REPORT TO THE SUFFIELD WATER POLLUTION CONTROL AUTHORITY
March 9, 2010

Introduction. As measured by nitrogen removal, Suffield has the best performing municipal wastewater treatment facility in the state of Connecticut. The enclosed graph shows that Suffield's nitrogen discharge is more than three times better than it needs to be to comply with DEP's 2014 discharge limit. Very few treatment plants are bettering their year 2014 nitrogen discharge limits by a factor of 2; Suffield's ratio is 3.2.

The outstanding performance is the result of recent changes in operating procedures. After 2½ years of operating the treatment plant in accordance with Suffield's design engineer's recommendations with no impact on nitrogen removal, Suffield staff implemented several changes, beginning mid-2009. These changes have markedly improved the quality of the effluent discharged to the Connecticut River.

Prior to the changes, the Suffield treatment plant was not able to meet the 2009 nitrogen discharge limit of 52 pounds per day. Now, the facility is not only meeting the more restrictive 2014 limit of 45 pounds per day, since mid-August, the discharge has averaged 14 pounds per day of nitrogen. The concentration of nitrogen in the treated effluent has improved from 6.8 mg/L to 1.2 mg/L.

Concurrent with the improvement in nitrogen removal, phosphorus removal has also improved. Prior to the changes, effluent phosphorus averaged 1.7 mg/L. Suffield's phosphorus discharge now averages 0.4 mg/L. DEP has proposed new statewide phosphorus limits. For now, municipalities discharging to the Connecticut River are exempt. If DEP policy changes and Suffield is required to meet phosphorus limits, Suffield would meet DEP's 0.8 mg/L limit without any additional investment in equipment.

Because the process changes that brought about improved treatment involve reduced pumping and less aeration, Suffield is spending less for better treatment. A preliminary review of electrical consumption indicates annual savings of approximately $30,000. The reduced electrical consumption means less CO_2 is emitted; thus, the Suffield plant is also operating with a lower carbon footprint.

The improvements are so noteworthy that the Water Environment Federation is considering having Chief Operator Bernie Gooch and the president of the Water Planet company, Grant Weaver, make a presentation at their annual conference in New Orleans this October. An outline of their presentation is appended. In January, Grant Weaver spoke to 150 people at the New England Water Environment Association conference in Boston. Suffield was featured in a presentation titled "Nitrogen Removal: Lessons Learned." A copy of the presentation is appended.

More improvements are under consideration. Now that monitoring equipment and better controls have been installed, Suffield staff is working with the Water Planet company to gain an even better understand current conditions, so that further process refinements can be made in order to further reduce ratepayer costs, CO_2 emissions, and provide ever more consistent, higher quality effluent.

Facility Upgrade. A $5.3 million upgrade of Suffield's wastewater treatment facility was completed in 2006. The treatment plant was upgraded in order to: (i) bring Suffield's 2.03 MGD dual train, two-step oxidation ditch facility into compliance with new Long Island Sound nitrogen limits, (ii) accommodate a high industrial organic loading, and (iii) replace chlorination with UV disinfection.

The upgrade successfully improved settling. The ultraviolet disinfection system has worked as designed. Nitrogen removal, however, was unaffected. The discharge of effluent nitrogen before and after the upgrade averaged 75 pounds per day, or 6.8 mg/L.

In an attempt to improve nitrogen removal, a pre-anoxic tank and two internal recycle pumps were installed. To improve sludge settling, the anoxic tank was built as a series of smaller tanks – a "selector" – and a third final clarifier was installed. To eliminate the use and discharge of chlorine, UV disinfection replaced the gas chlorine system. Effluent BOD and TSS improved to 5 mg/L, but the new equipment did not improve nitrogen removal. Effluent nitrogen averaged 75 lbs/day (6.8 mg/L), considerably more than Suffield's 2014 nitrogen discharge limit of 45 pounds per day.

New Equipment. Suffield staff purchased and installed the equipment described below after the upgrade was completed. Staff purchased the equipment listed in order to improve their ability to monitor and control the upgraded treatment plant.

Fixed, in-place dissolved oxygen meters were installed in the two oxidation ditches and the meters were wired into the computerized control system. Staff programmed the SCADA system to control the aeration mixer speeds in order to maintain established dissolved oxygen settings.

ORP (oxidation-reduction potential) meters were installed in the new pre-anoxic tank to monitor the biochemical activity in the anoxic tanks. With these meters, it became possible to effectively operate the anoxic (low oxygen) tank in a zero-oxygen (anaerobic) mode.

Variable frequency drives (VFDs) were installed on the new internal recycle pumps in order to provide operator control of the pumping. As installed, the equipment could be operated in a fully on or off mode only.

A nitrate-nitrogen analyzer was installed to provide continuous monitoring of effluent quality. This staff installed meter was connected to Suffield's computerized control system and data is collected and logged around the clock, 24 hours a day, 365 days a year. Subsequent to its installation, the nitrate analyzer has been temporarily relocated to various locations around the treatment facility to monitor nitrogen removal, as requested by the design engineer. Staff anticipates using the nitrate meter for further diagnostic monitoring this summer. Data will also be collected to provide supplemental information for the New Orleans presentation.

Process Changes. The following changes were implemented during the summer of 2009 to provide the treatment improvements. One of the two internal recycling pumps (2,400 GPM) has been turned off and the second pump is operated only 18 hours per day. Mechanical aeration mixer settings were changed to provide less aeration in the first pass and more in the second, the opposite of the engineer's settings. The sludge holding tank blower used to operate continuously. It is now used only when the sludge press is operated; approximately 3½ hours daily.

Technical Discussion. The relatively minor changes in equipment settings listed in the preceding paragraph created new bacterial habitats. The altered environmental conditions provide more effective nitrogen as described below.

The reduced internal recycle pump rate (2.5 million gallons per day now versus 6.9 MGD before this summer's change), has reduced the flow rate through the treatment plant by 50%. As a result, the hydraulic retention time in the pre-anoxic zone had doubled to 2+ hours, beneficially causing the tank to become anaerobic. Because the tank is anaerobic, and because the influent contains a high organic strength (BOD averaging 350 mg/L or more), the pre-anaerobic tank both removes organic-nitrogen and produces volatile fatty acids. Effluent organic-nitrogen now averages 0.7 mg/L, with an average of 0.8 mg/L organic-nitrogen removed in the pre-anaerobic tank. As an incidental bonus, the volatile fatty acids (VFAs) produced in the tank promote biological phosphorus removal in the downstream aeration tank. Effluent phosphorus now averages 0.4 mg/L.

The reduced flow associated with the reduced internal recycle rate also provides for a doubled hydraulic retention time in the parallel oxidation ditches. With new aeration settings, the dual zone oxidation ditches provide ammonia removal and nitrate removal as described below.

The oxidation ditches' mechanical aeration mixer settings were changed to provide a small aerobic zone in the first pass and a longer aeration zone in the second. The current settings are as follows. In both of the parallel tanks, the second aerator is set to maintain a dissolved oxygen content of 0.7 mg/L. (Each tank's dissolved oxygen probe is located two-thirds of the way from the second mechanical aerator to the overflow weir.) The first aerator is set to run at 35% of the speed of the second aerator.

Nitrification (ammonia removal) occurs in the second aerobic zone. The lower internal recycle rate increases the retention time and the aeration settings provide sufficient dissolved oxygen. Denitrification (nitrate removal) occurs in the first aerobic zone. Enough oxygen is added to solubilize the particulate BOD coming from an ice cream manufacturer, but not so much oxygen that the BOD is aerobically degraded. Instead, the high strength waste passes into the first anoxic zone where is promotes complete nitrate removal.

The pre-anoxic tank provides little to no nitrate removal. Instead, this tank serves as a selector to improve solids removal. And, as mentioned previously, the tank supports VFA production and organic-nitrogen removal.

Suffield's sludge holding tank had historically been operated as an aerated tank. One 60 Hp motor running at a 50% variable frequency drive, VFD, setting provided a non-stop source of oxygen. This past summer, the blower was turned off in order to convert the tank to a fermenter, that is, to produce volatile fatty acids (VFAs) that could be used to improve nitrate removal in the pre-anoxic tank. With experimentation, it was determined that it was not necessary to return sludge back to the influent for nitrate removal. Yet, the experiment demonstrated that it was not necessary to continuously aerate the sludge tank contents. Significant electrical savings have been realized by operating the blowers as mixers when sludge is pumped out of the holding tank for processing.

All totaled, the Suffield plant removes 95% of the influent nitrogen. For the past six months the effluent has averaged 1.2 mg/L making the Suffield wastewater facility the most effective nitrogen removing municipal wastewater treatment plant in the state of Connecticut.

Better treatment, with a smaller carbon footprint, and at lower cost. The Suffield way!

NITROGEN REMOVAL: LESSONS LEARNED

Grant Weaver, PE & ABC Class 4

New England Water Environment Association
Boston, Massachusetts
January 26, 2010

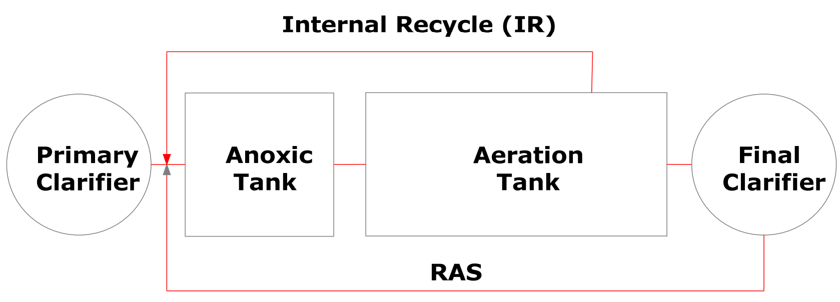
Using existing equipment differently, wastewater treatment plant professionals can improve nitrogen removal. In a big way. Example: a 2006 multi-million dollar upgrade did nothing to improve nitrogen removal at the Suffield (CT) municipal wastewater treatment plant until process changes – 2½ years later – reduced effluent total-nitrogen from 6.8 mg/L to 1.2 mg/L, bringing the facility into compliance with its 4.0 mg/L limit.

Process changes not only improve treatment, when electricity usage is reduced, facilities realize O&M savings and lessen the wastewater treatment plant's carbon footprint.

Wastewater professionals are encouraged to make process changes in order to make timely, effective, and sustainable wastewater treatment improvements. Regulators, design engineers, academia, and environmental interest groups are encouraged to support wastewater treatment personnel in providing better treatment with equipment on-hand.

A discussion of lessons learned as operator of more than fifteen nitrogen removal wastewater treatment facilities over the course of a dozen years follows. The majority of the nitrogen removal experiences were obtained at facilities equipped with pre-anoxic tanks (that is, MLE designs). First hand experiences operating facilities having post-anoxic tanks and those with no anoxic tanks are also provided.

A schematic of a typical pre-Anoxic design follows. The design strategy is ingenious. Fully nitrified wastewater containing nitrates is returned to a low-oxygen tank. The nitrates are mixed with BOD-rich influent so that bacteria can convert the nitrate-nitrogen to nitrogen gas. The gas escapes harmlessly into the atmosphere. All of this is done without overloading the clarifier.



The design is not without its weaknesses. Three of the most important considerations follow. One, air is contained in the internal recycle; and, air shuts down the denitrification process. Two, the greater the recycle rate, the lower the hydraulic retention time in the both the anoxic and aeration tanks. Three, the process is dependent upon the influent for BOD; and, sometimes there isn't enough soluble BOD to fully remove all of the nitrates.

Operators willing to experiment can bring about significant water quality improvements by experimenting with process adjustments. Such are the lessons learned…

Lesson #1: slowing down the internal recycle rate can provide better treatment.
It has been my experience that doing so almost always improves treatment. Changing the internal recycle rate from three times the influent flow rate to one times the wastewater flow doubles the hydraulic retention time in both the anoxic and aerobic zones (assuming a 50% RAS rate) and reduces the amount of oxygen returned to the anoxic tank by one-third. The result: improved ammonia removal at lower dissolved oxygen concentration, improved nitrate removal because of (a) an increased hydraulic retention time and (b) less "toxic" air entering the anoxic tank.

A common theme connects lessons two through five. It is this: importing BOD can markedly help with nitrate removal (denitrification).

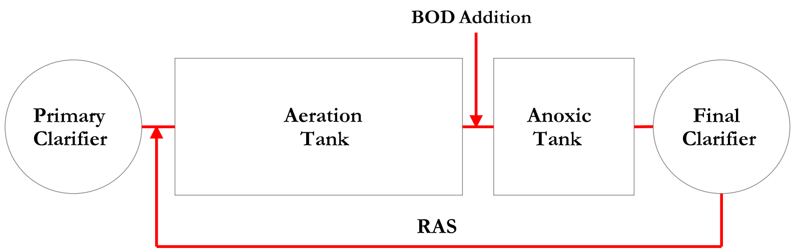
Lesson #2: more septage can be better.
Nitrate removal requires BOD and the volatile fatty acids (VFAs) in septage are among the best forms of BOD. The Willimantic (CT) wastewater treatment plant – with no internal recycle – discharged 8 mg/L total-N largely because of the denitrifying support provided by their very high septage load.

Lesson #3: inefficient primaries may help treatment.
When nitrate removal is affected by a lack of soluble BOD, it may be advisable to "de-tune" primary treatment in order to get more BOD into the pre-anoxic tank. That is, if doing so doesn't cause problems elsewhere. Ways to "detune" primary clarifiers include taking one or more primary clarifiers off line, overloading the in-service primaries by not pumping as much sludge, and/or bypassing some or all of the flow around the primary clarifiers. By simply drilling five one-inch holes in a slide gate, East Hampton's Scott Clayton doubled nitrate removal.

Lesson #4: waste activated sludge can be used as a source of BOD.
Partially digested ("fermented") sludge contains VFAs (the same compound that makes septage a good denite food source). Returning up to ten percent of the waste activated sludge (WAS) back into the wastestream can improve denitrification. Provided, that is, that aeration capacity exists and the secondary clarifiers can handle the extra load. It's something I've done at East Haddam's SBR (sequencing batch reactor) treatment plant.

Lesson #5: make it a pre-Anaerobic zone.
If the organic loading is high enough and the retention time is long enough, the pre-anoxic tank can be made anaerobic in order to create VFAs and improve nitrate removal. The volatile fatty acids will also provide for some biological phosphorus removal, as was experienced at Suffield (CT). And, the anaerobic zone may convert up to 1.0 mg/L of organic-nitrogen to ammonia, allowing effluent total-nitrogen values to fall below 1.0. Yes, below 1.0 mg/L!

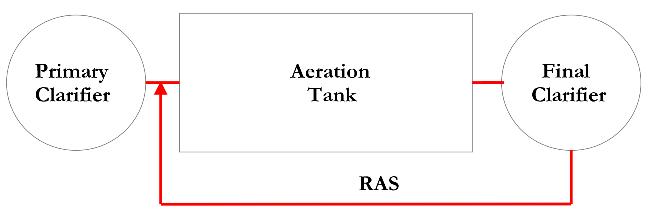
The sixth lesson was learned at treatment plants employing post-anoxic nitrate removal. A schematic of a post-anoxic tank follows. Post-anoxic is a linear treatment sequence that, because of the absence of internal recycling, allows treatment to occur in smaller tanks.



The biggest problem with this design strategy is the fact that BOD supplement needs to continuously be added. Carbon substrates are not only costly, they are potentially hazardous: alcohol is flammable.

Lesson #6: ongoing operator attention and adjustment is required.
Fluctuations in influent t-N affect the amount of soluble BOD that needs to be added. When too much BOD is added, it passes through the post-anoxic tank into the effluent. As a result, effluent BOD rises. This, in turn, can create an increase in effluent TSS. If not enough BOD is added, the nitrate will not completely breakdown to nitrogen gas and the nitrate will pass through into the effluent, increasing effluent total-nitrogen. Another operating factor: alkalinity testing needs to be performed in the aeration tank. The use of final effluent alkalinity readings will give misleading information. As a safer alternative to alcohol, sugar, Micro-C and other non-flammable sources of BOD can be used.

Conventional activated sludge treatment plants such as that shown schematically below can oftentimes be easily modified to provide effective total-nitrogen removal.



Lesson #7: SBR-like cycling of aeration
If nitrification is complete, periods of little to no air can benefit operations by creating periods of anoxic conditions and therefore provide a temporary anoxic tank for nitrate removal. Operators who experiment with cycling aeration air on and off will generally find that doing so not only improves nitrogen removal, but it results in fewer filaments, and – during extreme wet weather – reduces the solids loading on hydraulically stressed final clarifies and retains more mixed liquor in the plant. If existing conditions provide effective BOD removal and fully nitrify ammonia to nitrate, operators can begin experimenting by turning air off for periods of one-half hour every six hours. If this doesn't adversely affect ammonia removal, the off cycle can be extended to an hour and the on cycles shortened to four hours, or until effective nitrate removal occurs.

The following slides were used in the "Nitrogen Removal: Lessons Learned" presentation given at the New England Water Environment Association meeting January 26, 2010.

Case Study: Suffield, Connecticut

Objective:

Reduce total-N to 4.0 mg/L (45 lbs/day)

Process changes:

1. Create pre-anaerobic tank by reducing internal recycle pumping rate
2. Adjusted aerator settings
3. Stop aerating sludge in holding tank

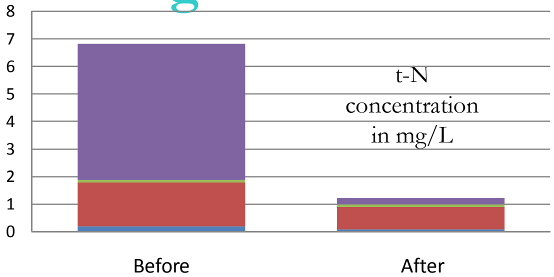
Chief Plant Operator:
Bernie Gooch

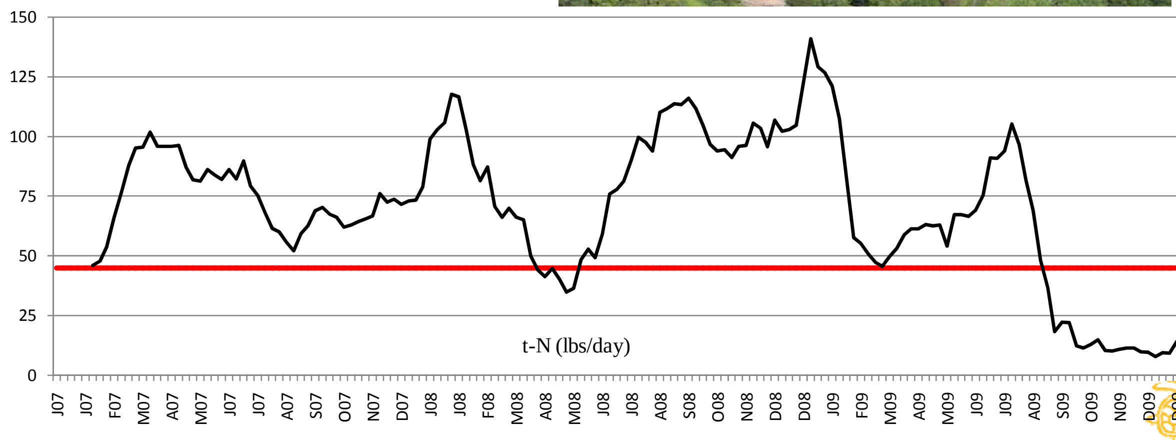
Design Flow: 2.03 MGD
Actual Flow: 1.3 MGD

$5.3 Million 2006 Upgrade

2½ years operation with no impact on effluent t-Nitrogen

Suffield, CT Nitrogen Results





PROCESS CHANGES REDUCE TOTAL-NITROGEN TO 1.5 MG/L AT SUFFIELD (CT) MUNICIPAL WASTEWATER TREATMENT PLANT

ABSTRACT SUBMITTED TO WATER ENVIRONMENT FEDERATION FOR PRESENTATION AT WEFTEC '10 – OCTOBER 2-6, 2010
NEW ORLEANS, LOUISIANA

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Description of Facility and Wastewater Characteristics

In 1989, a 2.03 MGD dual train, two-step oxidation ditch municipal wastewater treatment facility was constructed to meet the needs of Suffield, Connecticut. The facility serves 2,909 residential and 101 commercial-industrial-institutional customers, including an ice cream manufacturing facility and a state prison.

Compliance with conventional permit requirements has been routine. Prior to the 2006 facility upgrade, flow averaged 1.4 MGD and the facility produced an effluent with typical BOD and TSS concentrations of 5 and 10 mg/L respectively.

2004-2006 Facility Upgrade – what was done & results

An engineering study was performed in 2004 to accommodate the high organic loading associated with the ice cream manufacturer and to address concerns about nitrogen pollution of Long Island Sound. A $5.3 million facility upgrade was completed in 2006. To improve nitrogen removal, two internal recycle pumps were installed and a pre-anoxic tank was constructed. In addition, a third final clarifier was installed, and UV disinfection replaced the gas chlorine system.

With a third clarifier, effluent BOD and TSS are now consistently below 5 mg/L, but effluent nitrogen was unaffected by the upgrade. The total-N concentration remained unchanged at approximately 7 mg/L. Because the new equipment had minimal effect on nutrient removal, Suffield was not able to meet their nitrogen loading allocation of 52 pounds per day.

After two and one-half years of operating the facility using the settings established by the design engineer, treatment plant staff experimented with process changes in an effort to improve nitrogen removal.

2009 Process Changes

The following process changes were made:

- one of the two fixed speed internal recycling pumps (2,400 GPM) was turned off and the second pump was operated 18 hours per day
- the mechanical aeration mixer settings were changed to provide less aeration in the first pass and more in the second, reversing the engineer's settings

- Daily field testing of Ammonia, Nitrite, Nitrate and Alkalinity was performed to monitor results. Weekly lab testing of nitrogen parameters continued.

The changes significantly altered treatment:

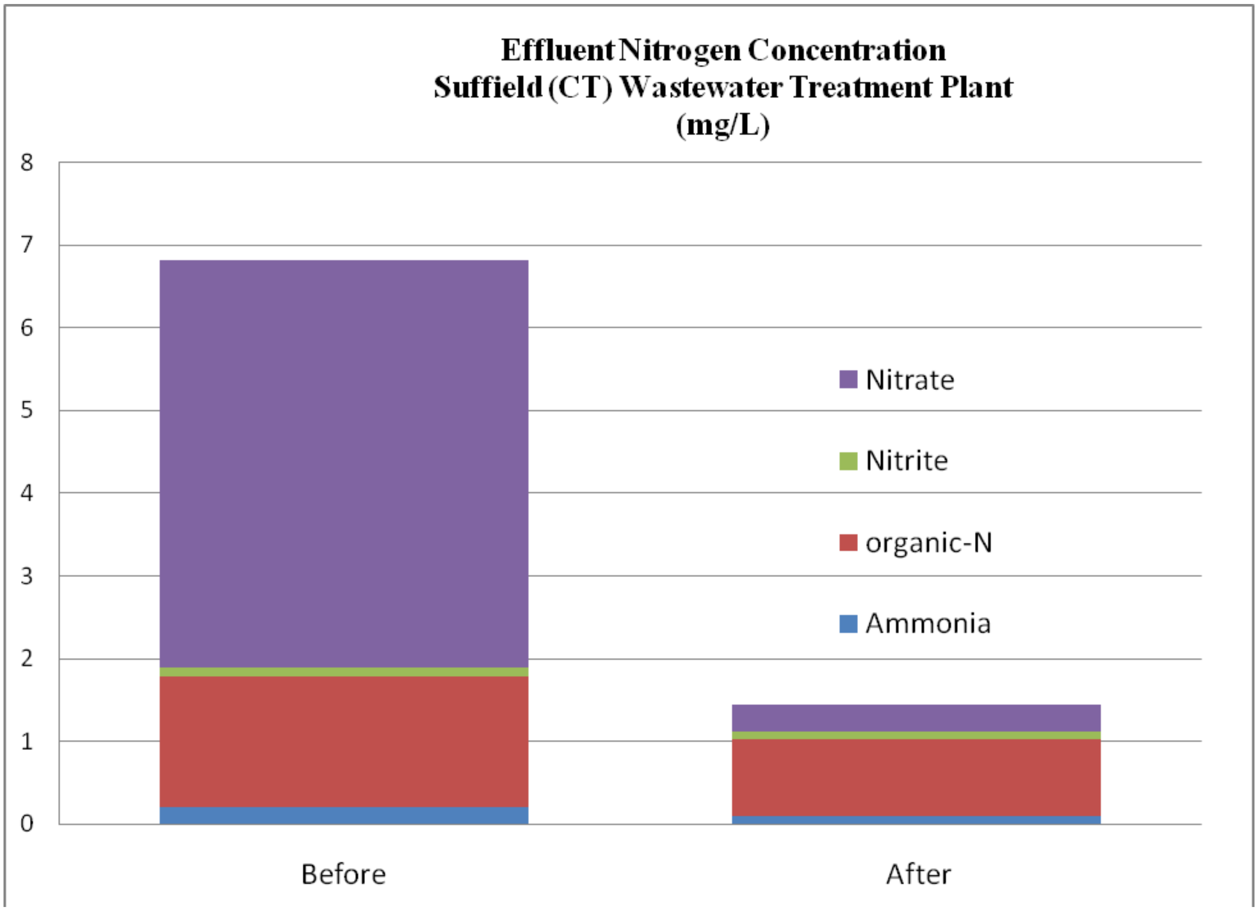
- the reduced internal recycle rate doubled the hydraulic retention time in the pre-anoxic zone, causing the tank to become anaerobic; as a result, the tank now provides additional organic-Nitrogen removal (a 0.7 mg/L improvement)
- the short, initial aeration zone solubilizes the high particulate BOD waste from the ice cream manufacturer, and as a result, provides a ready supply of BOD to promote Nitrate removal in the subsequent anoxic zone (a 4.6 mg/L improvement)
- the longer retention time in the second aeration zone that results from the reduced internal recycle rate provides for more consistent, complete Ammonia removal (a 0.1 mg/L improvement)

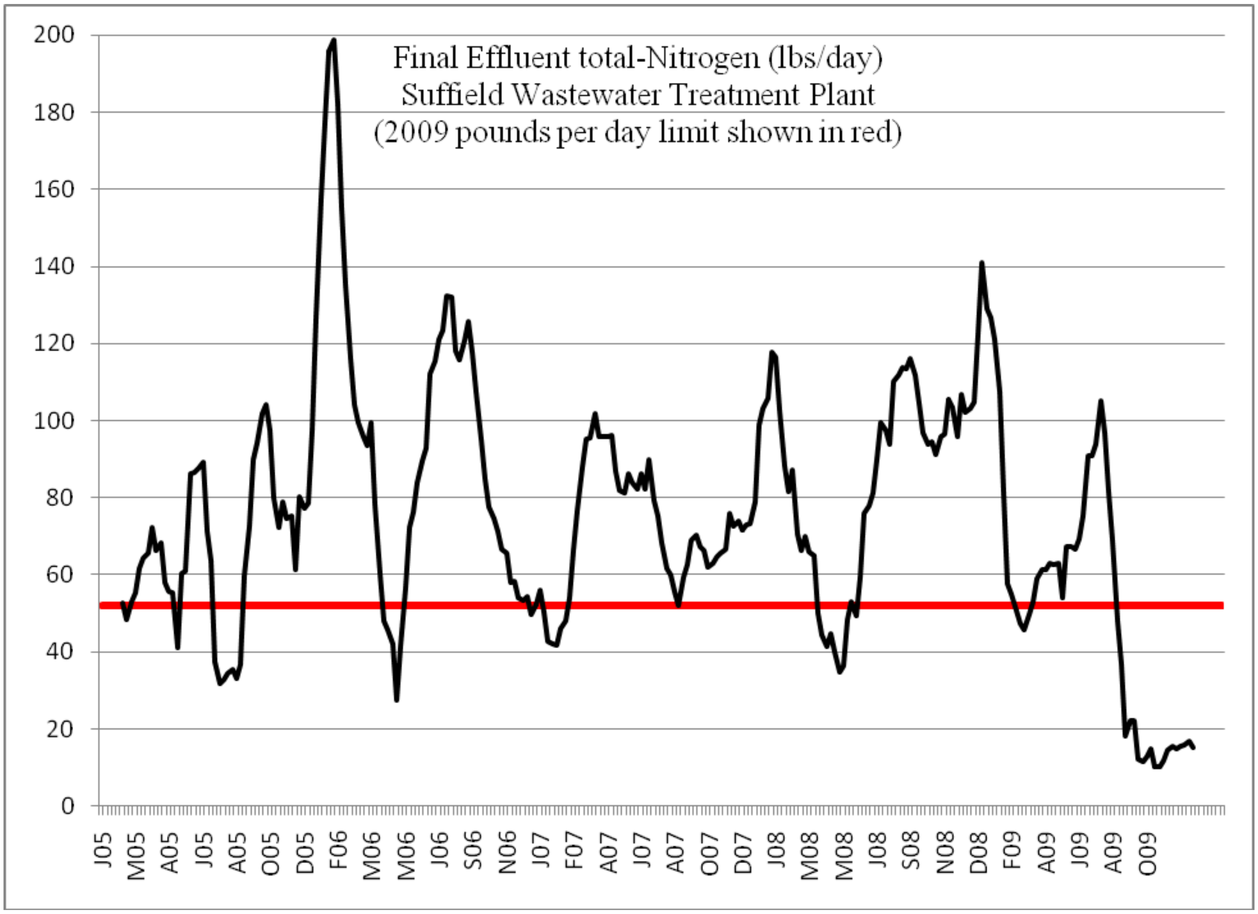
Full compliance with all permit conditions is routine:

- effluent BOD and TSS are consistently below 5 mg/L
- effluent total nitrogen loading is now 12 pounds per day – less than one-third of the 45 pounds per day 2014 discharge limit – and one-sixth of the 79 pounds per day prior to the changes
- effluent total nitrogen concentration is now less than 1.5 mg/L; prior to the process changes it averaged 6.8 mg/L
  - effluent Ammonia improved slightly and is now consistently 0.1 mg/L or less
  - effluent TKN dropped to less than 1.0 mg/L, a 0.7 mg/L organic-N reduction
  - effluent Nitrite + Nitrate fell to less than 0.5 mg/L, a 4.6 mg/L decline in Nitrate (essentially zero Nitrite in the effluent before or after the process changes)

Future

Suffield is experimenting with further process modifications in an attempt to maintain the high level of nitrogen removal while using less energy. Doing so will reduce the facility's carbon footprint. As a side benefit, annual electrical savings of approximately $50,000 are anticipated.


Effluent Nitrogen Concentration
Suffield (CT) Wastewater Treatment Plant
(mg/L)
8
7
6
5
4
3
2
1
0
Nitrate
Nitrite
organic-N
Ammonia
Before
After


Final Effluent total-Nitrogen (lbs/day)
Suffield Wastewater Treatment Plant
(2009 pounds per day limit shown in red)
200
180
160
140
120
100
80
60
40
20
0
J05
M05
A05
J05
A05
O05
D05
F06
M06
M06
J06
S06
N06
J07
F07
A07
J07
A07
O07
D07
J08
M08
M08
J08
S08
N08
D08
F09
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