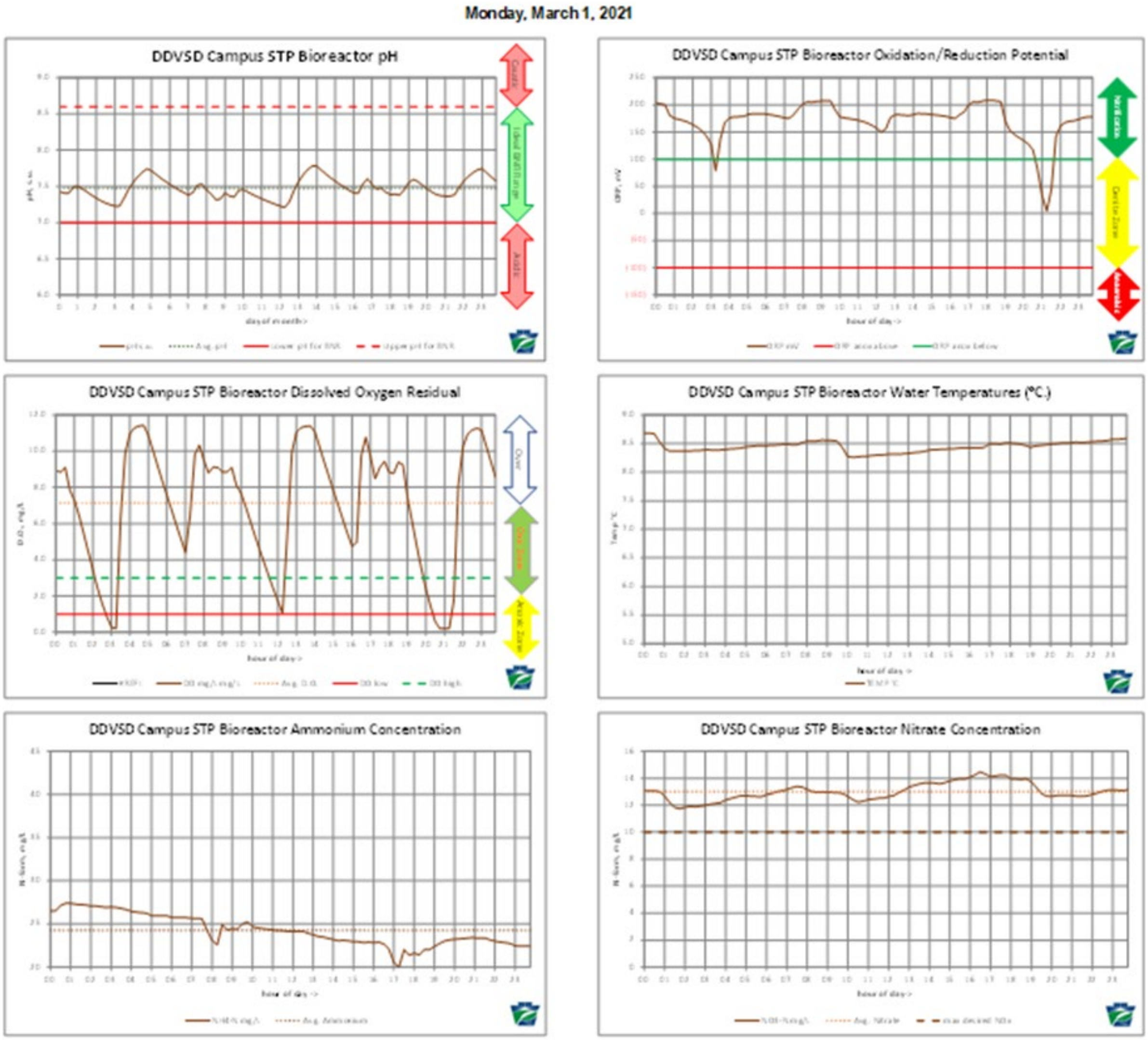


2021 April Bioreactor Nitrate-nitrogen and Ammonia-nitrogen Concentrations: high ammonia-nitrogen concentrations indicated that nitrification was inhibited; therefore, little nitrate was produced in the process, and minimal denitrification occurred. Data collection terminated April 29, 2021

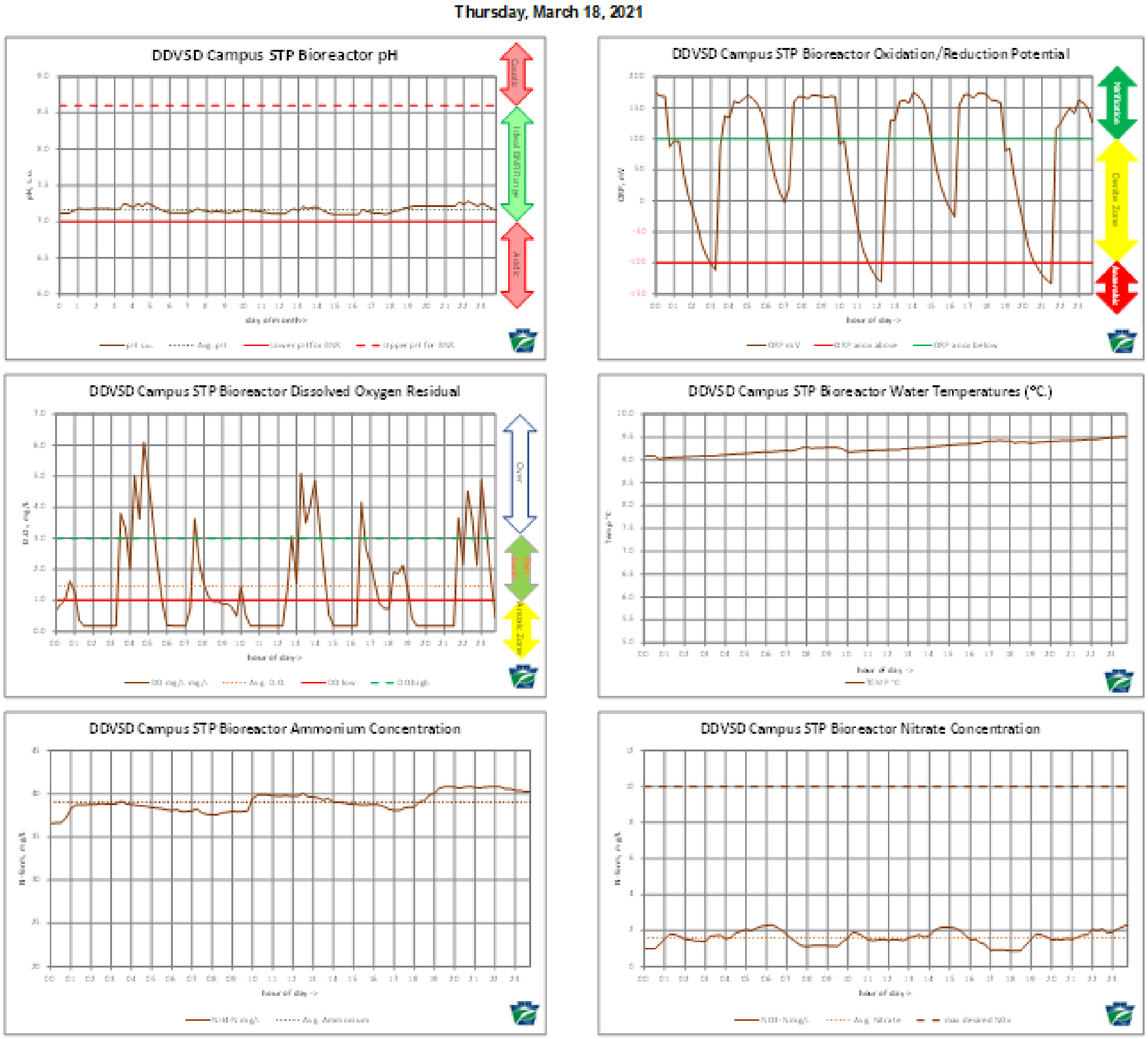
It took a while to get here, but in late April, after adjustments to the SBR programming to feed sugar carbon at a critical part of the denitrification phase, ammonia and nitrate concentrations were both lower that previously, indicating successful BNR:



April 25-29, 2021, Ammonium and Nitrate graph shows reduction in ammonium concentration without concurrent increase in nitrate concentration, evidence of denitrification working in the presence of supplemental carbon and alkalinity.



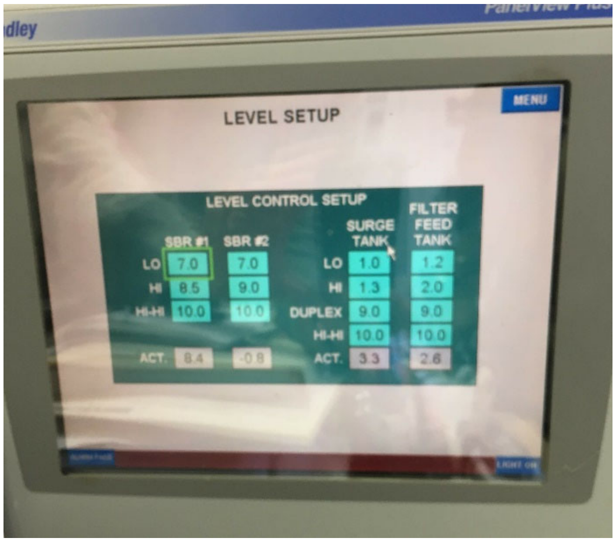
Example of daily monitoring graph for March 1, 2021: Note two complete SBR bioreactor cycles in the center-left graph of the dissolved oxygen residual.



Example of daily monitoring graph for March 18, 2021: Ammonium was high, and nitrate was low, (bottom two graphs) indicating the bioreactor was not nitrifying at the time. For successful BNR, one would look for both ammonium and nitrate concentrations to be comparatively low.

ATTACHMENT D: PHOTOGRAPHS

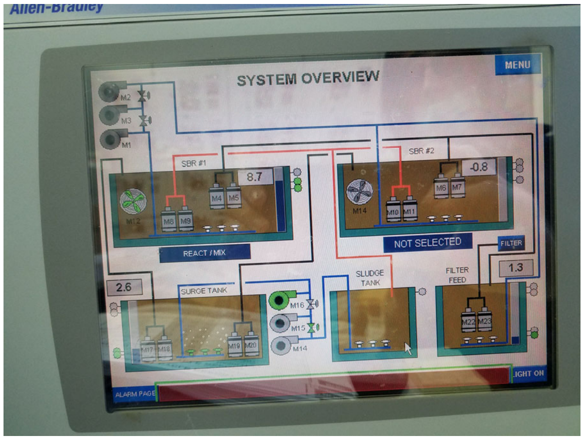
Active Treatment Unit



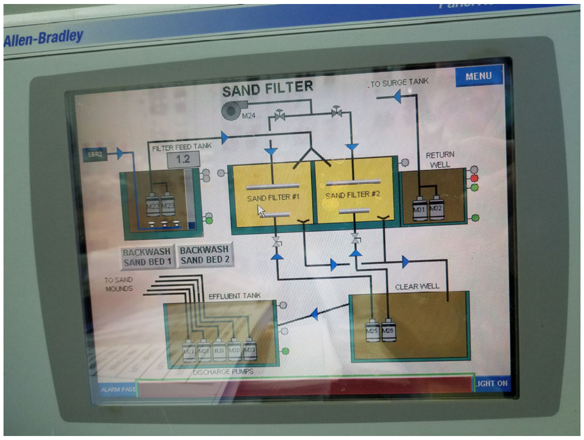
LEVEL CONTROL SETUP

	SBR #1	SBR #2		SURGE TANK	FILTER FEED TANK
LO	7.0	7.0	LO	1.0	1.2
HI	8.5	9.0	HI	1.3	2.0
HI-HI	10.0	10.0	DUPLEX	9.0	9.0
			HI-HI	10.0	10.0
ACT.	8.4	-0.8	ACT.	3.3	2.6

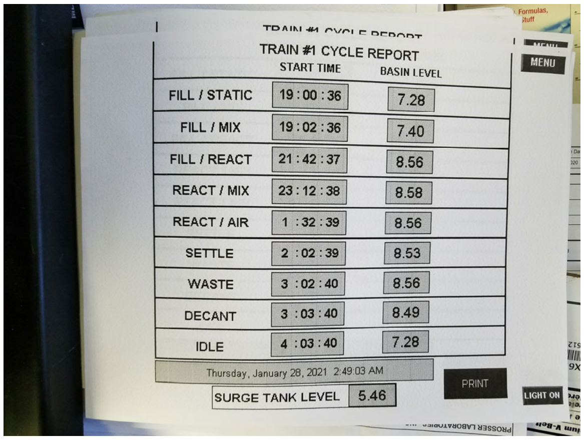
Display Screen with Level Set-points



System overview on SCADA



Idle sand filter units



TRAIN #1 CYCLE REPORT

	START TIME	BASIN LEVEL
FILL / STATIC	19 : 00 : 36	7.28
FILL / MIX	19 : 02 : 36	7.40
FILL / REACT	21 : 42 : 37	8.56
REACT / MIX	23 : 12 : 38	8.58
REACT / AIR	1 : 32 : 39	8.56
SETTLE	2 : 02 : 39	8.53
WASTE	3 : 02 : 40	8.56
DECANT	3 : 03 : 40	8.49
IDLE	4 : 03 : 40	7.28

Thursday, January 28, 2021 2:49:03 AM

SURGE TANK LEVEL 5.46

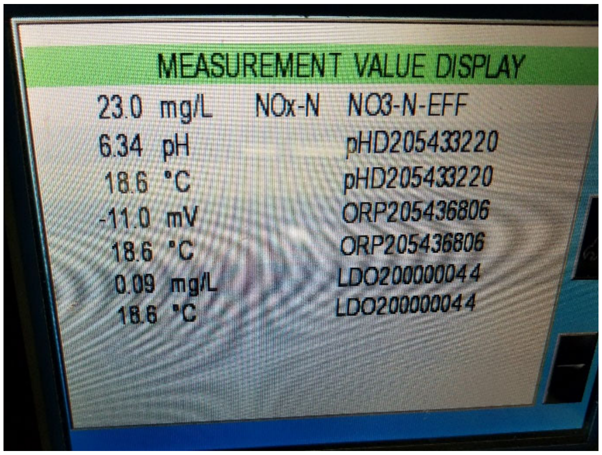
Example treatment report with times and basin levels

ORP205436806

TEMP	50.8	°F
ORP	102.8	mV
TEMP	50.6	°F
DO	8.41	O2 mg/l

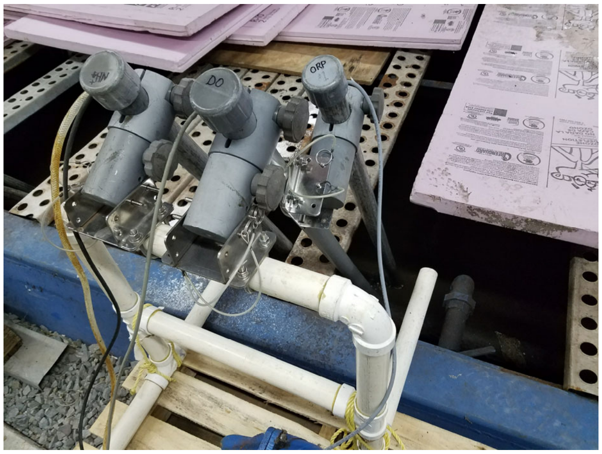
SC200 Data Output Screen

4-probe setup, October/November 2020



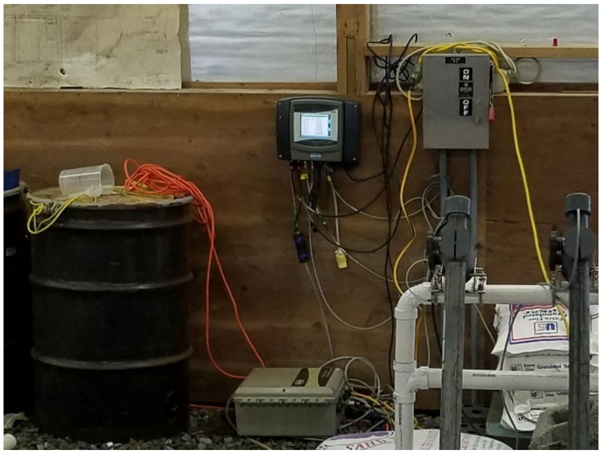
```
MEASUREMENT VALUE DISPLAY
23.0  mg/L   NOx-N  NO3-N-EFF
6.34  pH            pHD205433220
18.6  °C            pHD205433220
-11.0 mV            ORP205436806
18.6  °C            ORP205436806
0.09  mg/L          LDO200000044
18.6  °C            LDO200000044
```

October/November 2020 output screen

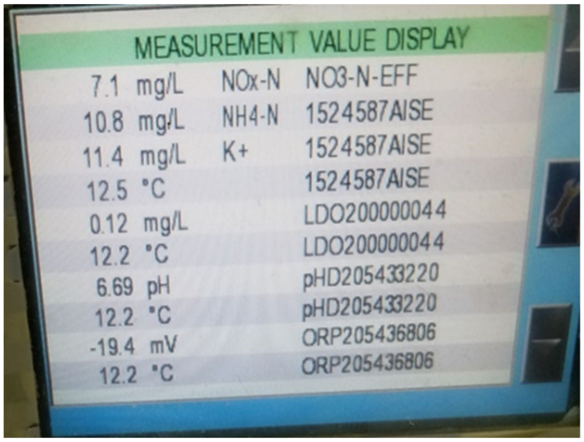


5-probe setup, December-April: ORP, D.O., NH4-N

5-probe setup: pH and NO3-N

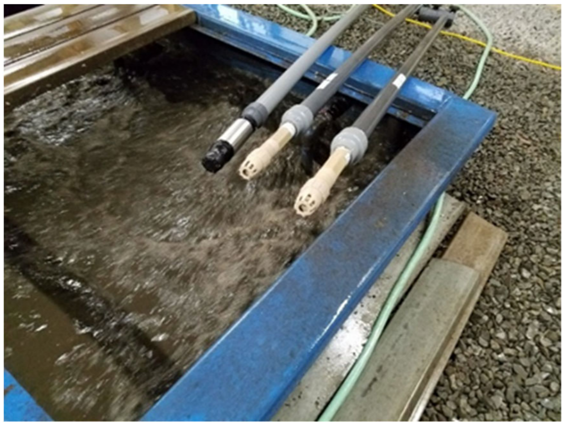


SC1000 Probe Controller & AISE Compressor

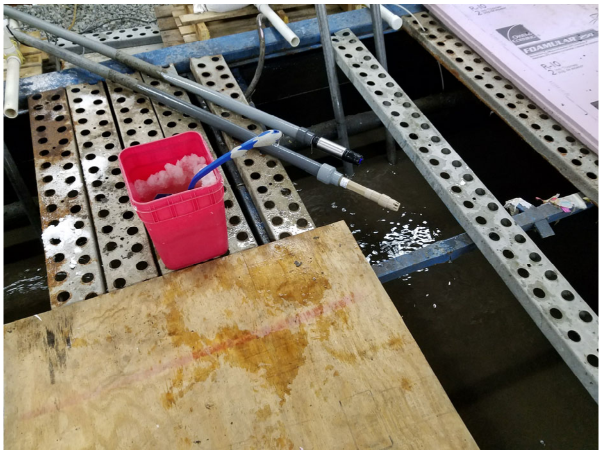


```
MEASUREMENT VALUE DISPLAY
7.1   mg/L   NOx-N  NO3-N-EFF
10.8  mg/L   NH4-N  1524587AISE
11.4  mg/L   K+     1524587AISE
12.5  °C            1524587AISE
0.12  mg/L          LDO200000044
12.2  °C            LDO200000044
6.69  pH            pHD205433220
12.2  °C            pHD205433220
-19.4 mV            ORP205436806
12.2  °C            ORP205436806
```

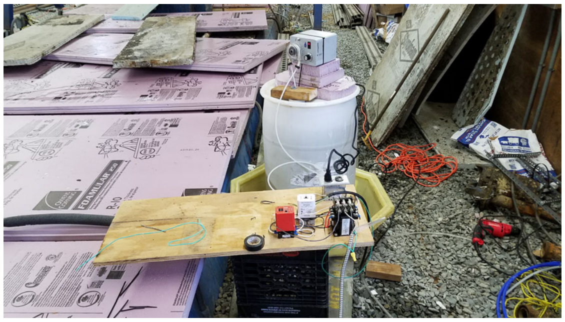
SC1000 Data Output Screen, after October 2020



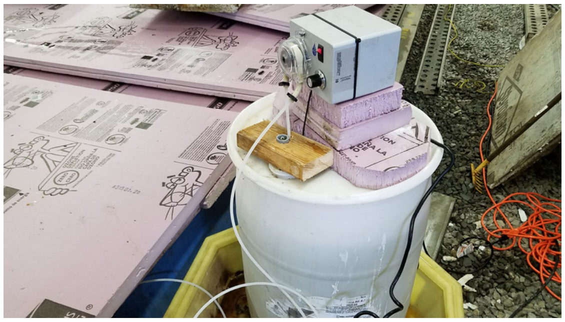
DO, pH, and ORP probes



Probe Cleaning every week a must

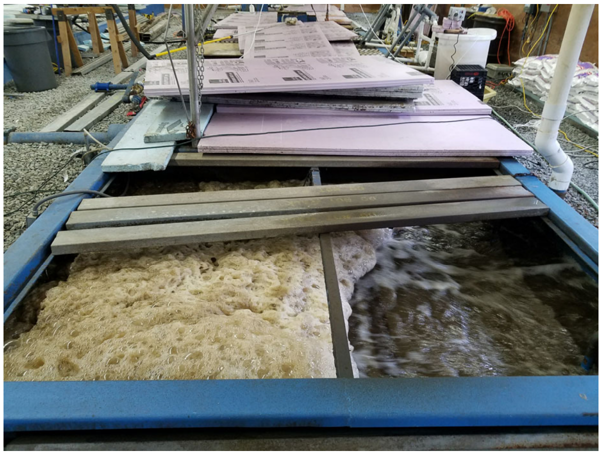


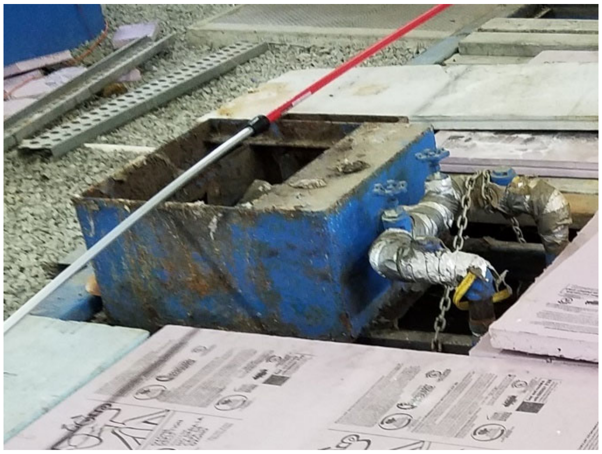
Sugar feed system for supplemental carbon, using original timer arrangement

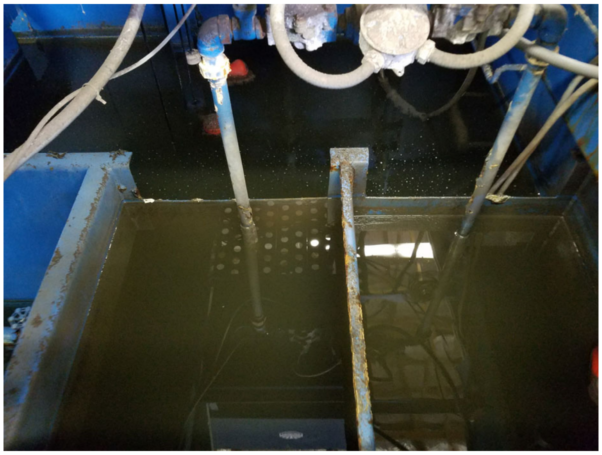


Perisdaltic pump eventually connected to SCADA for more precise delivery.


Sludge holding decant pipe


Sludge being wasted to holding tank.


Distribution box (idle)


Sand filters (not in service)


Effluent Wet Well


Detritus on control float switches & cables

Influent splitter bypass pump

Influent entering SBR1 during fill cycle

Effluent Distribution Fields

Effluent Distribution Field

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ATTACHMENT E: PERMIT LIMITS FOR DINGMAN-DELAWARE VALLEY STP

Groundwater Discharge; Latitude 39º 52' 45", Longitude 79º 29' 32", Dingman Twp., Monroe County

DEL. VAL. SCHOOL DISTRICT-STP: 469107; Primary Facility ID 469107;
Primary Facility Other ID: 5292402

SN - Sewage Non-Publicly Owned (Non-Muni)

Client ID 82928; Client AKA 230281

Site: 444435 - DELAWARE VALLEY SCH DIST STP

	Mass Units (lb./day) (1)		Concentrations (mg/L)				Minimum (2) Measurement Frequency	Required Sample Type
	Average Monthly	Average Weekly	Minimum	Average Monthly	Daily Maximum	Instant. Maximum		
Flow (MGD)	**0.027 LD**	XXX	XXX	XXX	**Report**	XXX	**2/month**	**Measured**
pH (S.U.) May 1 - Sep 30	XXX	XXX	**6.0**	XXX	**9.0**	XXX	**1/day**	**Grab**
Carbonaceous Biochemical Oxygen Demand (CBOD5)	XXX	XXX	XXX	**25.0**	XXX	XXX	**2/month**	**8-hour Composite**
Total Suspended Solids	XXX	XXX	XXX	**30.0**	XXX	XXX	**2/month**	**8-hour Composite**
Nitrite-Nitrate	XXX	XXX	XXX	**10.0**	XXX	XXX	**2/month r**	**8-hour Composite**

Footnotes

(1) The facility is permitted for land discharge, (LD). Discharge Type: sand mounds.
(2) This is the minimum number of sampling events required. Permittees are encouraged, and it may be advantageous in demonstrating compliance, to perform more than the minimum number of sampling events.

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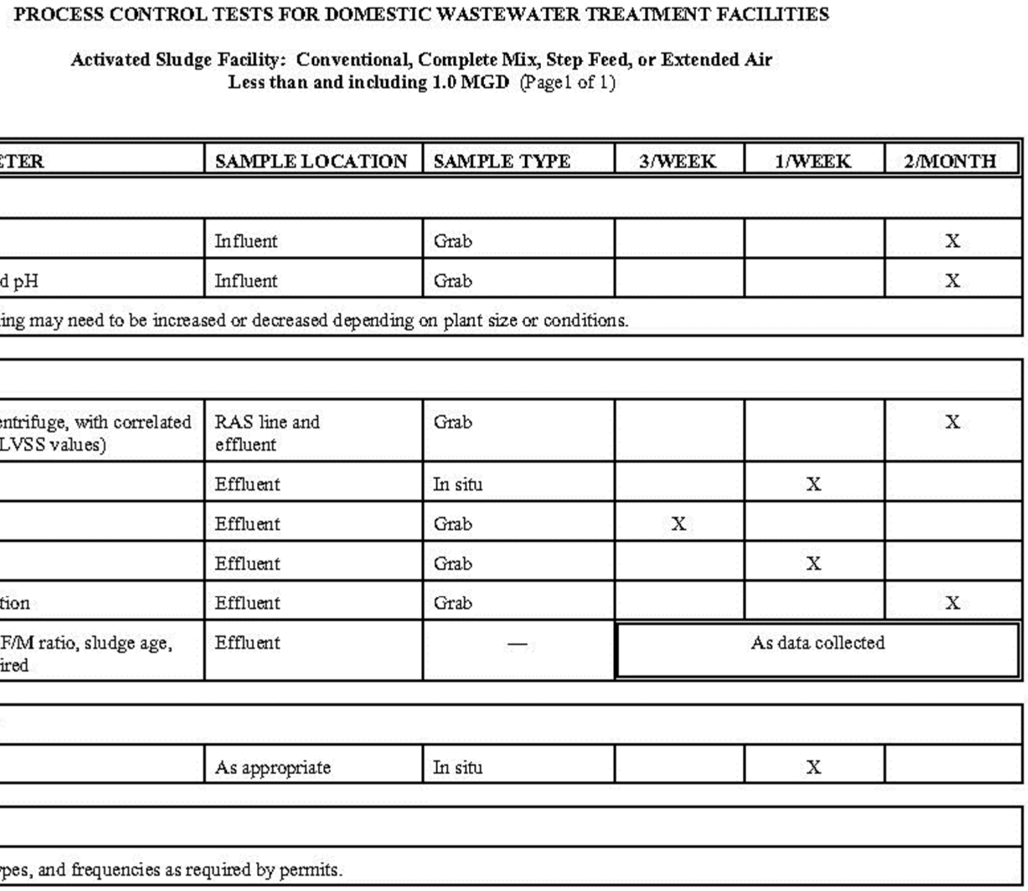
ATTACHMENT F: RECOMMENDED PROCESS MONITORING TESTS

Process monitoring testing is vital to an operator's ability to maintain a steady-state operating condition and to make operational control decisions that avert potential plant upsets and assure continued quality effluent.



PROCESS CONTROL TESTS FOR DOMESTIC WASTEWATER TREATMENT FACILITIES

Activated Sludge Facility: Conventional, Complete Mix, Step Feed, or Extended Air
Less than and including 1.0 MGD (Page1 of 1)

SAMPLE PARAMETER	SAMPLE LOCATION	SAMPLE TYPE	3/WEEK	1/WEEK	2/MONTH
Raw Influent*					
BOD$_5$ and/or COD	Influent	Grab			X
TSS/VSS, NH$_3$-N, and pH	Influent	Grab			X
* Frequency of sampling may need to be increased or decreased depending on plant size or conditions.					
Aeration Basin					
MLSS/MLVSS (or centrifuge, with correlated data from periodic MLVSS values)	RAS line and effluent	Grab			X
Dissolved oxygen	Effluent	In situ		X	
Settleability (SV30)	Effluent	Grab	X		
pH	Effluent	Grab		X	
Microscopic examination	Effluent	Grab			X
Computation of SVI, F/M ratio, sludge age, and/or MCRT, as desired	Effluent	—	As data collected		
Secondary Clarifier					
Sludge blanket depth	As appropriate	In situ		X	
Final Effluent					
Parameters, sample types, and frequencies as required by permits.					

Process monitoring is vital to maintaining a well-operated wastewater treatment facility. Engineers design wastewater treatment plants to meet steady-state operating conditions based on constant parameters such as Food-to-Mass ratio, Solids Retention Time, or Cell Residence Time. In the absence of large flow equalization and storage capacity, treatment operators maintain F/M, SRT, or MCRT by controlling the amount of active biosolids available to treat the incoming organic and nitrogenous load. They do this by regulating sludge wasting rates.

Every treatment facility should waste a little bit of its biomass on a consistent schedule. Wasting sludge every day is ideal, but in small package plants this may not always be practical. However, wasting should be done no less than every few days in such facilities, as sludge wasting promotes growth of new microorganisms while removing those that are endogenous.

The table reproduced above lists suggested sampling frequencies for facilities of capacity up to 1.0 MGD. This represents the minimum monitoring requirements; however, experience suggests that process monitoring tests be performed more frequently when a facility is experiencing any changes. These changes include any process changes made by the operators and any changes due to unavoidable circumstances, such as slug loading or equipment service interruptions. Generally, the higher the level of treatment, the more process control testing is necessary. For example, denitrification operations require additional process monitoring when compared to nitrification operations.

The facility routinely performs settled sludge volume testing and solids-by-volume centrifuge tests. It is recommended that centrifuge solids tests are done twice weekly at a minimum and backed up with gravimetric solids tests once or twice a month to maintain centrifuge calibration (Weight-to-Concentration Ratio, or WCR.) Microscopy and water chemistry should be done on the mixed liquor weekly until the operators have reasonable understanding of a 4-season set of reference data to which they may refer in future years, after which the testing may be done twice per month. Whenever process or treatment methods change, the test data set would need to be reproduced. Also, whenever the facility experiences plant upset conditions more frequent process-monitoring and control testing should be performed by the operators, until conditions stabilize.

Process Monitoring testing is often not the same as those performed by contract laboratories in that approved test methods are not utilized. Compliance testing refers to those analyses used by certified laboratories for reporting parameters required by the NPDES permit. Over the years, many small treatment facilities began to contract compliance testing to certified environmental laboratories. This eased the burden on operators, and it saved the facility owner the cost of maintaining certification of its own laboratory. However, over time, many facilities ceased to perform regular process monitoring tests, as well. It is important for operators to know the condition of their facilities, the sludge solids inventory, and the qualities of the treatment solids (i.e., quantity and quality of “bugs”) to effectively optimize operations.

DEP’s WWTAP has adopted the process monitoring tests recommended by US-EPA and the professional trade organization, Water Environment Federation (WEF.) These tests include the following:

- Centrifuge solids test: percent volume/volume measurement of activated sludge solids for activated sludge-type plants: Calculations stemming from this data include solids inventory (expressed as dimensionless “sludge units” (SLU).)
- Clarifier blanket level: a core-sampling of the clarifier contents provides a proportional quantity of mixed liquor and supernatant that can be used for developing awareness of how much mixed liquor is detained in the effluent clarifier, representing part of the overall sludge inventory.
- Settleometry test: 30- and 60- minute activated sludge settling rates in wide half-gallon or 1-liter, calibrated vessels: Settled sludge volume (SSV) is expressed in standard 30-minute intervals and used to calculate Settled Sludge Concentration (SSC) which is a qualitative measure of how well the activated sludge settles in the clarifier, mimicking clarifier performance in terms of supernatant quality as well. Using WCR, it is also possible to calculate and track Sludge Volume Index (SVI).
- Oxygen Uptake Rate (a.k.a. Soluble Oxygen Uptake Rate): By measuring the rate of dissolved oxygen depletion in a sample of mixed liquor, one may demonstrate the relative effect of BOD loading on the biomass, how quickly this material will be metabolized by the activated sludge organisms. Expressed in “milligrams Oxygen per hour,” when mixed liquor volatile suspended solids concentration is known or can be extrapolated, then one may determine the actual Respiration Rate, in mg. Oxygen per hour per gram of activated sludge. OUR and RR are also useful for comparing the relative health of the biomass under toxic conditions, should there be undesirable contaminants in the raw wastewater, or anoxic conditions, should the aeration be insufficient to treat the incoming waste load using the available amount of oxygen.
- Raw Wastewater and Effluent Chemical Oxygen Demand (COD): an analog of the 5-day Biochemical Oxygen Demand test, COD can be determined in about three hours and give

operators a quick assessment of relative strength of wastewater and/or the amount of material remaining in treated effluent, thereby providing an analog of treatment efficiency.

- Nutrient Tests: A portable wastewater laboratory provided during the WTE consists of materials for conducting various colorimetric analyses for nutrients such as ammonia-nitrogen, nitrite, nitrate, organic nitrogen, phosphorus, etc. to determine whether the facility is removing or treating nutrients. For process monitoring purposes, nutrient test strips provide ample, low-cost, low-trouble test results. They are available in most supplier catalogs (USA Blue Book, Hach, Grainger, et al.)
- Various other tests included in the portable wastewater laboratory include alkalinity testing (the buffering capacity of the mixed liquor or the clarified supernatant,) chlorides, sulfides, halogens such as Total Residual Chlorine and Free Chlorine, and metals including aluminum and iron, known contaminants to downstream aquatic life.

The objective of all this testing is to develop a unique profile for the facility useful in developing operations trends, showing conditions that become predictive of how the facility responds to various beneficial or adverse conditions that could affect effluent quality and treatment efficiency. Once enough data exists, operators should have a cogent understanding of how the facility responds to process adjustments and what they must do to maintain it in good condition.

Typically, operators should determine an overall treatment strategy for their facility, using standard industry calculations for:

- Food to Mass Ratio (F/M)
- Mean Cell Residence Time (MCRT)
- Sludge Age or Dynamic Sludge Age

These values can be determined using the equipment described above. These calculations provide set-points unique to the facility that can be adjusted either through changes in sludge wasting rates or, where possible, treatment capacity (by adding or subtracting additional treatment units,) assuming that the concentration of waste in the wastewater is a variable that operators cannot control.

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ATTACHMENT G: DISCUSSION OF BIOLOGICAL NUTRIENT REMOVAL (BNR)

Why Nitrate in the Effluent is a Concern:

Dissolved nutrients in treated wastewater effluents create both environmental and health concerns. They cause over-fertilization of algae and plant growth that sets up a cycle of excessive growth followed by eutrophication and decay. The excessive growth robs the natural environment of its capacity to support local biota that are the source of food for aquatic organisms and displaces native plant species. Once eutrophication has been established, large algal die-offs result in decay that robs the aquatic environment of dissolved oxygen, causing entire aquatic populations to suffer and die. This degrades water quality for higher uses, as well, including withdrawals for drinking water filtration, swimming and recreation, angling, and other activities.

DEP has an operator training manual covering this topic, found here .

Nitrate is a pollutant of concern in surface waters filtered for human consumption and in groundwater sources for drinking water wells. EPA has set an enforceable standard called a maximum contaminant level (MCL) in potable drinking water for nitrates at 10 parts per million (ppm) (10 mg/L) and for nitrites at 1 ppm (1 mg/L). Many regulators are calling for similar limits for point-source and ground water discharges.

Human health concerns are a major factor in regulatory efforts to reduce nitrate in wastewater discharges. Exposure to nitrate also increases the risk of thyroid disease[3] and may lead to certain types of cancers of the colon and bladder[4], as well as a very specific birth defect called neural tube disorders caused early in pregnancies.[5] Nitrate acts on hemoglobin in red blood cells to form methemoglobin, reducing the oxygenation of organs and tissues.[6] Acquired methemoglobinemia in infants may occur when they consume nitrate in water used to mix infant formula or in nitrate-rich foods, medications such as benzocaine or dapsone, or through household exposure to naphthalene found in mothballs, toilet deodorants, plastics, and chemicals.[7] Nitrate may also be implicated in diabetes, miscarriages, and acute respiratory infections. The medical science on the effects of nitrates continues to develop.

Nitrification and Denitrification:

During the 1970s, treatment facilities were required to nitrify ammonia wastes to eliminate this pollutant that was killing aquatic life in receiving waters. Nitrification employs autotrophic bacteria in highly aerated conditions to convert ammonia to nitrate. The bacteria, normally found in topsoil, are found in activated sludge. During the past thirty years, microbiologists have discovered that there exist many genera of nitrifying bacteria, some of which are capable of completely nitrifying inorganic ammonia to nitrate.[8] *Nitrospira* and *nitrococcus* come to mind. Traditional explanation

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[3] Epidemiology: **May 2010 - Volume 21 - Issue 3 - p 389-395** (Nitrate converts to nitrite in vitro which becomes nitrosamines, leading to a host of health issues.)

[4] Schullehner J, Hansen B, Thygesen M, Pedersen CB, Sigsgaard T. Nitrate in drinking water and colorectal cancer risk: A nationwide population-based cohort study. Int J Cancer. 2018 Jul 1;143(1):73-79. doi: 10.1002/ijc.31306. Epub 2018 Feb 23. PMID: 29435982.

[5] Epidemiology: July 2004 - Volume 15 - Issue 4 - p S184; The Lancet, Volume 14, 100286, March 1, 2022

[6] Kross BC, Ayebo AD, Fuortes LJ. Methemoglobinemia: nitrate toxicity in rural America. Am Fam Physician. 1992 Jul;46(1):183-8. PMID: 1621630

[7] Wisconsin Dept. of Health Services website, Infant Methemoglobinemia (Blue Baby Syndrome) , (rev. 04/15/2021)

[8] van Kessel, M., Speth, D., Albertsen, M. et al. **Complete nitrification by a single microorganism**. Nature 528, 555–559 (2015). https://doi.org/10.1038/nature16459

of nitrification, prior to these discoveries, focused on a two-step process performed by two different genera of bacteria. These two genera of nitrifiers work in tandem: *nitrosomonas*, an ammonia-oxidizing bacteria (AOB), converts ammonium to nitrite, after which *nitrobacter*, a nitrite-oxidizing bacteria (NOB) converts nitrite to nitrate. The net reaction is shown below:

$$\mathrm{NH3 + O2 + H2O} \quad \rightarrow \quad \mathrm{NO3- + 5H+ +4e} \qquad (1)$$

The first step reaction by *nitrosomonas* is shown here:

$$NH_4^+ + 3/2\,O_2 \rightarrow NO_2^- + 2\,H_2O + 2\,H^{+\,9} \qquad (2)$$

Additional oxygen and detention time are necessary to allow *nitrobacter* to oxidize the biologically active nitrite ion to chemically inert nitrate ion.[10]

$$NO_2^- + \tfrac{1}{2}\,O_2 \rightarrow NO_3^- \qquad (3)$$

Nitrification requires several factors to complete the process. These include

- Sufficient detention time, 10 to 14 days: most of the cBOD must first be consumed by heterotrophic and facultative bacteria in the activated sludge.
- Dissolved oxygen residual between 1.5 mg/L and 3.5 mg/L in the bioreactor.
- 4.6 lb. of oxygen consumed per pound of ammonia converted to nitrate: this can double the amount of oxygen required, compared to only treating for cBOD.
- pH generally above 7.0 s.u., ideally between 7.3 and 8.6, but no lower than 6.5 s.u.
- 7.14 pounds of alkalinity is needed to convert every 1 lb. of ammonia.
- Alkalinity in the raw wastewater should be over 200 mg/L as $CaCO_3$ or be supplemented to assure effluent alkalinity remains between 50 mg/L and 100 mg/L after treatment.
- Water temperature above 5 degrees Celsius (41 deg. Fahrenheit).

Nitrosomonas and nitrobacter are very sensitive to toxicity, as well, and one or the other can easily be suppressed by the presence of many household and commercial cleaners, excessive metals, and other contaminants.

Considering these factors, it is important for wastewater operators to regularly perform process control testing to determine whether the conditions are favorable for nitrification. If nitrification breaks down, these tests may help to determine what conditions are affecting the bacteria and which, *nitrosomonas* or *nitrobacter*, are most affected. Testing for pH, alkalinity, are dissolved oxygen residual are critical to maintaining effective nitrification.

Many wastewater treatment facilities built or upgraded in recent times have been equipped for biological nutrient removal (BNR). Denitrification is a process by which facultative, heterotrophic bacteria in the activated sludge will reduce nitrate to nitrogen gas that leaves the water and returns to the atmosphere. The balanced chemical equations are shown below:

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[9] This is the first half of the reaction, converting ammonium to nitrite. The nitrite, in red, associates with the hydrogen, also in red, as nitrous acid, resulting in lower pH if alkalinity is inadequate.

[10] The chemical oxidation state of nitrate ion is such that it does not necessarily associate with hydronium to produce more acid. It more typically associates with metal ions and is inert.

$$6\,NO_3^- + 2\,H_3COH \rightarrow 6\,NO_2^- + 2\,CO_2 + 4\,H_2O$$ [11]

$$6\,NO_2^- + 3\,H_3COH \rightarrow 3\,N_2\uparrow + 3\,CO_2 + 3\,H_2O + 6\,OH^-$$ [12]

For successful denitrification, the following conditions are necessary:

- anoxic treatment conditions, where no dissolved oxygen is present. Generally, dissolved oxygen should be below 0.3 mg/L for denitrification.
- nitrate-rich environment: nitrification should be complete to the best extent possible. Nitrate dissolved in the water will provide the oxygen needed by the bacteria for metabolism.
- Presence of organic carbon as a food-source for the bacteria: usually, this comes from the raw wastewater but sometimes is required as supplemental cBOD in for form of simple chemicals like methanol, citrate, or glycerol, or as food manufacturing wastes such as molasses sugar, fruit juice waste, or whey powder.

Denitrification is a rapid reaction under the right conditions. If a treatment facility can successfully nitrify, there should be little or no problems denitrifying. In fact, in conventional and extended aeration facilities, denitrification is sometimes observed occurring in secondary clarifiers when the sludge blanket there has been retained too long: fine bubbles form in the floc causing clumps of sludge to rise to the surface. This “lava lamp” effect, called “rising sludge,” can cause effluent violations when solids are carried over the clarifier weirs to the outfall. Excessive solids carryover will also inhibit downstream disinfection processes by consuming available chlorine or by occluding the penetration of ultraviolet light.

Alkalinity is Critical

During nitrification, the nitrifying bacteria consume inorganic carbon in the form of dissolved carbonate / bicarbonate in the water. Alkalinity provides buffering against rapid and drastic pH changes, but it also provides a source of inorganic carbon. For every pound of ammonia oxidized, 7.14 pounds of alkalinity are consumed. (Given water chemistry and cellular metabolism, this amount is often rounded up to 7.2-to-7.5 lb. alkalinity per 1 lb. ammonia oxidized.)

If the biomass is deficient of alkalinity, the AOB conversion of ammonia to nitrite will lower the pH. This is because the nitrite released from the bacteria, as a waste product, is the anionic half of nitrous acid. The metabolism of ammonia produces hydronium ion that acidifies the water. To counteract this, supplemental alkalinity is often required in many parts of Pennsylvania where, excepting the limestone-rich geology of the Great Valley and similar areas, most of the geography is naturally deficient in alkalinity. Acid-mine drainage also contributes to lowering the pH of surface and ground waters.

While the rule-of-thumb holds that a facility is in good stead if effluent alkalinity is 100 mg/L and influent alkalinity is over 200 mg/L, experience has demonstrated that facility operators should

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[11] In this equation, H_3COH represents methyl alcohol, a simple organic carbon most often used in denite filters.

[12] The carbon dioxide and hydroxyl ion combine in water to produce carbonate alkalinity. Almost half of the alkalinity consumed by nitrification is returned to the treatment process by denitrification, resulting in reductions of alkalinity needed up front as well as energy consumed in oxygenating the water.

calculate alkalinity demand in the course of their routine process monitoring and control tests. DEP has developed alkalinity calculator spreadsheet tools to aid in this, found at this website .

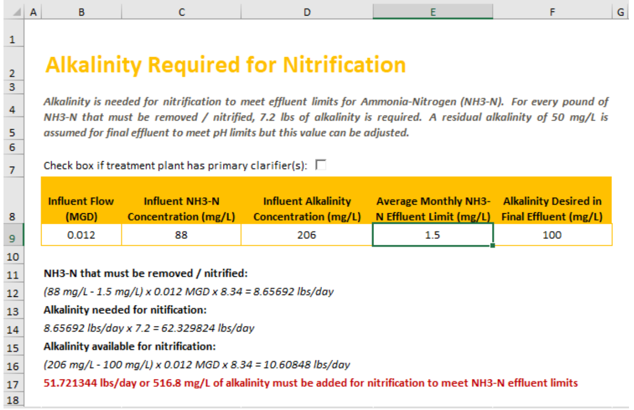
Using the calculator, operators enter test value for influent ammonia concentration and for influent alkalinity. Entering the estimated flow in million-gallons-per-day (MGD) calculates the ammonia and alkalinity loads present, the alkalinity required to oxidize the ammonia, and the equation produces a net result of how much additional alkalinity to add to the process.

It should be noted that conversion factors should be applied, based on the type of alkalinity chemical being deployed. These are found in a table on the following page. To use this table, select the ratio for the chemical being used and divide this into the estimated amount required to treat the ammonia to meet the ammonia effluent limit.

E.G., from the calculator and table:

51.7 lb./day as $CaCO_3$ ÷ 1.06 = 48.8 lb./day as Soda Ash

For practical purposes, the operator could round this example result up to 50 lb./day, since the Soda Ash is provided in 50 lb. sacks.



Alkalinity Required for Nitrification

Alkalinity is needed for nitrification to meet effluent limits for Ammonia-Nitrogen (NH3-N). For every pound of NH3-N that must be removed / nitrified, 7.2 lbs of alkalinity is required. A residual alkalinity of 50 mg/L is assumed for final effluent to meet pH limits but this value can be adjusted.

Check box if treatment plant has primary clarifier(s): ☐

Influent Flow (MGD)	Influent NH3-N Concentration (mg/L)	Influent Alkalinity Concentration (mg/L)	Average Monthly NH3-N Effluent Limit (mg/L)	Alkalinity Desired in Final Effluent (mg/L)
0.012	88	206	1.5	100

NH3-N that must be removed / nitrified:

(88 mg/L - 1.5 mg/L) x 0.012 MGD x 8.34 = 8.65692 lbs/day

Alkalinity needed for nitification:

8.65692 lbs/day x 7.2 = 62.329824 lbs/day

Alkalinity available for nitrification:

(206 mg/L - 100 mg/L) x 0.012 MGD x 8.34 = 10.60848 lbs/day

51.721344 lbs/day or 516.8 mg/L of alkalinity must be added for nitrification to meet NH3-N effluent limits

Example alkalinity calculator

Compounds	Alkalinity-Ratio, ppm/ppm $CaCO_3$
Soda Ash	1.06
Acetate	0.82
Hydrated Lime	0.74
Quick Lime	0.56
Bicarbonate	1.68
Caustic soda	0.8
Magnesium hydroxide	0.5

Alkalinity ratios to use in converting alkalinity doses

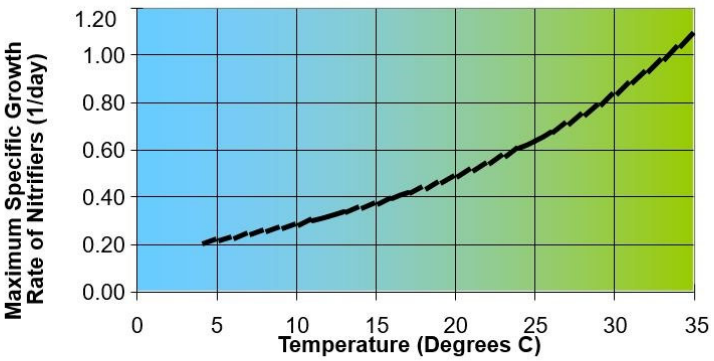
When adding any chemical to a biological treatment process, it helps if the chemical is dosed over the course of the day rather than dumped as a bulk or slug load. Therefore, it is beneficial to mix powders with water as a diluted solution and use metering pumps to deliver the chemical dose in a twenty-four-hour period. For example, if a 50 lb. sack of Calcium carbonate is dissolved into 100 gallons of water in a day tank, the metering pump should be set to deliver 4.2 gallons per hour.

PA DEP has a training manual for chemical feed systems, found here .

Inhibition of Nitrification

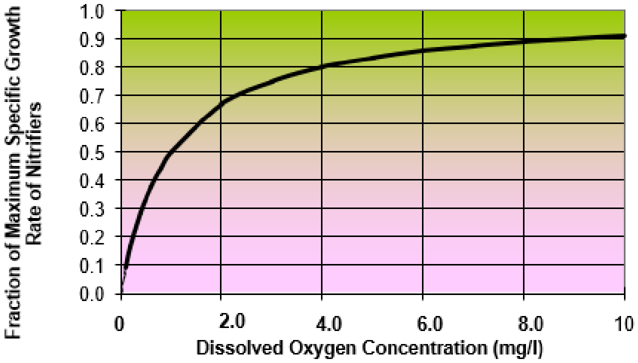
Many factors may lead to inhibition of nitrification. These include:

- pH out of range for the biomass, causing nitrifiers to stop reproducing and get washed out of the system.
- Low water temperature: Below 5 degrees Celsius, the biological reaction slows considerably, as see in this graph:



Growth of nitrifiers is dependent on temperature, and at colder temperatures, they do not replicate quickly enough to be effective

- Dissolved oxygen:



- Mean Cell Residence Time:
- Alkalinity concentration should be sufficient to maintain pH within a range from 7.0 s.u. to 8.6 s.u., and the effluent alkalinity residual should remain between 50 and 100 mg/L.
- cBOD removal:
- Toxic compounds in the wastewater will inhibit the metabolism and reproduction of nitrifying bacteria that are more sensitive to environmental changes than are the facultative heterotrophs that consume cBOD and denitrify nitrate.
- Facility design affects nitrification because of detention time, limits on hydraulic loading, quality of aeration and mixing, removal of trash and detritus, and capacity of waste sludge holding.
- Wet weather operation and inflow/infiltration affects nitrifiers because they reproduce slowly and are easily washed out of the system by hydraulic surges and overloads.

Effect of Partial Nitrification on Chlorine Disinfection

If conditions are unfavorable for complete nitrification, nitrite level will rise and exert a chlorine demand by reacting with both free chlorine and chloramines. This is called “nitrite lock.” Low D.O., insufficient alkalinity, or acidic pH; high temperature or pH; and toxic or inhibitory substances will inhibit the final oxidation step from nitrite to nitrate. Nitrite lock also may occur during facility startup or during seasonal transitions, because *nitrobacter* grow more slowly than *nitrosomonas*. For example, in the seasonal temperature transition range from 10° C to 17° C, the rate of nitrite formation is slower than the rate of nitrite disappearance. 1 mg/L of nitrite will consume 5 mg/L of chlorine as Cl_2. When the nitrite concentration in the clarified effluent exceeds 1 mg/L, nitrite lock makes it seem like operators cannot add enough chlorine to their disinfection process; total chlorine residual (TRC) becomes non-detectable even at high chlorine doses, and fecal coliform counts exceed permit limits.

Since nitrite lock has many potential causes, the remedies for it are also variable. Maintaining desirable pH and alkalinity in the mixed liquor is important. Eliminating toxic or inhibitory substances in the waste stream will help, too. Sometimes these substances may be generated internally, too. For example, using small doses of liquid bleach to control filamentous growth in the biomass will likely inhibit *nitrobacter* before it affects *nitrosomonas*, resulting in higher nitrite concentrations. While water temperature cannot be easily controlled, low water temperatures generally call for longer MCRT, and this may be achieved by building up the concentration of biomass by reducing the sludge wasting rate.

For more immediate remedies to nitrite lock, if a treatment process has more than one treatment train and both are independent of one another, it may be possible to blend low-nitrite effluent with the problematic high-nitrite effluent to dilute the nitrite. Also, if the facility permit allows it, increasing the concentration of ammonia in the effluent above that of the nitrite concentration may solve the problem, because chloramines forming in the disinfection process appear to be less prone to nitrite lock than free chlorine.

Most treatment facilities test for nitrite and nitrate together. From a process control standpoint, though, it may be better to test the two separately. That way, the operators can be alert to rising nitrite concentration in time to avert problems.

Nitrogen Removal Without Major Process Changes

In modern treatment facility design, biological nutrient removal (BNR) has become common. Many process designs exist to support both nitrification and denitrification. However, it is not necessary for older treatment facilities to be radically redesigned to achieve nitrogen removal. The simplest method is called “intermittent” or “on / off” aeration, where the aeration blowers are cycled to provide either full-on aeration for oxidation of organic and ammonia waste, or turned off to provide periods of anoxic treatment where denitrification reduces nitrate to nitrogen gas in the bioreactor, preventing rising sludge from occurring in the clarifier.

Intermittent aeration requires some minor modifications to make it work successfully:

- Dissolved oxygen control: Ideally, D.O. during oxidative periods should range from 1.5 mg/L to 3.5 mg/L to achieve complete nitrification.
- Anoxic, subsurface mixing: During air “off” period, denitrification will be optimal if mechanical mixing is present in the bioreactor to maintain the bacteria, cBOD, and dissolved nitrate all in contact with one another. Without anoxic mixing, the denitrification reaction will occur mostly at the top of the sludge blanket that forms, although rising sludge (as in a clarifier) does occur, showing that denitrification will occur, albeit inefficiently, throughout the sludge blanket.
- Organic carbon: Facultative, heterotrophic bacteria that denitrify require a carbon source for cellular metabolism and reproduction. Usually, this organic carbon comes from raw wastewater continuing to enter the bioreactor while it is in the “off” period. If necessary, supplemental carbon in the form of commercially prepared additives or otherwise as simple food processing wastes, sugar, rabbit or fish food, may be substituted.

Operational Benefits of Biological Nitrogen Removal

It is said that if a facility is required to nitrify ammonia wastes as part of its NPDES permit, it should denitrify the nitrate, as well, because of the economic benefit of doing so. Nitrification is energy intensive, and there are costs associated with power consumption, maintenance costs for aeration systems, chemical expenses associated with alkalinity addition, and use of polymer for sludge settling aids that counteract rising sludge in clarifiers.

Denitrification reduces the overall amount of power and chemicals consumed. These may be quantified as follows:

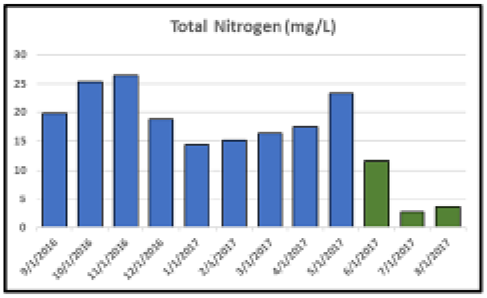
- 3.57 lb. of alkalinity as $CaCO_3$ is recovered for every 1 lb. NO_3-N reduced to nitrogen gas, N_2. Remember, 7.14 lb. of alkalinity are consumed by nitrification of ammonia, so roughly 50% of alkalinity is returned.
- 2.86 lb. O_2 is recovered for every 1 lb. NO_3-N reduced. This means the work required of motor-driven air compressors brush rotors, or surface aerators is reduced.
- Electricity conservation is observed in the use of intermittent aeration in conventional activated sludge treatment, where aeration run times may be reduced by as much as sixty percent. Activated sludge aeration need not be constant.

Case History

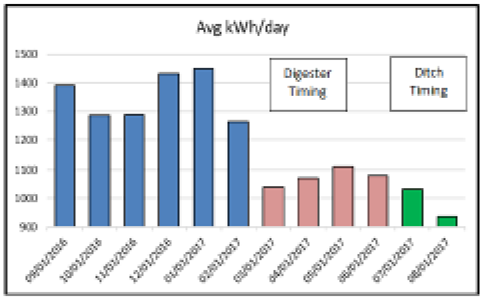
Intermittent aeration was tried at the Adamstown, Lancaster County, wastewater treatment facility to reduce effluent total nitrogen—mostly nitrate—so that the facility operators could save money by avoiding annual purchase of nitrogen credits to meet their Chesapeake Bay nutrient reduction goals. The facility includes two secondary bioreactors as oxidation ditches, aerated through surface mechanical aerators.

Using instrumentation to monitor dissolved oxygen, pH, and oxidation / reduction potential (ORP), and installing simple timers on the aerators' motor controls, the operators were able to reduce aeration time from 24/7/365 to 2 hours "on" and 3 hours "off" for every five-hour cycle.

Based on feedback from the instrumentation, the operator manipulated the timing regime from 24hr/day ON to 9.6 hours/day ON to optimize denitrification (TN removal). At the close of the project, effluent Total Nitrogen (TN) and energy consumption were reduced by 74% and 30%, respectively.



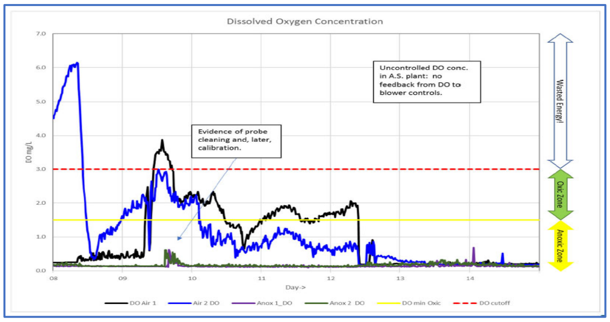
Figures: Effluent Nitrogen Reduction



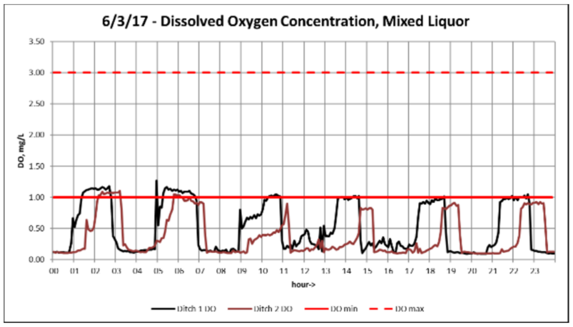
Electrical Consumption

Instrumentation and Automation

Excessive dissolved oxygen residual in bioreactors could be controlled by using variable frequency motor drives (VFD) to regulate the motors driving aeration blowers. The principle is to install continuous monitoring dissolved oxygen probes in the bioreactors and using a 4-to-20 milliamp signal from the probe controller to signal the VFD to maintain blower speed that maintains D.O. residual between 1.5 mg/L and 3.5 mg/L. The graphs below compare unregulated D.O. residual to controlled residual within aeration tanks:



Unregulated D.O. residual in bioreactor



Controlled D.O. residual via VFD feedback loop

The technology of the dissolved oxygen probes is limited at the lower end of the scale, where any reading below 0.3 mg/L may be considered to be zero. To better understand the effective ranges for denitrification, oxidation / reduction potential (ORP) probes are used, where anoxic process is favorable between 150 mV and -150 mV. In practice, the denitrification “sweet spot” occurs between 0 mV and -50 mV, although experience may be different among differing treatment technologies. ORP probes are installed in the same bioreactor in the cases of intermittent aeration, sequencing batch reactors (SBR), oxidation ditches, Orbals, Schreiber process tanks, membrane bioreactors (MBR), and the like. Where anoxic processes occur in separate tanks, the ORP probes are placed in anoxic (denitrification) tanks or in anaerobic selectors. Process automation may use ORP probes to regulate the addition of supplemental carbon or to control the nitrate recycle rate as ways to optimize denitrification.

Because nitrifier bacteria are very sensitive to pH changes, and because the action of AOB to oxidize ammonia to nitrite produces acidification of the biomass, it is important to monitor pH in the aeration tank. Automation may use pH set points to regulate the addition of alkalinity to control pH. Nitrosomonas has an optimal pH between approximately 7.0 and 8.0 s.u., and the optimum pH range for Nitrobacter is approximately 7.5 to 8.0 s.u.

ATTACHMENT H: METHOD FOR ALKALINITY DOSING CALCULATION

Typically, alkalinity in effluent should be 50 mg/L or match that of the receiving stream; however, because of bioavailability of alkalinity at the pH range needed by nitrifying bacteria, this concentration should be higher in the Aeration Tanks, 100 mg/L up to 220 mg/L.

Alkalinity demand should be calculated. Since each 1 mg/L of ammonium in the secondary influent requires 7.14 mg/L alkalinity as $CaCO_3$[13], multiply the influent (or raw) TKN (total Kjeldahl nitrogen, which is organic nitrogen and ammonium nitrogen, combined)[14] concentration in mg/L x 7.14 mg/L alkalinity to determine a minimum amount of alkalinity needed for ammonia removal through nitrification. Then determine the influent alkalinity concentration already present and subtract this from the alkalinity demand you just calculated for your influent ammonium.

Example:

- **88 mg/L Influent Ammonia-nitrogen in Raw Wastewater**
  (Estimated that Ammonia-nitrogen is 70% of TKN in domestic wastewater)
  (88 x 100%) ÷ 70% = 126 mg/L TKN estimated
- **126 mg/L Influent TKN x 7.2 mg/L alkalinity per 1 mg/L TKN = 905.1 mg/L alkalinity required**

If the secondary influent already has 403 mg/L of alkalinity, then the net alkalinity demand is:

915.2 mg/L alkalinity needed to treat: 403 mg/L alkalinity in Influent = 502.1 mg/L alkalinity demand exists

To convert this to an actual chemical dose, you will have to multiply the net demand concentration by the Influent flow rate:

If the average flow is 0.0122 MGD, then the amount of alkalinity required would be

502.1 mg/L x 0.0122 MGD x 8.34 lb./gal = 51.1 lb./day.

To convert this to a chemical dose, you will have to determine the available alkalinity in the chemical. For example, 1 lb. Soda Ash has 1.06 lb. alkalinity[15]. This means that to provide 52 lb./day alkalinity as $CaCO_3$, you need to divide this by the ratio of chemical to alkalinity:

51.1 lb./day ÷ 1.06 = 47.3 lb./day of Soda Ash (round up to 50 lb.)

Figure adding 1 fifty-pound bag over 24 hours, not all at once. Using the 100-gallon day tank, the feed rate would be

50 lb./day ÷ 24 hours = 2 lb., 1⅓ oz. per hour (100 gal. per day = c. 4.2 gal./hr.)

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[13] To account for bioavailability of alkalinity at the desired MLSS pH of 7.2 to 7.5, substitute 8 mg/L for 7.14 mg/L. This increased the alkalinity required but is also more realistic, since 7.14 mg/L is the **minimum** required.

[14] If you can't test for TKN, substitute a test for ammonia-nitrogen and multiply the result by 1.25 to approximate the combination of organic nitrogen and ammonium nitrogen, together.

[15] See the table on the next page.

Keeping track of the alkalinity demand over time should help when determining the size and capacity of the chemical feed pump and the size of the line needed. When using this dosing method, it doesn't hurt to round up to easier quantities to work with; for example, 47.3 pounds of demand rounds up to 50 pounds.

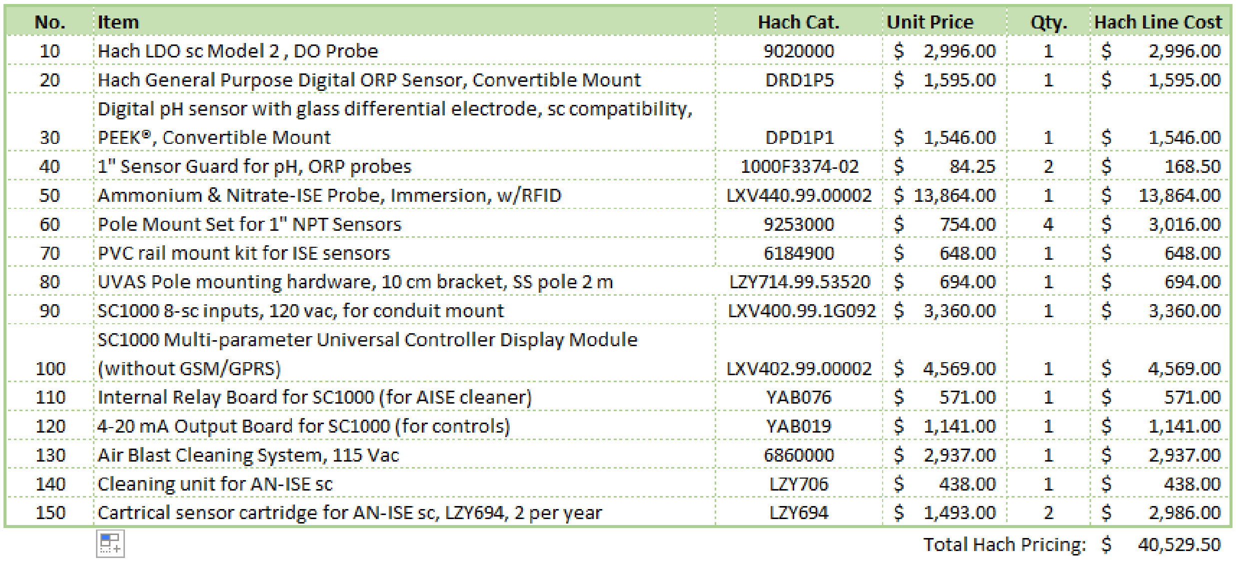
Supplemental Alkalinity Buffering Compounds

Compounds	Alkalinity-Ratio, ppm/ppm $CaCO_3$
Soda Ash	1.06
Acetate	0.82
Hydrated Lime	0.74
Quick Lime	0.56
Bicarbonate	1.68
Caustic soda	0.80
Magnesium hydroxide	0.50

ATTACHMENT I: MONITORING PROBES & CONTROLLER ESTIMATED COSTS

The equipment deployed at Dingman-Delaware Valley Campus wastewater treatment facility for this study was chiefly comprised of Hach products. In this attachment, the estimated cost for purchasing this equipment and maintenance parts is listed, excluding installation and service-contract costs. Modifications to the SCADA system to incorporate these probes for process control, such as using dissolved oxygen residuals to regulate variable frequency drives on blower motors, would have to be contracted with the SCADA provider at additional programming cost. The equipment costs listed here may not be current. Engineering costs for design and for regulatory approvals are not included. DEP staff strongly encourage facility owners and operators to seek professional engineering advice and to compare the offerings of different equipment manufacturers before settling on a brand or vendor.

Following is a table listing equipment needed for probe installation into two aeration tanks:[16] [17]



No.	Item	Hach Cat.	Unit Price	Qty.	Hach Line Cost
10	Hach LDO sc Model 2 , DO Probe	9020000	$ 2,996.00	1	$ 2,996.00
20	Hach General Purpose Digital ORP Sensor, Convertible Mount	DRD1P5	$ 1,595.00	1	$ 1,595.00
30	Digital pH sensor with glass differential electrode, sc compatibility, PEEK®, Convertible Mount	DPD1P1	$ 1,546.00	1	$ 1,546.00
40	1" Sensor Guard for pH, ORP probes	1000F3374-02	$ 84.25	2	$ 168.50
50	Ammonium & Nitrate-ISE Probe, Immersion, w/RFID	LXV440.99.00002	$ 13,864.00	1	$ 13,864.00
60	Pole Mount Set for 1" NPT Sensors	9253000	$ 754.00	4	$ 3,016.00
70	PVC rail mount kit for ISE sensors	6184900	$ 648.00	1	$ 648.00
80	UVAS Pole mounting hardware, 10 cm bracket, SS pole 2 m	LZY714.99.53520	$ 694.00	1	$ 694.00
90	SC1000 8-sc inputs, 120 vac, for conduit mount	LXV400.99.1G092	$ 3,360.00	1	$ 3,360.00
100	SC1000 Multi-parameter Universal Controller Display Module (without GSM/GPRS)	LXV402.99.00002	$ 4,569.00	1	$ 4,569.00
110	Internal Relay Board for SC1000 (for AISE cleaner)	YAB076	$ 571.00	1	$ 571.00
120	4-20 mA Output Board for SC1000 (for controls)	YAB019	$ 1,141.00	1	$ 1,141.00
130	Air Blast Cleaning System, 115 Vac	6860000	$ 2,937.00	1	$ 2,937.00
140	Cleaning unit for AN-ISE sc	LZY706	$ 438.00	1	$ 438.00
150	Cartrical sensor cartridge for AN-ISE sc, LZY694, 2 per year	LZY694	$ 1,493.00	2	$ 2,986.00
				Total Hach Pricing:	$ 40,529.50

An annual budget for maintenance costs should be included for renewal parts and standard solutions, plus professional service costs for replacement of seals, desiccant, and worn or broken parts. During professional service, the service technician also updates any firmware and recalibrates the probes:

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[16] This list makes substitutions for cost reduction to some of the items employed by DEP staff. At the time of this writing, technology is moving toward wireless communications, so probe controllers may employ newer technology than that of DEP's field equipment. Substitutions may also be made for types of probe controllers based on how a facility intends to use them.

[17] Costs are estimated based on current catalog pricing and are presented only for estimating purposes. Facility owners and operators should check and compare with equipment vendors as to the most appropriate equipment and pricing before drafting budgets. DEP makes no endorsement of any particular brand of equipment.

No.	Item	Hach Cat.	Unit Price	Qty.	VWR Line Cost
10	Salt bridge PEEK, PVDF junctions	SB-P1SV	$ 124.00	2	$ 248.00
20	Standard Cell Solution, Concentrated pH 7.0 Buffer (Equi-Transferrant), 500 mL	25M1A1025-115	$ 113.00	1	$ 113.00
	ORP Buffer Solution, 200 mV, 500 ml.L, or	25M3A1001-115	$ 101.00	1	$ 81.39
30	Zobell's ORP Buffer Solution, 500 ml. (alternative)	2316949	$ 81.39	1	$ 81.39
40	LDO Replacement Sensor Cap Kit for LDO2sc	9021100	$ 350.00	1	$ 350.00
50	Nitrate Standard, 25 mg/L NO3, 500 ml.	LCW828	$ 86.09	1	$ 86.09
				Total Hach Pricing:	$ 959.87

Service plans are available for these probes, but the costs are not listed. Hach offers differing levels of instrument service in annualized contracts:

- Bench Service Preventative Maintenance Partnership, one or two services per year;
- Bench Service Partnership, one or two services per year;
- Field Service Partnership, one or two services per year;
- Warranty Service Partnership, one or two services per year.

Service plan costs may be obtained from the manufacturer or vendor. Some facility owners and operators prefer to service the dissolved oxygen, pH, and ORP probes themselves, saving on the expense of service plans. Others prefer to contract this work to manufacturer-qualified service providers. Costs vary upon level of service but should be budgeted into the annual operating costs. DEP staff estimates that the contracted service cost for sending the AN-ISE probe for bench service, including semi-annual replacement of the sensor cartridge, is $3,581 per year. Higher tier service plans, where a technician maintains the probes at the treatment plant site, reduces the probe maintenance turn-around time from approximately eighteen days to one or two. This is an important consideration when a facility does not have back-up equipment in reserve.

pennsylvania
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WASTEWATER TECHNICAL ASSISTANCE PROGRAM