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Innovative Nutrient Removal Technologies:
CASE STUDIES OF INTENSIFIED OR ENHANCED TREATMENT

WEF 2022 Webcast Series

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EPA Office of Wastewater Management

June 15, 2022

Presentation Outline

- Scope and Main Findings
- Operational and Statistical Analysis Performed
- Individual Case Studies:
  - Technologies
  - Results & Benefits
- Q&As After Presentation

Scope & Main Findings

- In-house project with detailed case studies of six innovative nutrient removal technologies for Nitrogen or Phosphorus removal. Includes one study on an ammonia removal process.

- Provides long-term (3-yr.) analysis of operational performance, statistical variability, benefits, and lessons learned.

- A number of highly innovative technologies have been introduced to the market which provide a number of advantages compared to conventional technologies.

- Longer-term performance analysis can be instrumental in assessing treatment efficacy and reliability in meeting effluent targets.

- Innovative technology options for lagoon systems are available for year-round ammonia removal to low levels even in cold climates.

Disclaimers

- EPA does not endorse specific treatment technologies or processes.
- Technology performance and variability information presented reflect an analysis of actual plant operating data and is not intended to reflect the best possible performance of the technologies or their operation.
- Actual performance and variability in effluent concentrations is affected by site-specific factors such as process design, wet weather flow, variability in influent flow and concentrations, process control capabilities, presence of biological inhibitors or toxics, presence of equalization tanks, sidestreams, and many other factors. In addition, a facility's permit limits and nutrient loading relative to the design capacity could be a significant factor that impacts performance. As such, the information in this report can be viewed as a guide based on the investigated plants' actual full-scale operation over 36 months but should not be used to translate performance or variability to other plants without careful consideration of the plant's site-specific conditions.
- The views expressed in this presentation are those of the speaker and do not necessarily represent the views or policies of the U.S. Environmental Protection Agency.

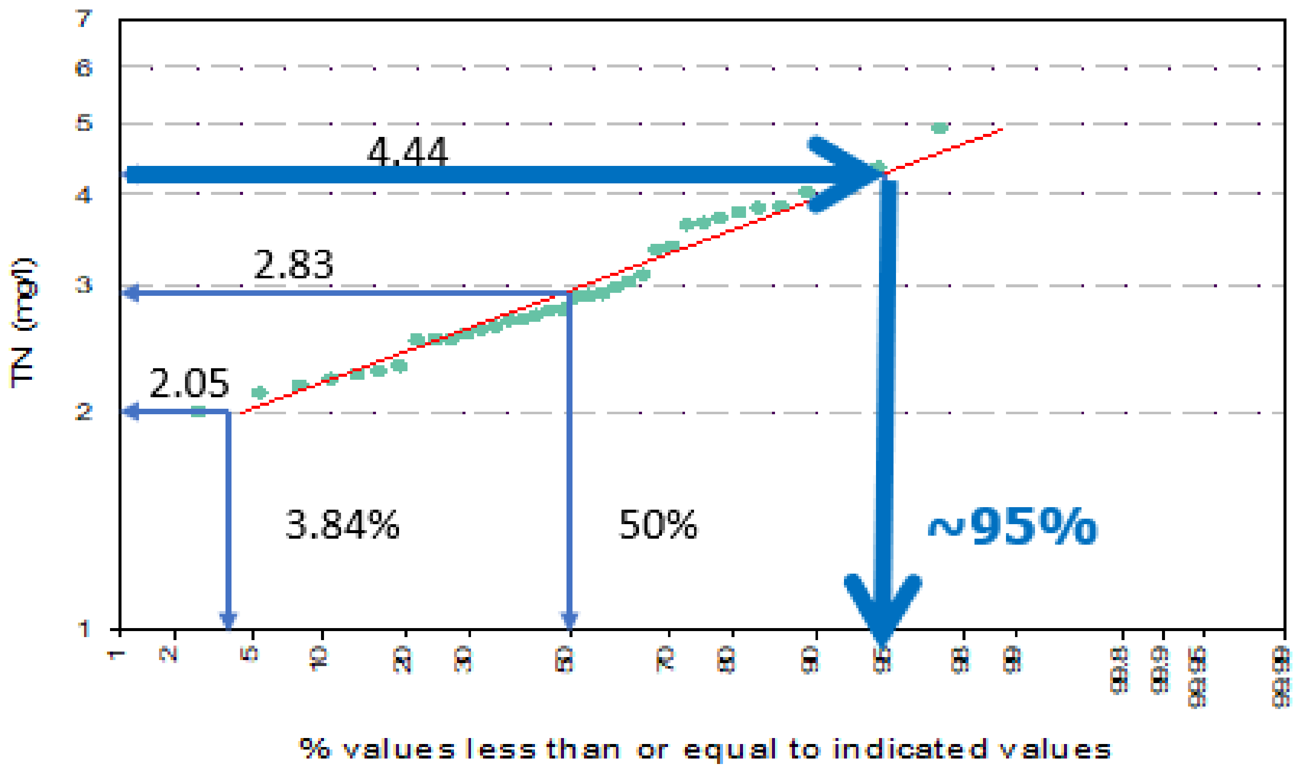
Acknowledgement

Facility	Representative
AlexRenew Advanced Water Resource Recovery Facility, City of Alexandria, Virginia	Hari Santha, Felicia Glapion
Westside Regional Wastewater Treatment Plant, District of West Kelowna, British Columbia, Canada	Bryan Mazda, Angela Lambrecht
F. Wayne Hill Water Resource Center, City of Buford, Georgia	Pierce Freeman, Gayathri Mohan, J.C. Lan, Robert Harris
City of Kingsley Wastewater Treatment Facility, City of Kingsley, Iowa	Steve Jantz
South Durham Water Reclamation Facility, City of Durham, North Carolina	Charles Cocker
Hillsborough Wastewater Treatment Plant Hillsborough, Town of Hillsborough, North Carolina	Jeff Mahagan

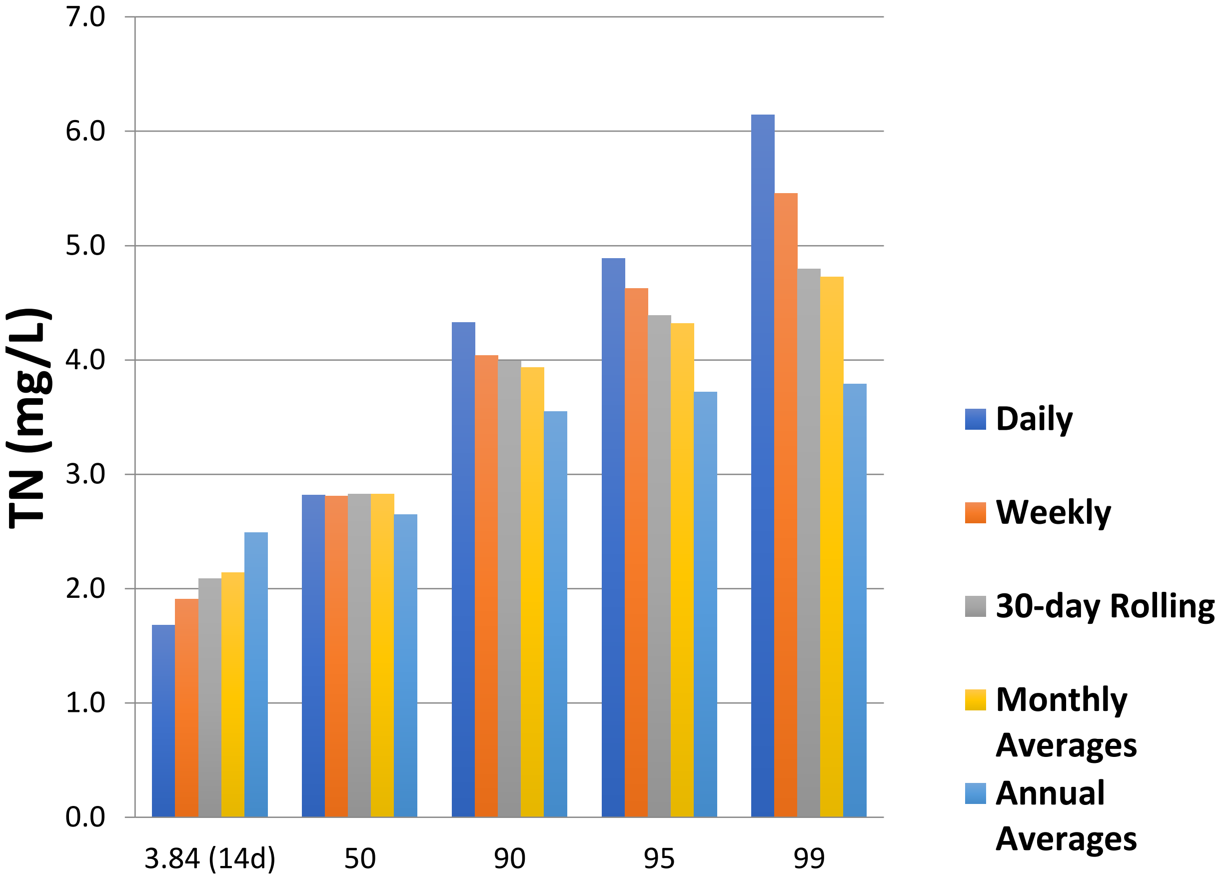
Operational Performance and Statistical Analysis

- A technical overview of each innovative process explaining how the process works, its nutrient removal mechanism, and advantages compared to conventional processes.
- Evaluate technology performance and stability under conditions it was achieved.
- Describe challenges addressed and lessons learned in implementing the technology.
- Analysis of <u>3 years</u> of nutrient species monitoring data
- Statistical Analysis includes:
  - ✓ Time series plots, probability plots, and conventional statistics
  - ✓ Data manipulations conducted based on daily, 30-day rolling average, monthly average, and 12-month rolling average (rolling annual average) values
  - ✓ Technology performance statistics and ratios

Example – Cumulative Probability Plots and Summary Charts



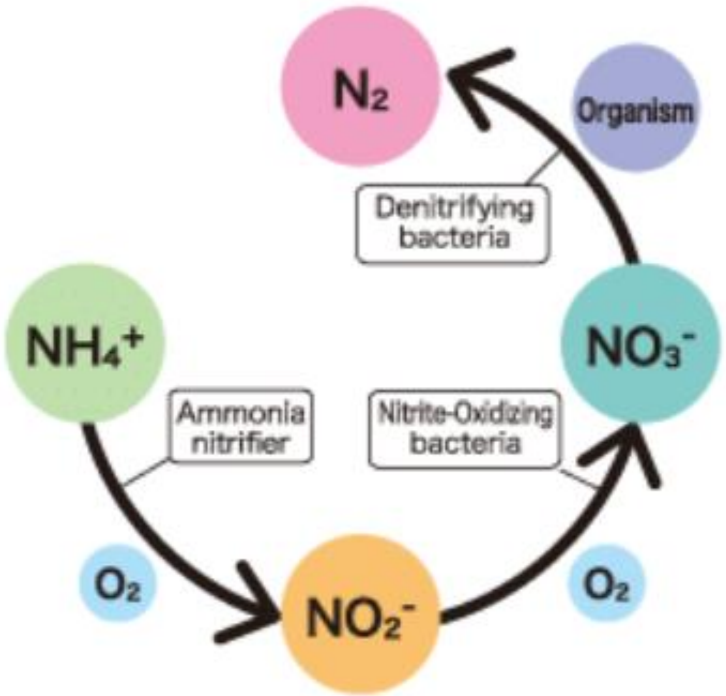
Monthly Average Probability Plot



Probability Summary Chart

Variability data informs reliability to meet a particular permit limit

Conventional Nitrogen Removal

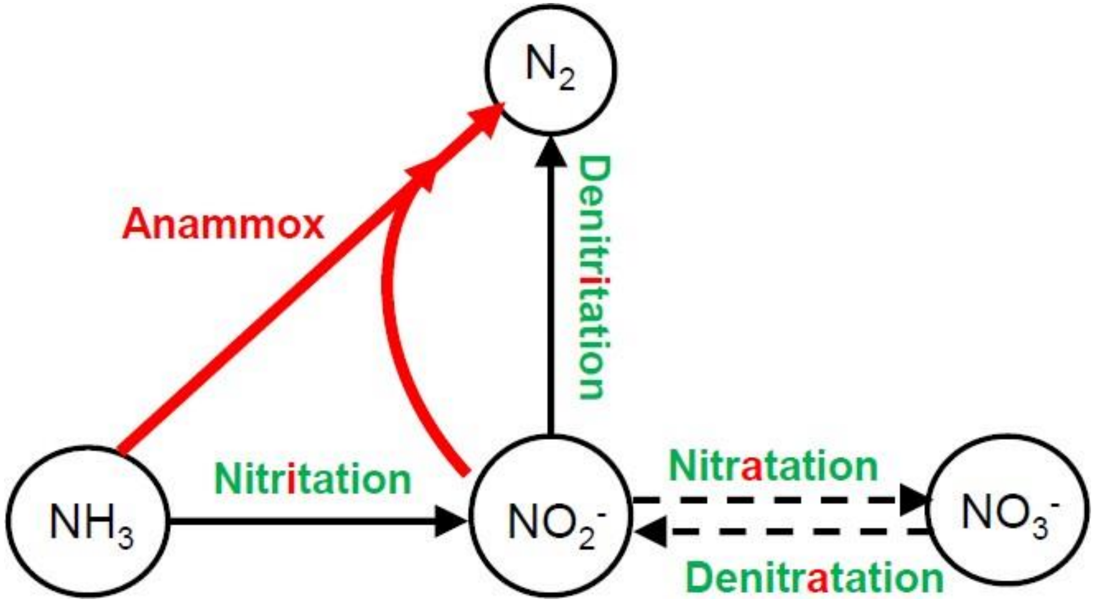


Conventional Phosphorus Removal

Chemical Addition – Metal Salts

Biological Phosphorus Removal (BPR)

Deammonification*



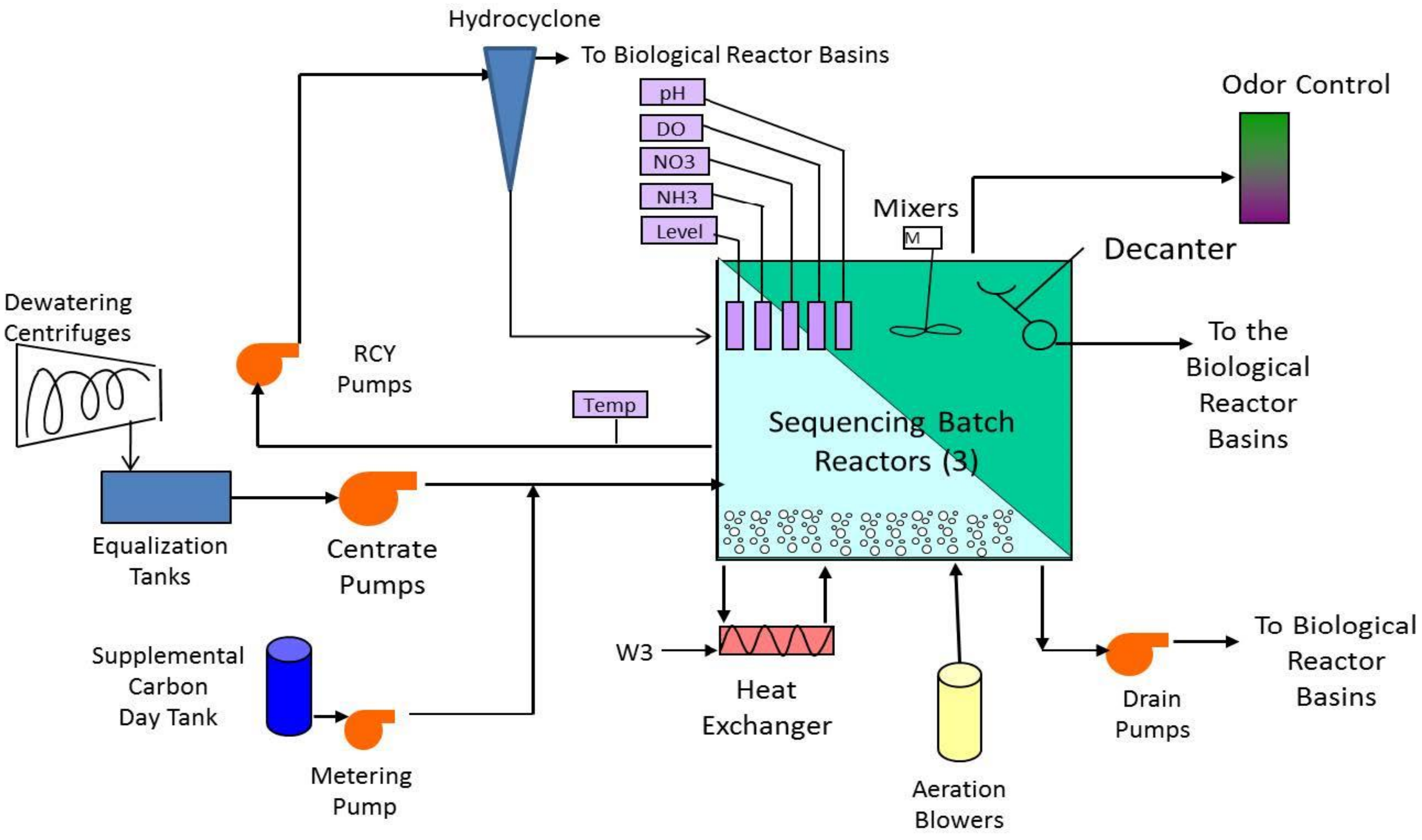
Benefits:

- Aeration energy needed is about 55-60% of that needed for conventional nitrification/denitrification process.
- No carbon is generally needed
- Alkalinity demand reduced by about 45%.
- Reduction in sludge production.

* *(WERF Nutrient Challenge (2014) "Deammonification")*

AlexRenew Advanced Resource Recovery Facility - Alexandria, VA - DEMON® Sidestream Deammonification

- 54 mgd Plant
- BNR either in MLE or step-feed mode
- Nitrogen Limits:
  - **3.0 mg/L TN Annual Avg**. (2017)
  - 493,381 lbs TN/yr (2015 & 2016) - equiv. to **4.5 mg**/l at actual AA flow
  - Seasonal Weekly & Monthly Avg. NH_3 Concentration Limits

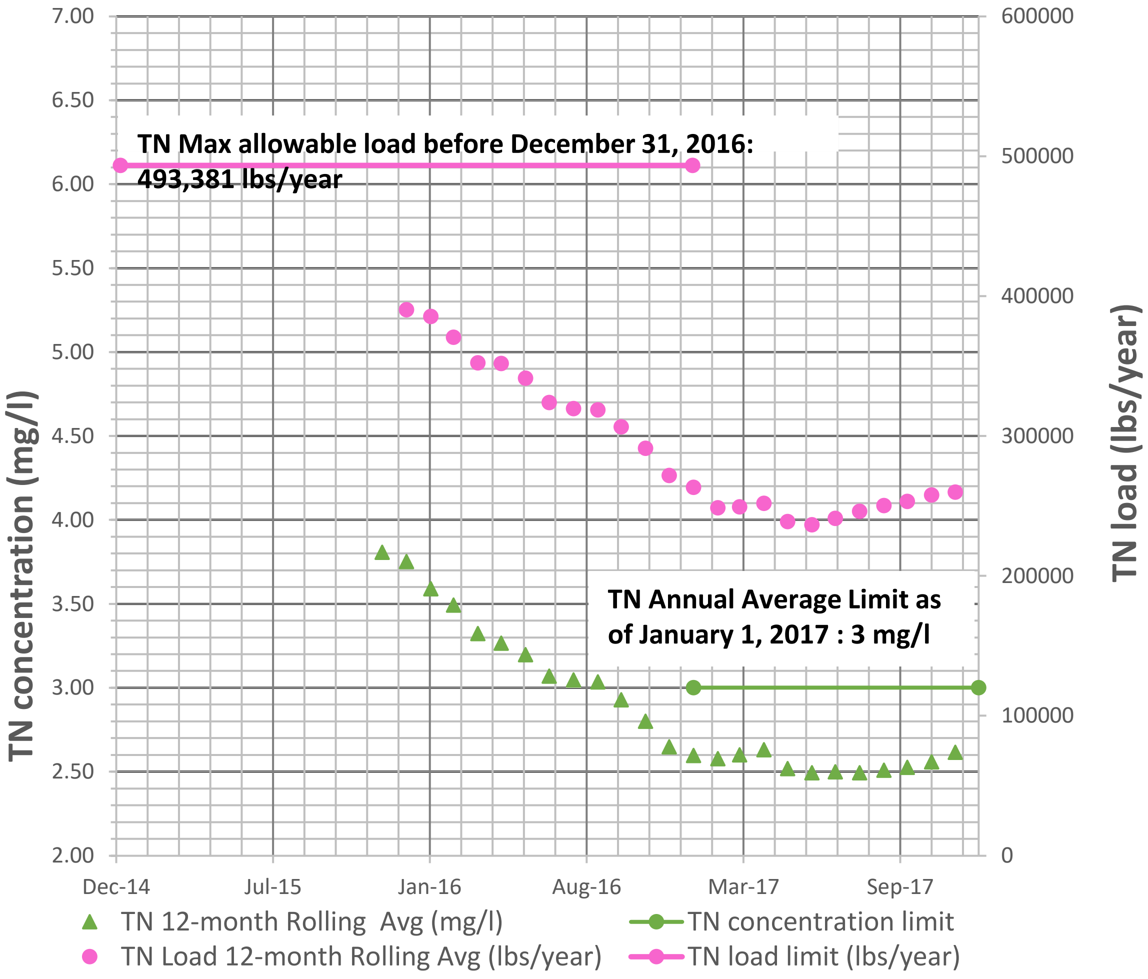


Schematic of Deammonification Reactor at AlexRenew (Sanjines et al, 2017)

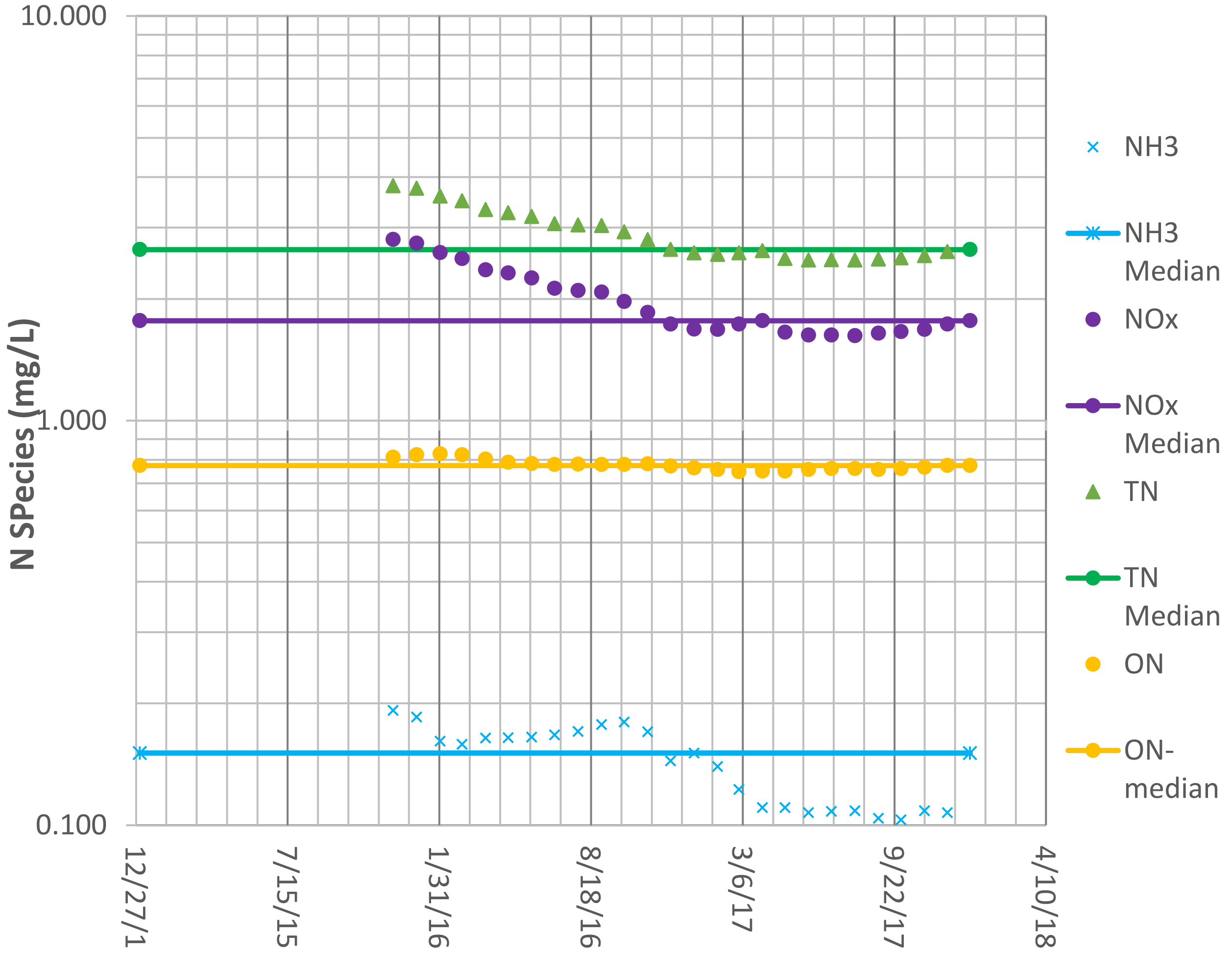
Process Description:

Centrate pre-treatment (CPT) system with the DEMON® sidestream deammonification process to remove anaerobically-digested sludge centrate nitrogen. Start-up: May 2015

Performance & Statistical Analysis - AlexRenew ARRF



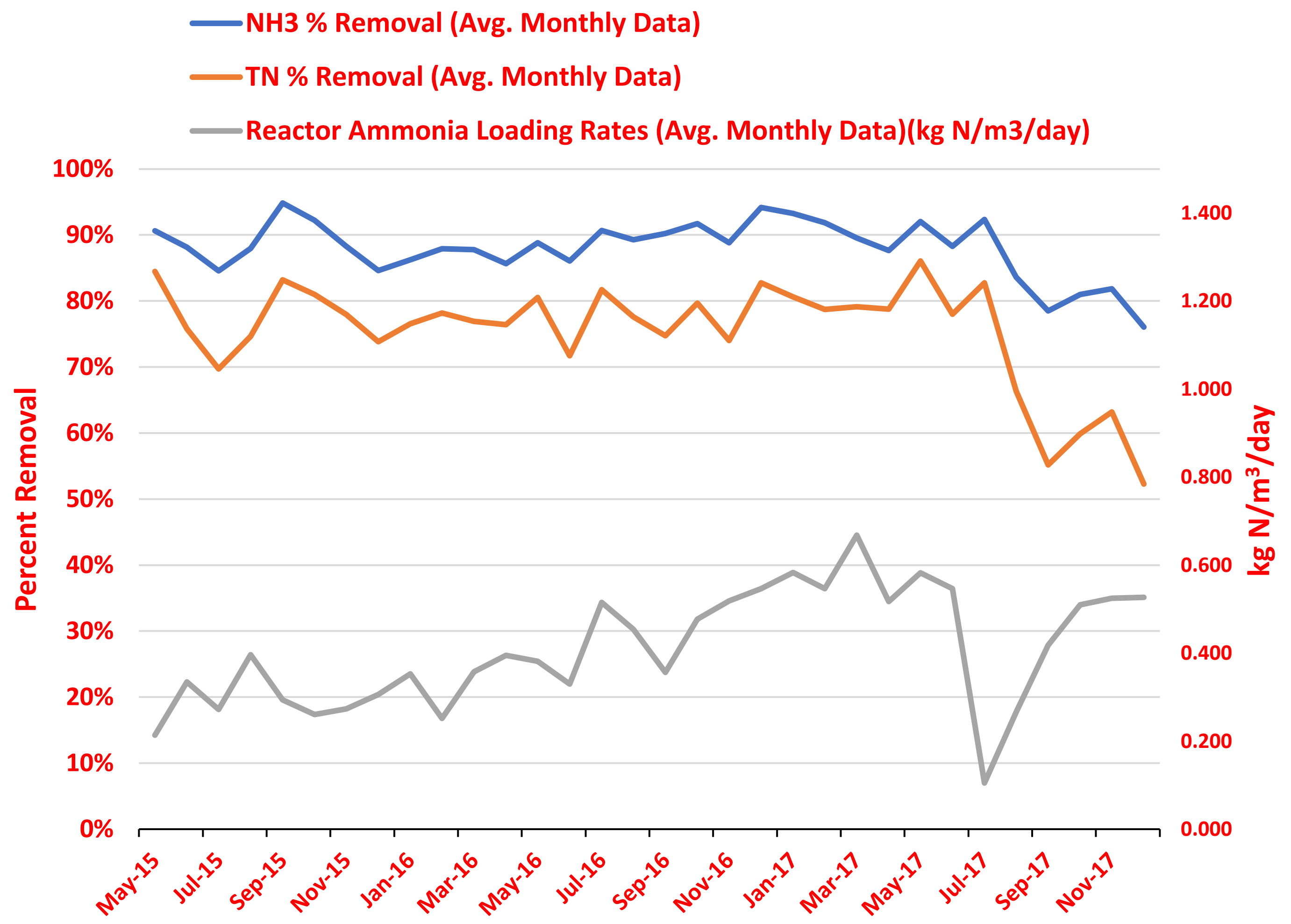
12-Month Rolling Average Plant Effluent TN load



12-Month Rolling Average Plant Effluent N Species

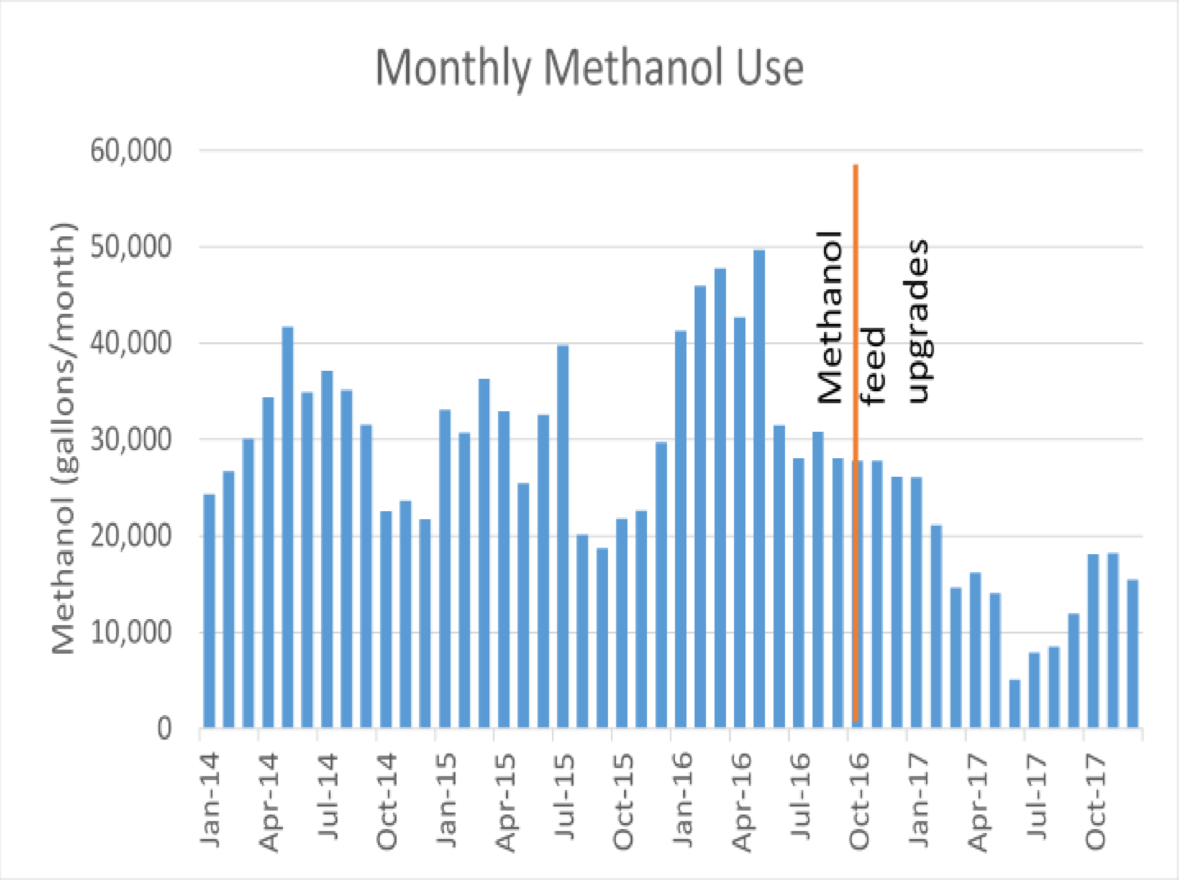
Year	Annual TN Limit	Effluent Discharge
2015	493,381 lbs/yr	388,919
2016	493,381 lbs/yr	268,976 lbs/yr
2017	3 mg/l	2.61 mg/l

Performance & Statistical Analysis - AlexRenew ARRF

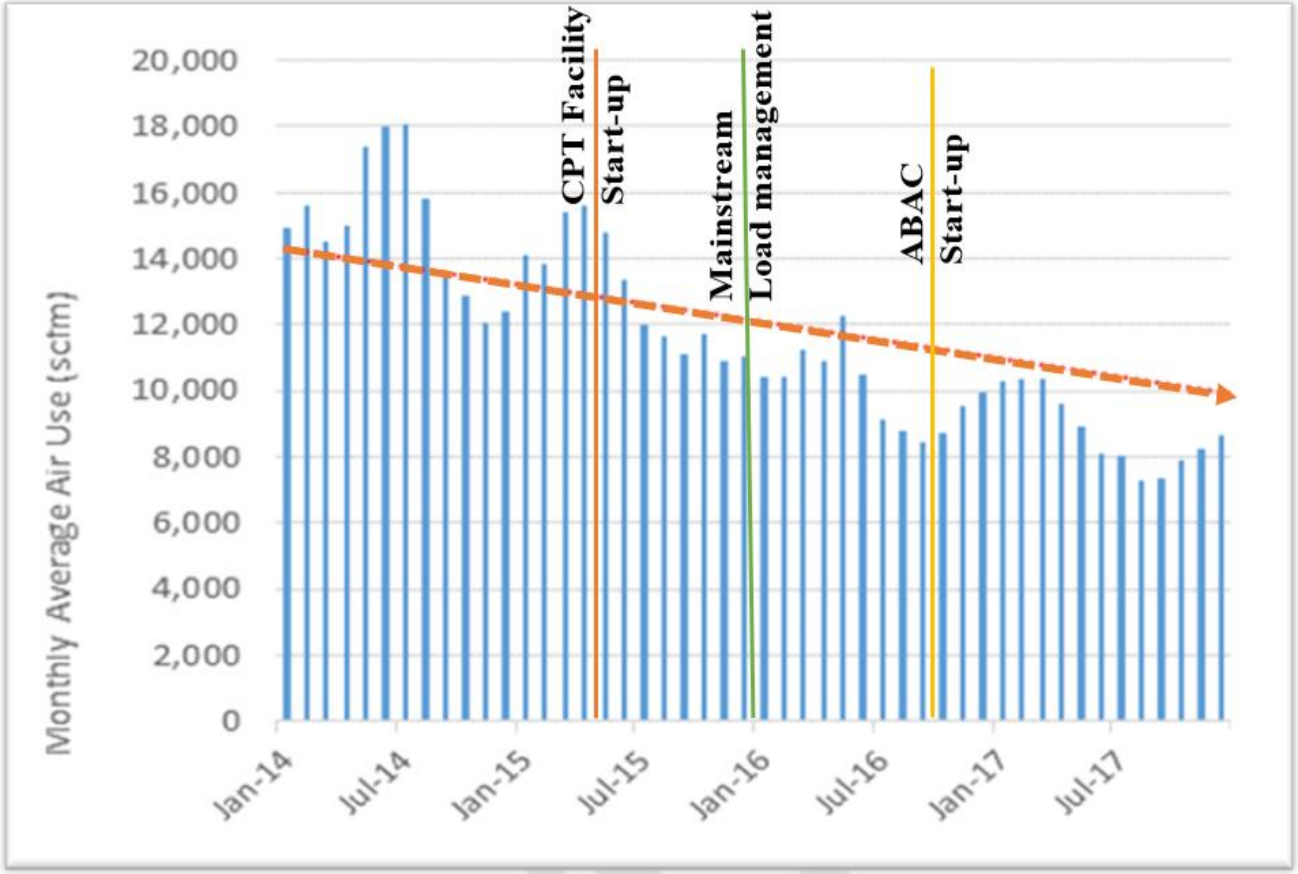


Ammonia & TN Removal Efficiency in Deammonification Reactor

Performance Analysis - AlexRenew ARRF



Average Monthly Methanol Use



Average Monthly BNR Aeration

Westside Regional Wastewater Treatment Facility, Kelowna, BC - Sidestream RAS Fermentation

Plant Description:

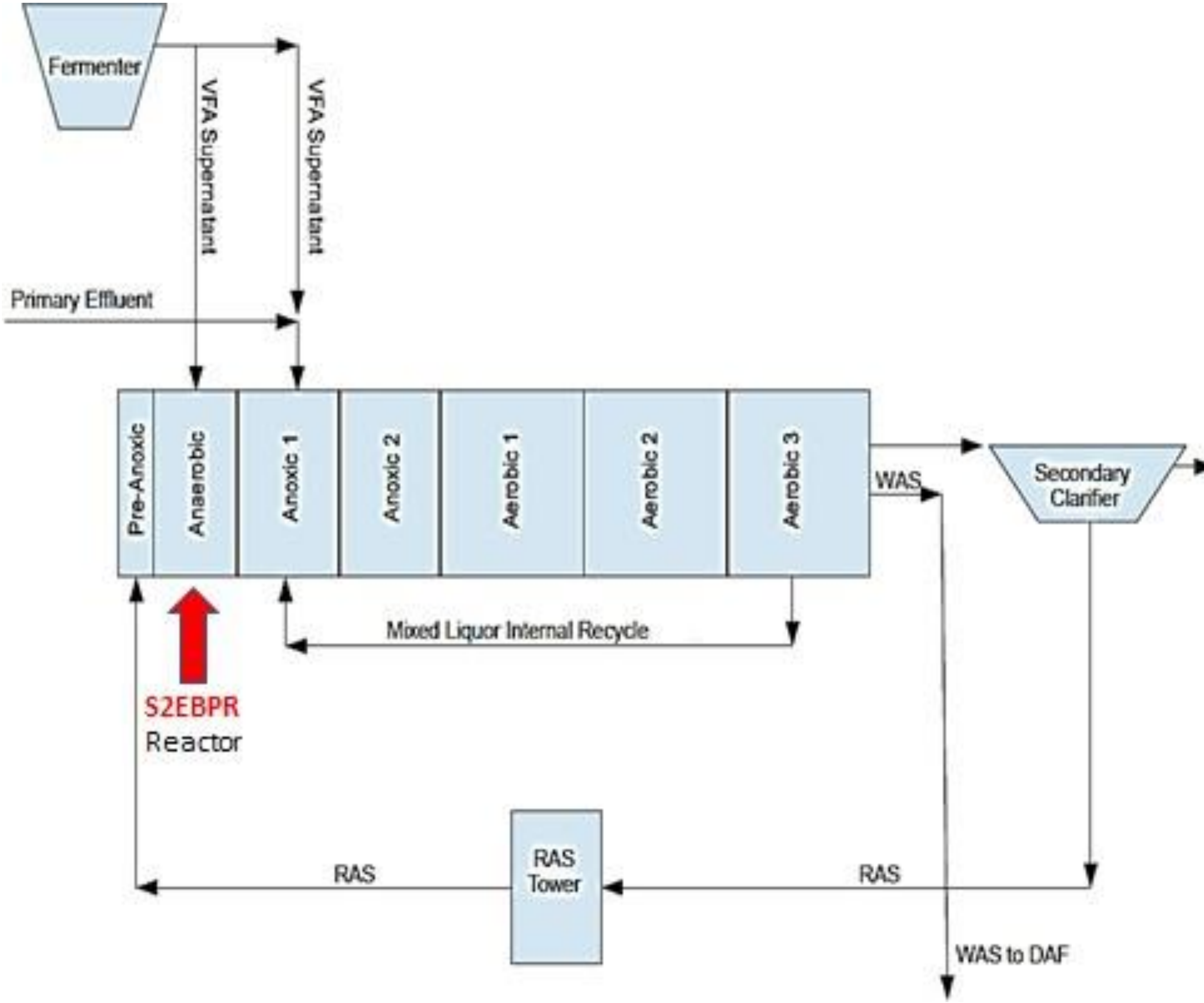
- 4.4 MGD Plant

- TP limit:
  - 0.2 mg/l (Annual Avg)
  - 2.0 mg/l (Daily Max)

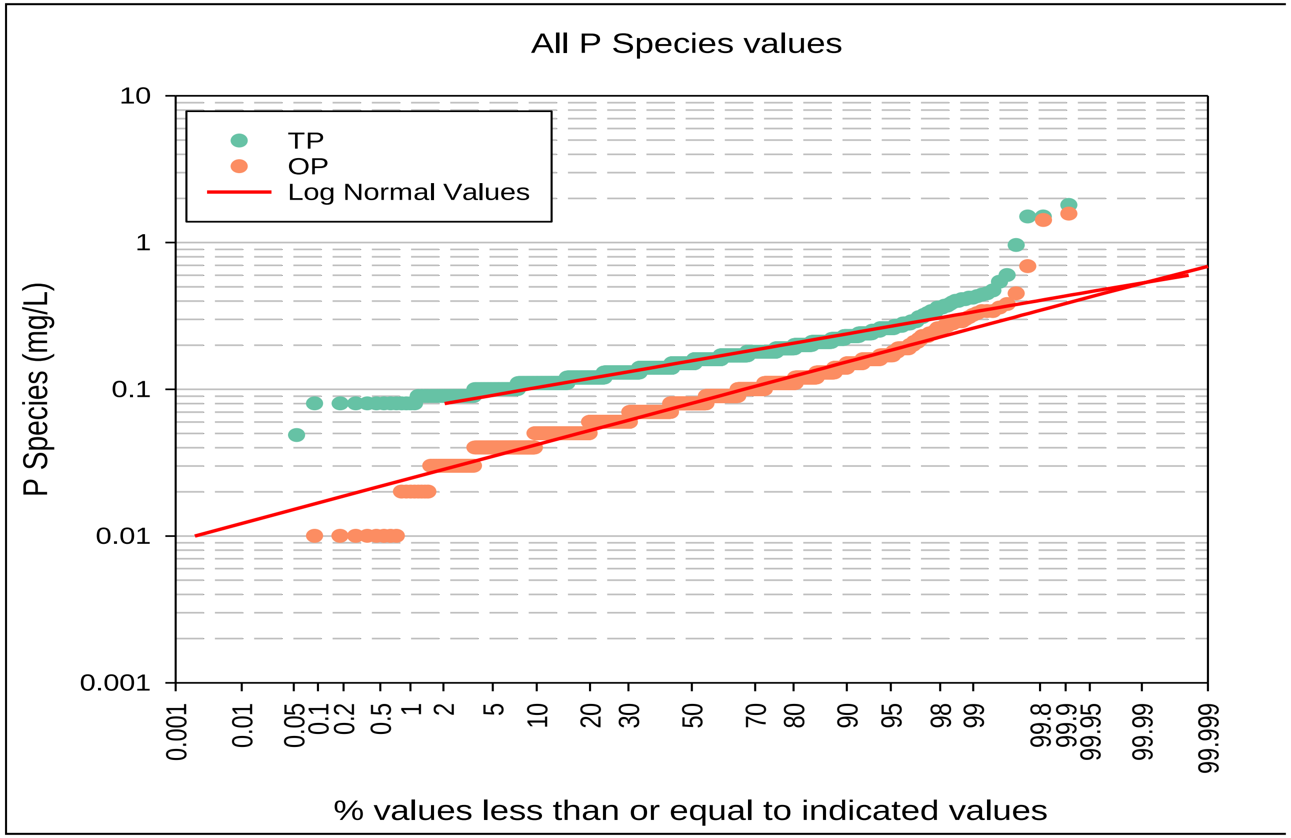
- Modified Westbank Process process with sidestream EBPR (S2EBPR), fermentate addition, Chemical P trim, cloth filters

Process Description:

S2EBPR: Anaerobic RAS sidestream treatment and PAO selection (with a portion of primary fermentate) following RAS anoxic pretreatment.

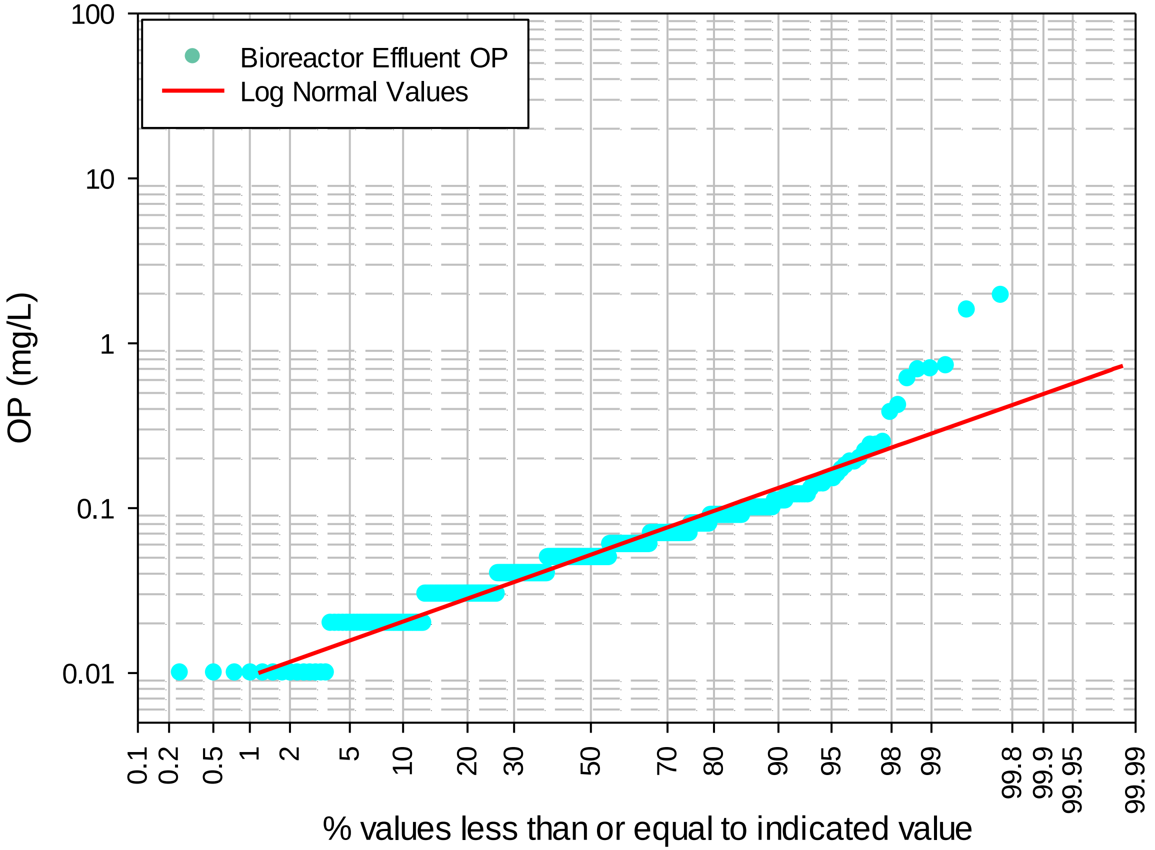


Performance Analysis - WRWTF



Probability Plots for <u>Plant Effluent</u> Daily Effluent TP

(95% TP= 0.26 mg/l)



Probability Plot for <u>Bioreactor</u> Daily Effluent OP

(95% TP= 0.15 mg/l)

Performance Analysis - WRWTF

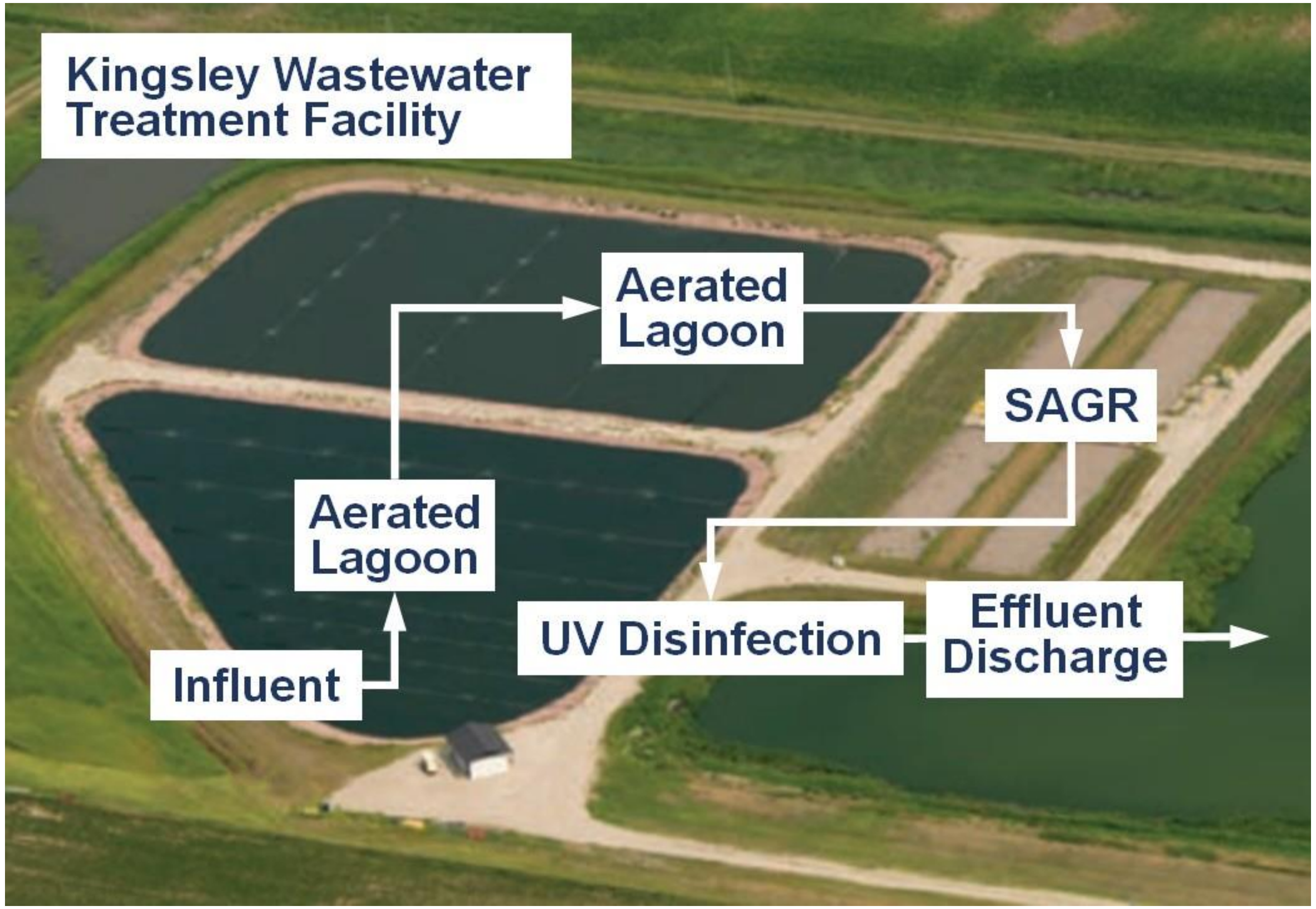
Effluent Concentration & Percentile	S2EBPR-Enhanced EBPR Reliability at WRWTP	Reliability at Five Conventional EBPR Facilities (Adapted from Neethling et al., 2005)	
		Average	Range
OP< 0.5 mg/l	99.8%	68%	24% - 95%
OP < 1 mg/l	100%	82%	64% - 99%
OP< 2 mg/l	100%	93%	85% - 100%
50% (Geometric Mean)	0.05 mg/l	0.26 mg/l	0.05 – 0.76 mg/l
90%	0.11 mg/l	1.6 mg/l	0.2 – 2.5 mg/l
90%/50%	2.2	11.5	2.0 – 24.0

Reliability - S2EBPR-Enhanced Bio-P vs. Conventional EBPR

Kingsley Wastewater Treatment Facility - City of Kingsley, IA
Submerged Attached Growth Reactor (SAGR ®)

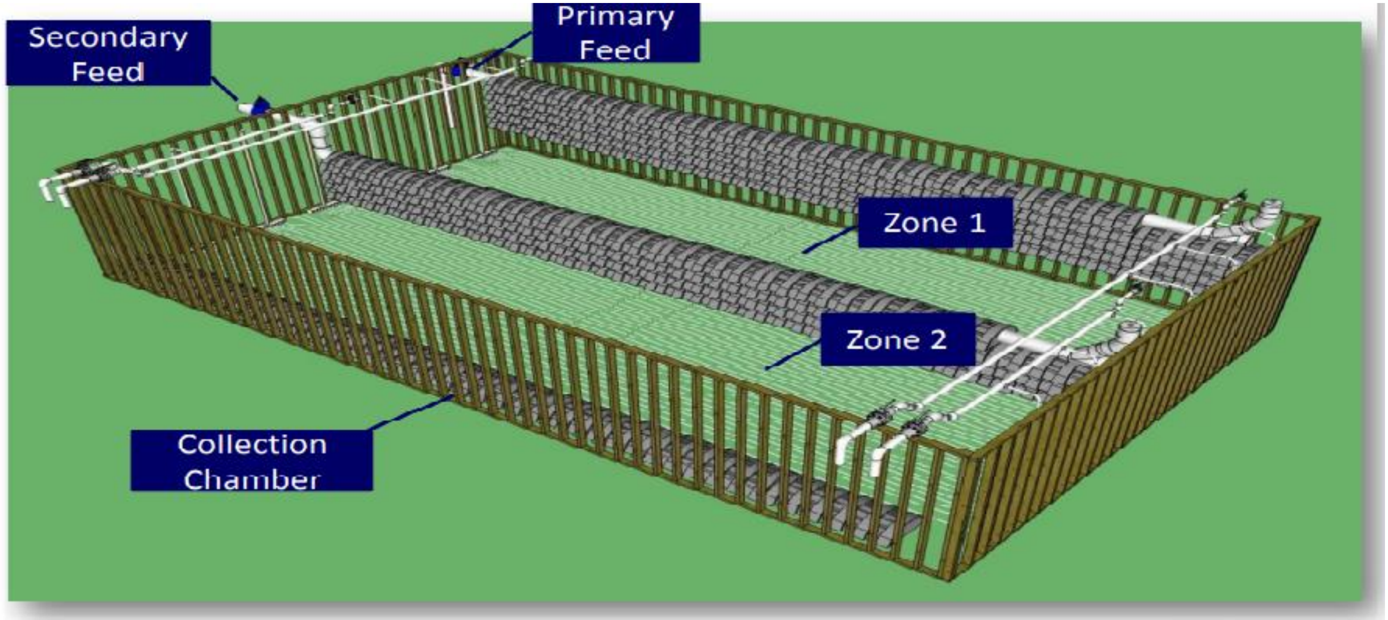
Plant Description:

- 0.3 MGD design flow
- 30-day average & Daily max. Ammonia-N limit vary each month
- As low as:
  - August: 2.4 mg/l (30-day avg) and 3.1 mg/l (daily max)
  - November: 3.2 mg/l (30-day avg and daily max) - Avg temp:-1^0C/-4^0C
- Two-cell aerated lagoon followed by a 2-stage SAGR



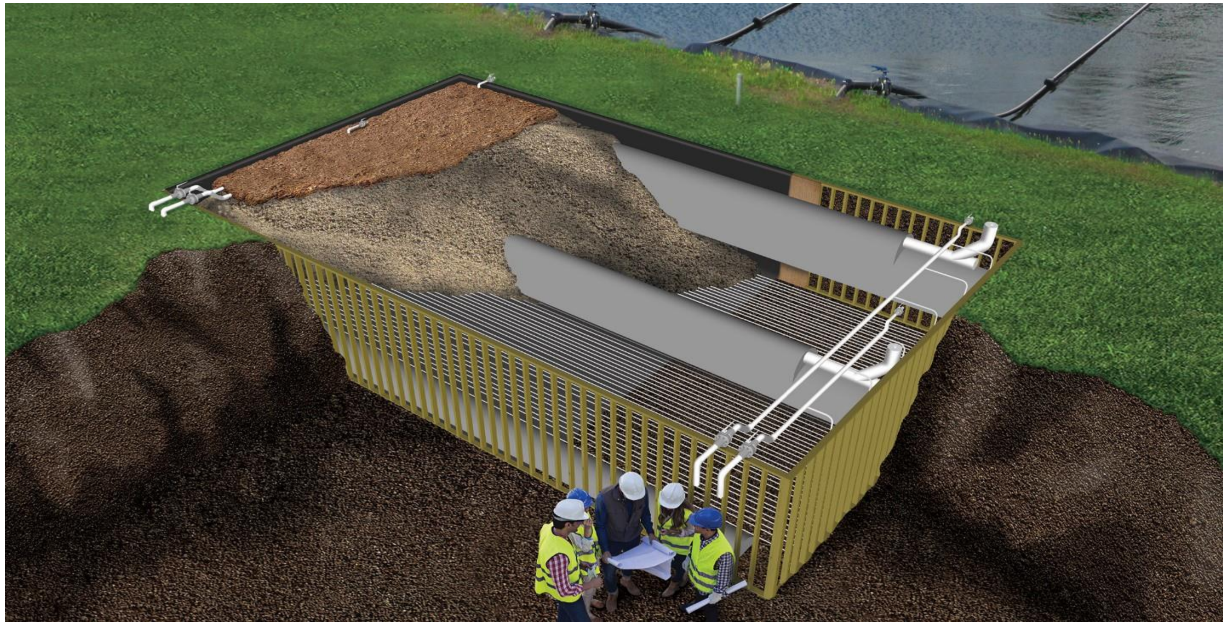
Project Description:

- SAGR enhanced nitirifcation. Diffuser-aerated gravel bed, even flow distribution. Instl. 2013.
- Step Feed procedure used to develop additional bacteria in the secondary bed zone to maintain full treatment through the duration of cold weather.



Schematic of SAGR Reactor

Cut-away with Air Distribution



SAGR Patented Step-Feed

- Designed to compensate for the slow nitrifier growth rate at cold water temperatures in the winter by pre-building and storing nitrifying bacteria.

- While the water is still warm > 54 °F (~12 °C), most of the ammonia removal happens in the first zone.

- As the water temperature drops in October, nitrifier activity slows down and more ammonia reaches the second zone for treatment.

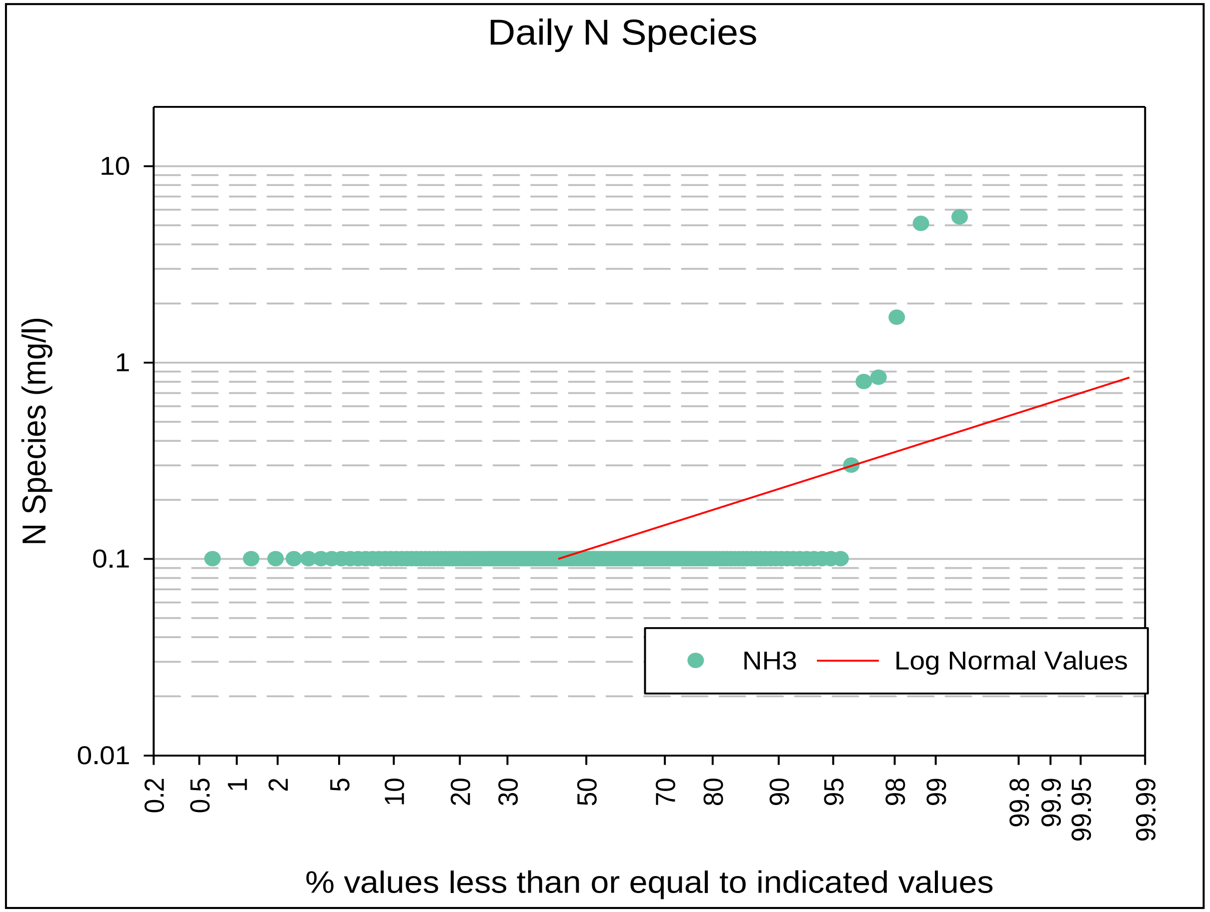
- During fall before temperature drops below 54 °F, the first zone is bypassed, and the entire influent runs only through the secondary zone.

- After approximately one month, the influent is sent back to the first zone (regular operation).

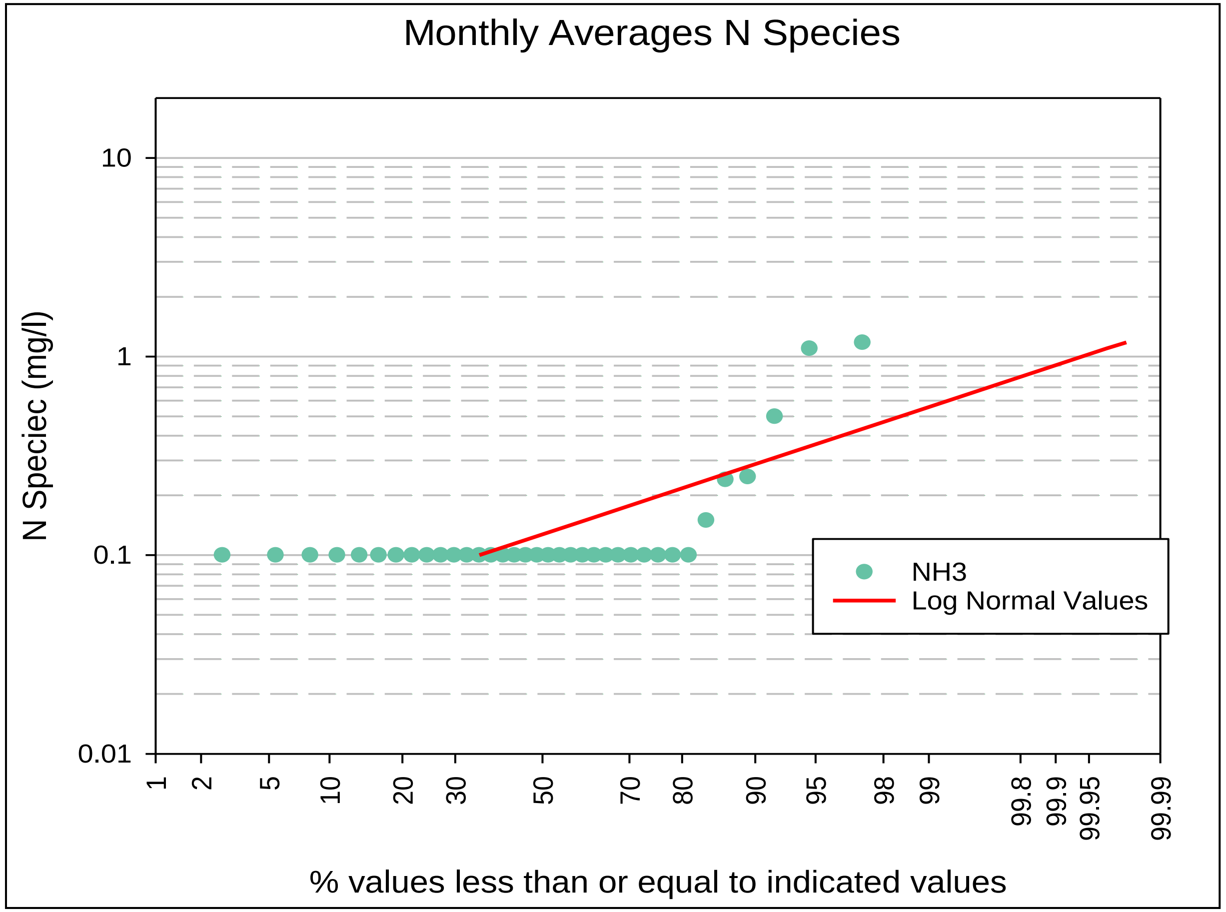
- Through this patented operational strategy, nitrifiers are grown in both zones of SAGR.

- Aeration remains in operation even for the zones that are not directly receiving lagoon effluent (allows for enhanced aerobic solids digestion and minimization of any long-term fouling effects).

Performance Analysis - KWTF



A



B

Effluent Ammonia Probability Plots (A) Daily Data, (B) Monthly Average

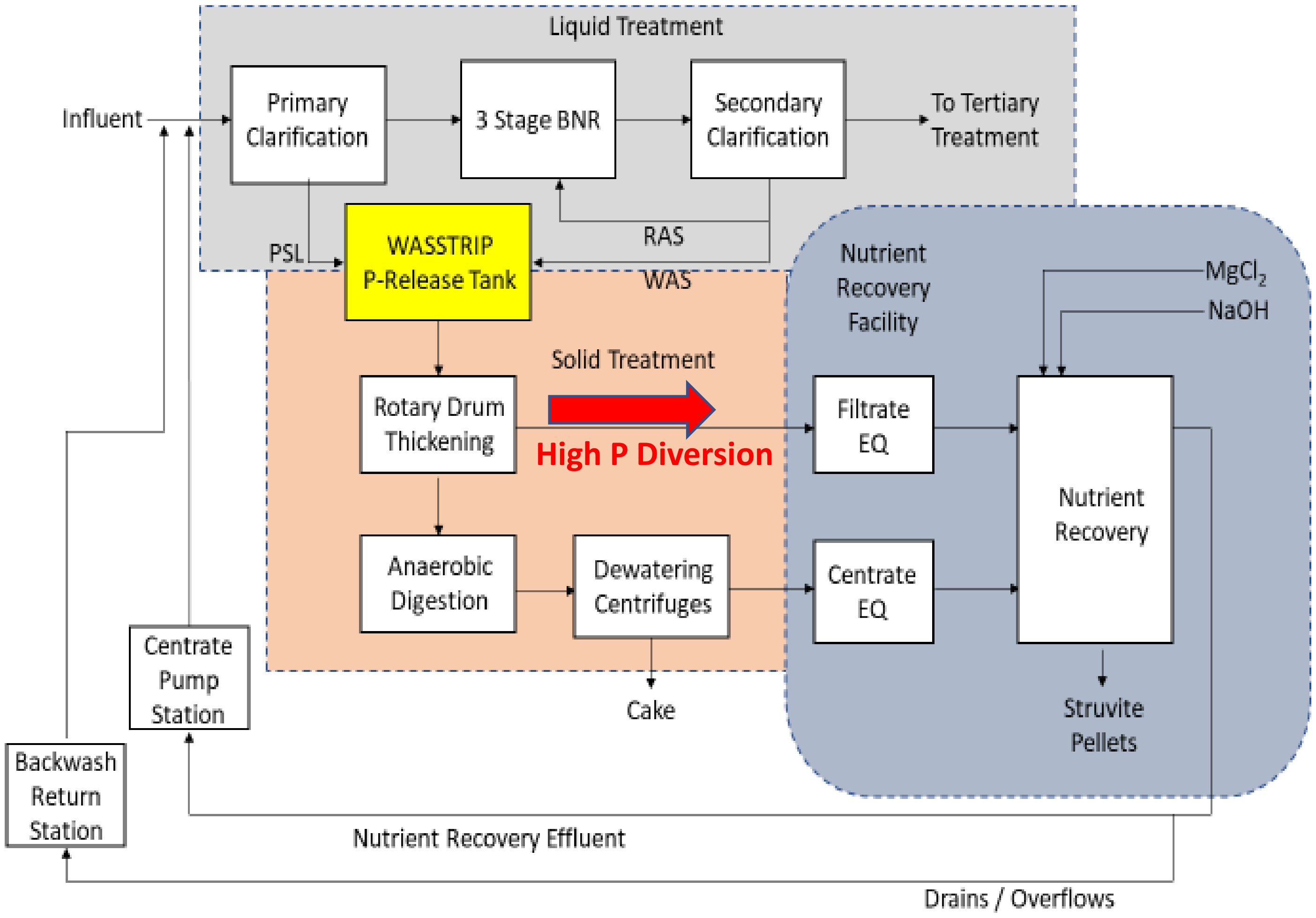
F. Wayne Hill Water Resources Center - Gwinnett County, GA
WASSTRIP ® & OSTARA Pearl®

- 60 MGD plant

- EBPR and chemical trim to meet a Monthly avg. TP limit of **0.08 mg/L**

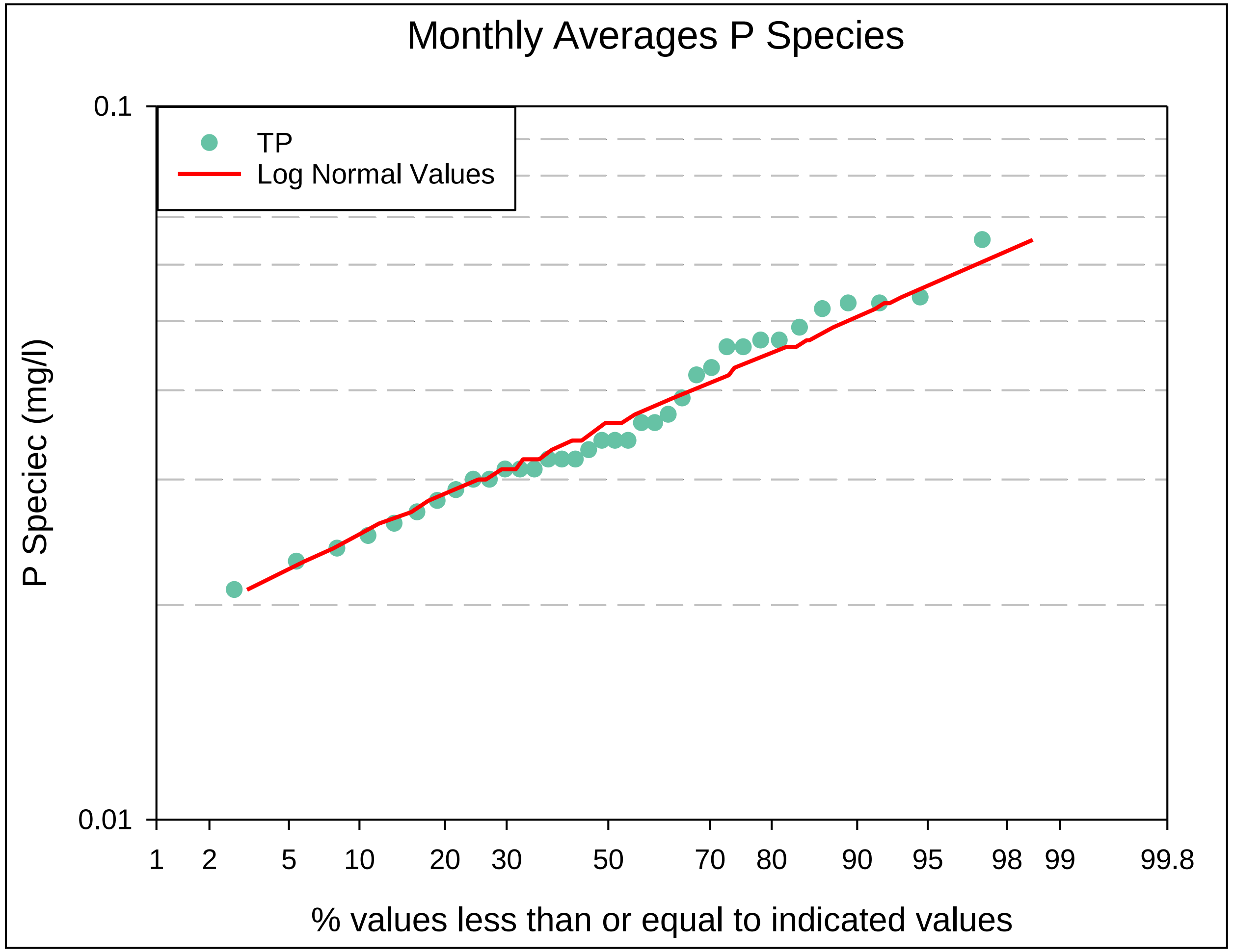
Process Description:

Implement WASSTRIP with OSTARA Pearl® struvite precipitation for P (and some N) recovery – Start-up May 2015



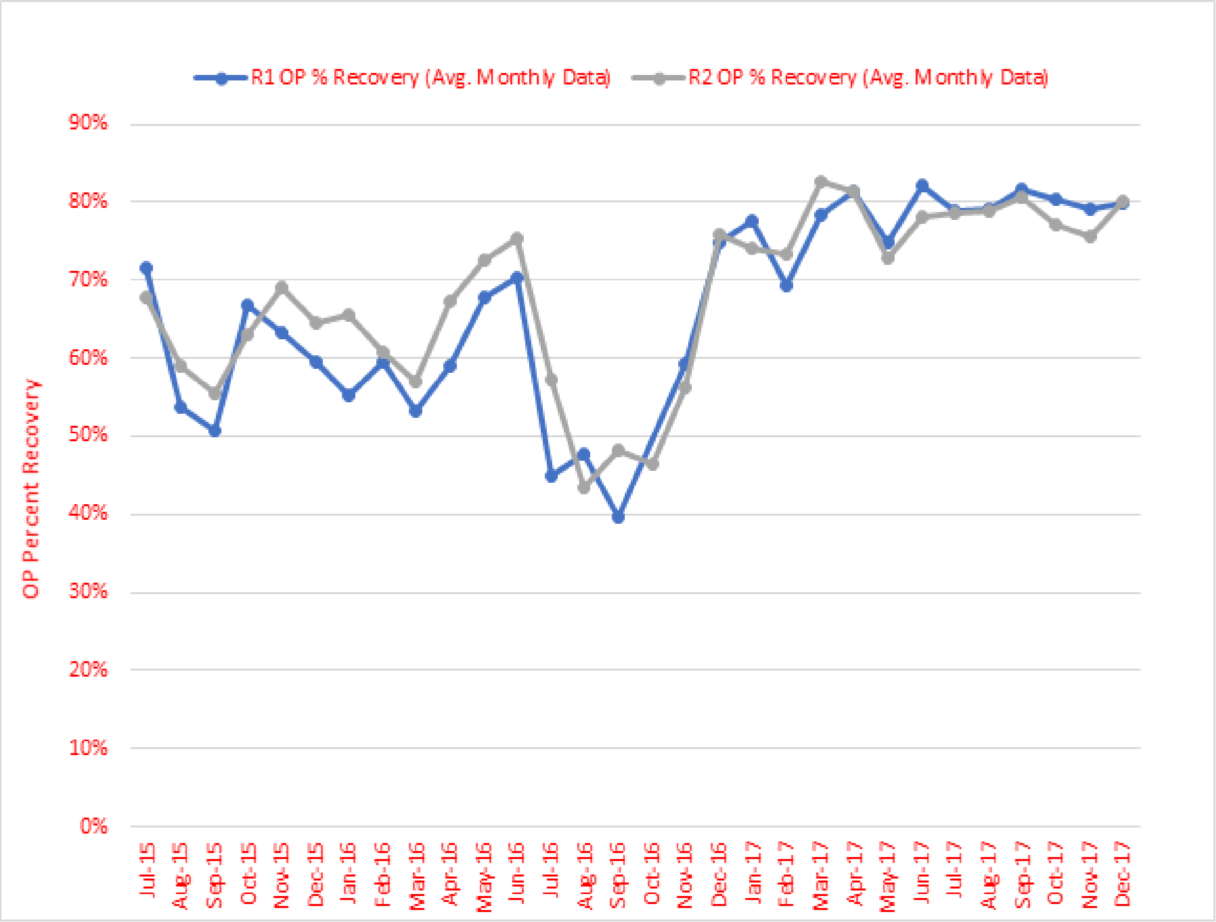
(Adapted from Latimer et al, 2017)

Performance Analysis - FWHWRC



Probability Plot - Monthly Average Plant Effluent TP

(95% TP= 0.06 mg/l)

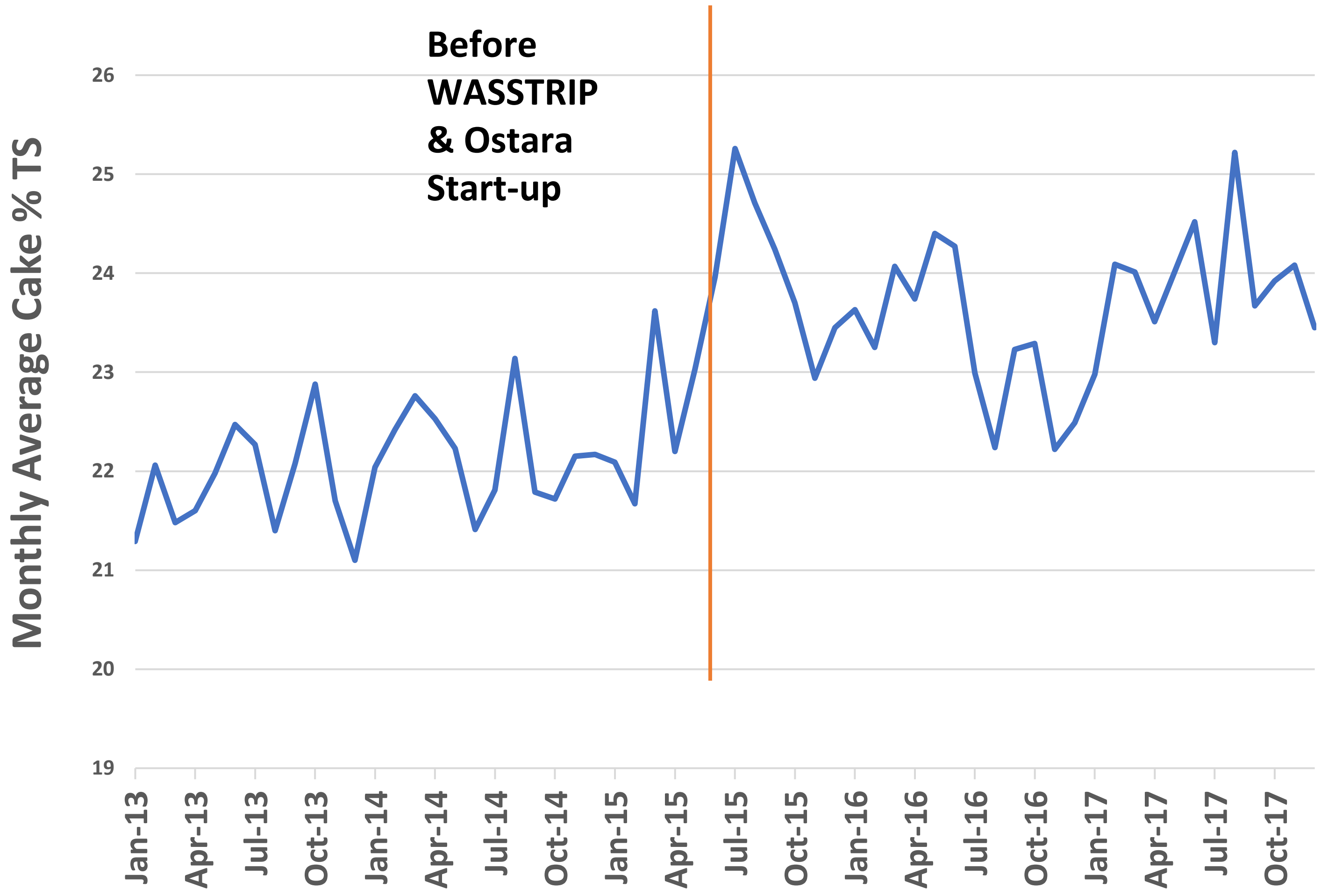


Orthophosphate Percent Recovery – Each Reactor

Performance Analysis - FWHWRC

- Significant reduction in undesirable struvite precipitation in piping and equipment.

- Significant improvement in sludge dewatering with WASSTRIP release and redirection of P & K prior to digestion*.



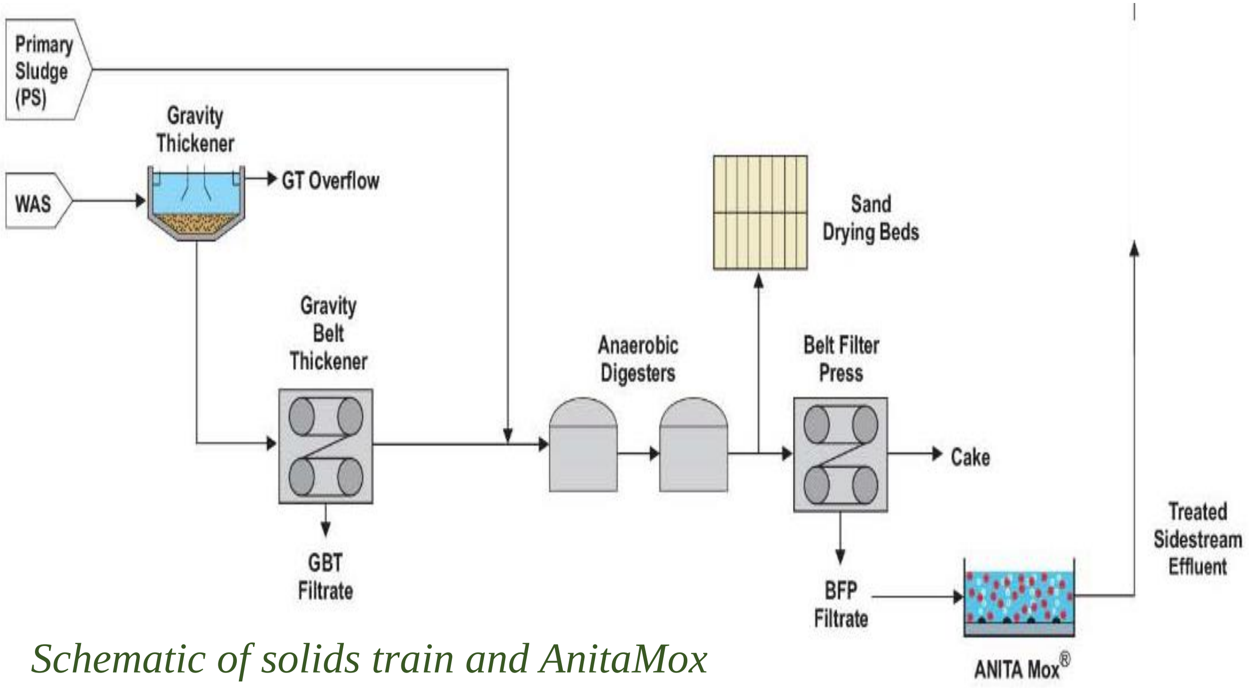
Sludge Cake Percent Total Solids – Monthly Average

* Higgins, Matthew; Bott, Charles; Schauer, Peter; Beightol, Steven. (2014). *Does Bio–P Impact Dewatering after Anaerobic Digestion? Yes, and not in a good way!*. Proceedings of the Water Environment Federation. 2014.

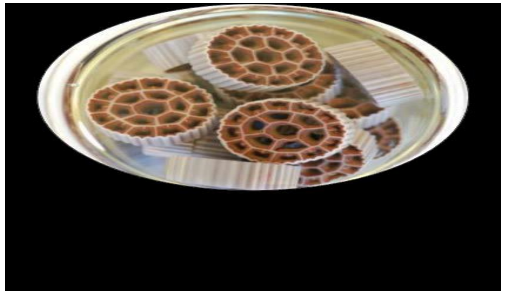
South Durham WRF - Durham, NC
Sidestream Deammonification – AnitaMox® MBBR

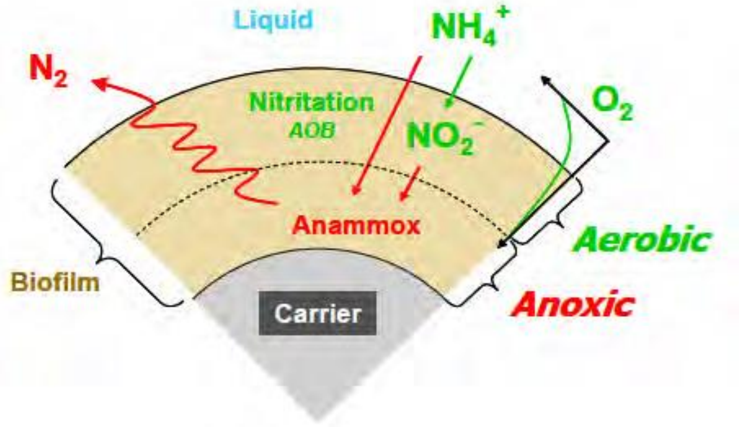
Plant Description:

- 20 mgd Plant
- 5-stage BNR
- TN limit: equiv. annual avg. 5.5 mg/L at design flow, 13 mg/l at 2017 flow (**Future expected: 3.0 mg/l Annual Avg.**)
- Seasonal weekly and monthly Avg NH3 limits



Schematic of solids train and AnitaMox deammonification (Bilyk et al, 2017)



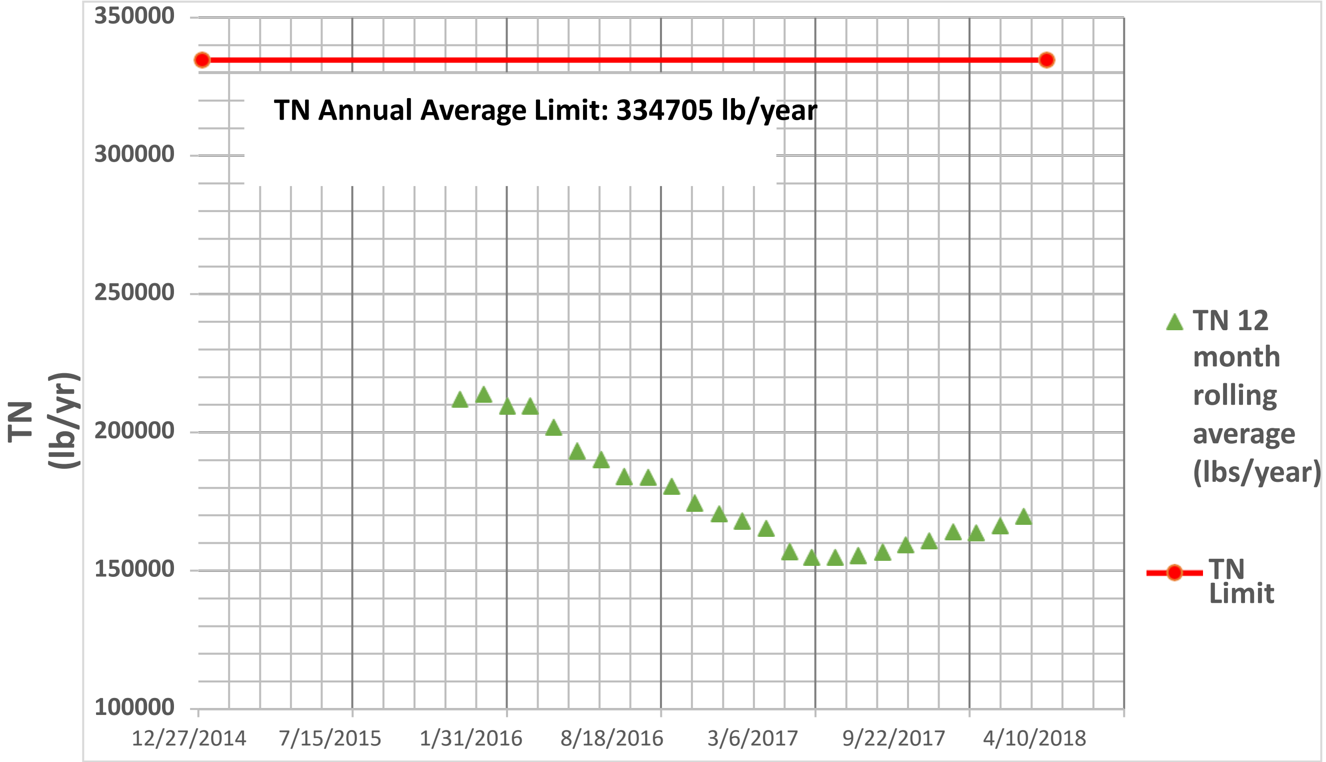


Project Description:

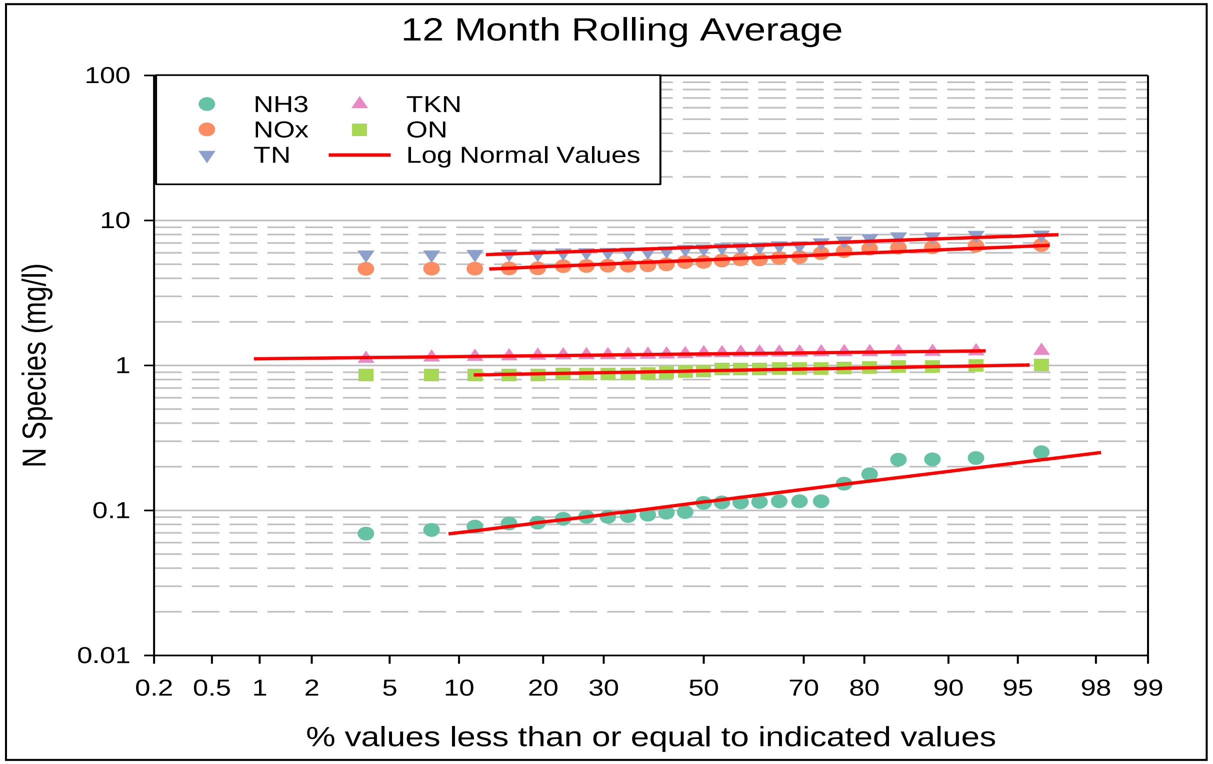
AnitaMox sidestream deammonification process to remove anaerobically-digested sludge filtrate nitrogen.

In full-scale operation: December 2015

Performance Analysis - SDWRF



12-month Rolling Average TN Time Series Plot

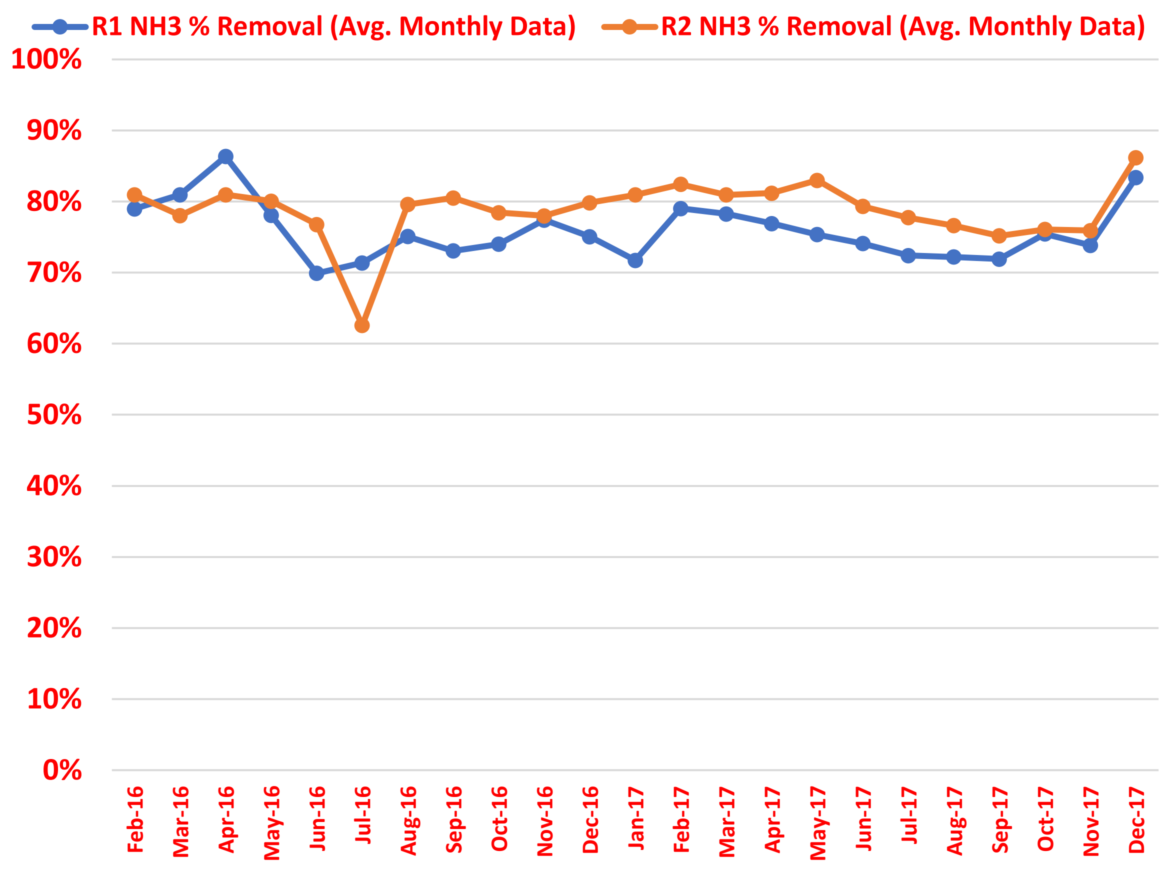


12-Month Rolling Average Probability Plot

3-yr TN 95th percentile: 9.36 mg/l

Year	Annual TN Load Limit	Equiv. Permit Limit at 20 mgd Design Flow	Actual Average flow	Equiv. Permit Limit at Actual Flow
2015	334,705 lbs/yr	5.5 mg/l	9.11 mgd	**12.1 mg/l**
2016	334,705 lbs/yr	5.5 mg/l	7.29 mgd	**15.1 mg/l**
2017	334,705 lbs/yr	5.5 mg/l	8.46 mgd	**13.0 mg/l**

Performance Analysis - SDWRF



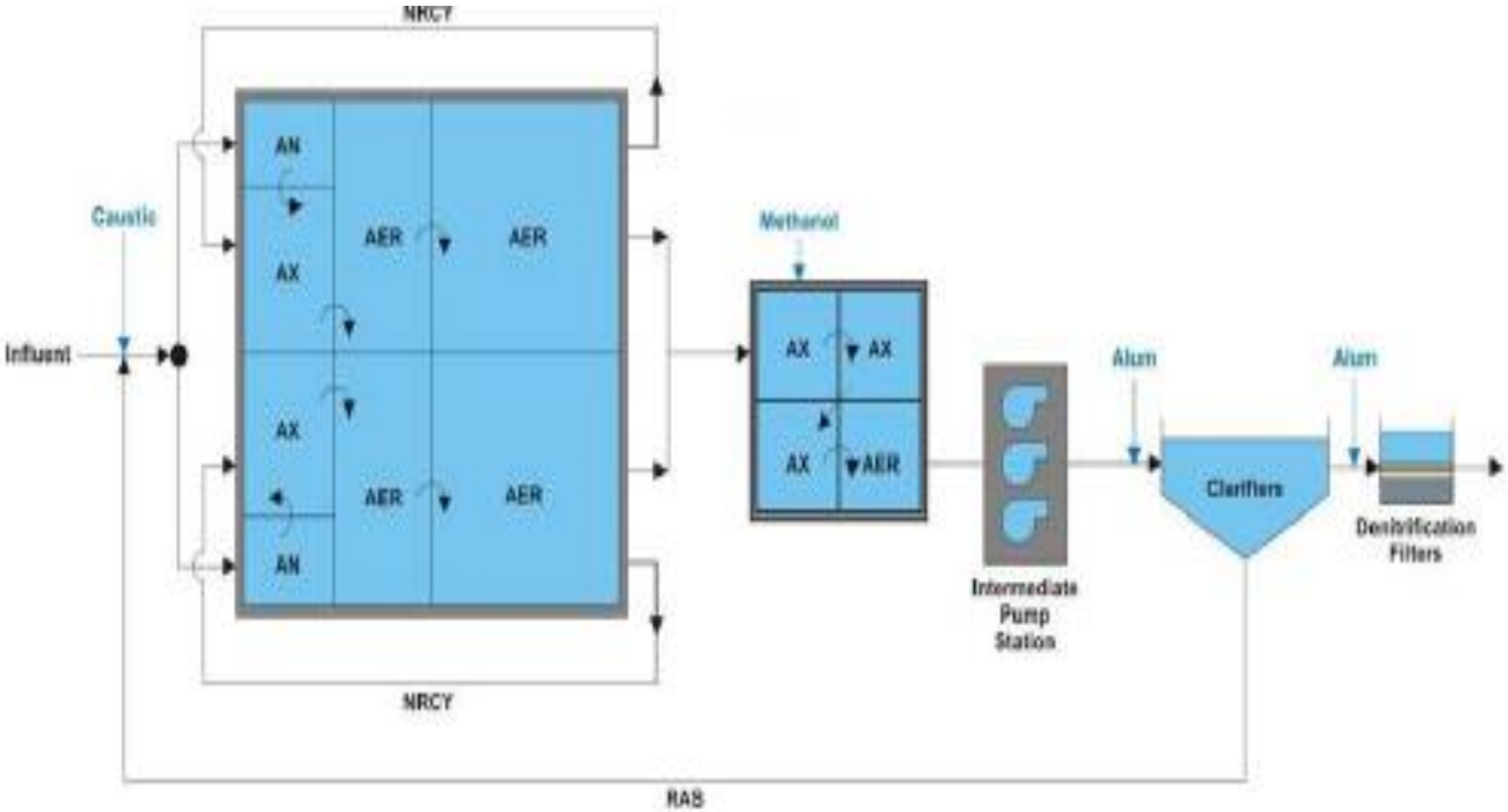
Monthly Average Ammonia Percent Removal for Sidestream Reactors 1 and 2

TN	Before Anita Mox (Jan 2015 – Nov 2015)	After Anita Mox (Dec 2015 – Dec 2017)
95th percentile (mg/l)	11.34	8.85
50th percentile (mg/l)	7.91	6.39

Hillsborough WWTP - Hillsborough, NC
Low TN modification – 5-Stage Bardenpho BNR

Plant Description:

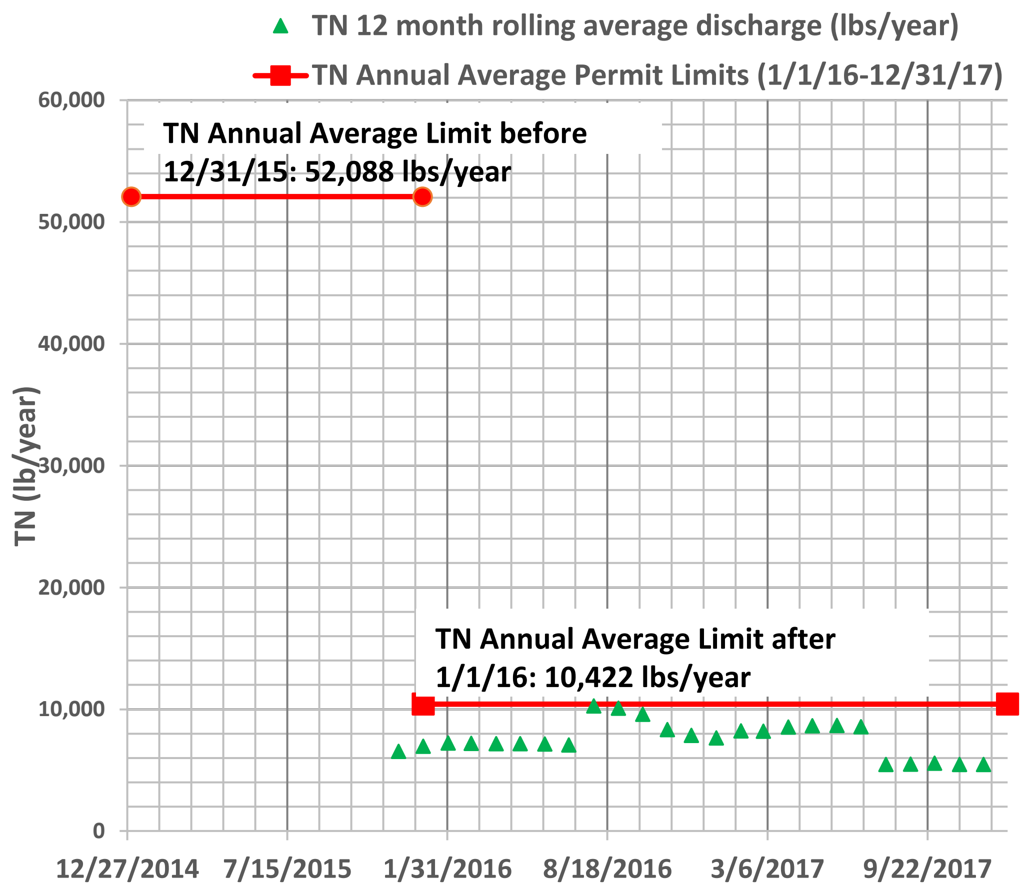
- 2.4 MGD Design Flow
- 5-Stage BNR
- TN Permit Limit as of Jan 2016: 10,422 lbs/yr (***1.43*** *mg/l at design flow or* ***3.6*** *mg/l at 2017 actual flow*)



Process Description:

Modified original (BIOWIN-verified) reactors volumes, hydraulic retention times, and nutrient recycle flow based on total flow leaving each zone (i.e. only 1st anoxic zone includes nutrient recycle (NRCY) flow (and not anaerobic, aerobic and 2nd anoxic zones) to ensure anoxic zone did not reach an anaerobic state. Resulted in 900% NRCY.

Performance Analysis - HWWTP



12-month Rolling Average TN Time Series Plot

	Original (Nov 2013 through June 2014)			Modified (July 2014 through Sep 2015)		
Zone	Volume (MG)	% of Volume Allocated	NRCY % of Inf	Volume (MG)	% of Volume Allocated	NRCY % of Inf
Anaerobic	0.125	6%		0.125	6%	
1st Anoxic	0.375	17%	200%	0.875	39%	900%
Aerobic	1.5	67%		1	44%	
2nd Anoxic	0.1875	8%		0.1875	8%	
Reaeration	0.0625	3%		0.0625	3%	
Avg Influent Flow: 1.038 MGD				*Avg Influent Flow: 0.898 MGD*		

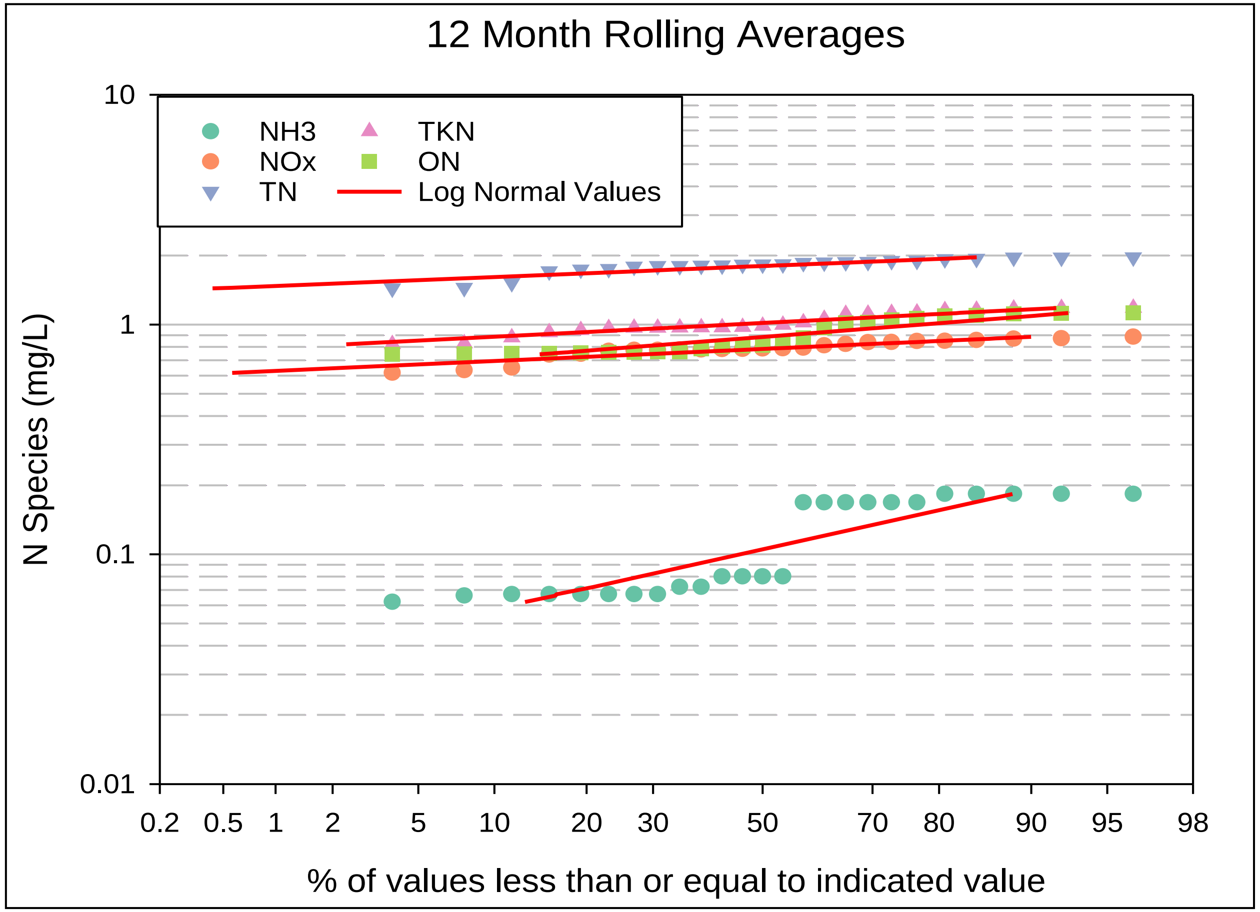
Modifications to the Original Design

(Adapted from Mahagan and Bilyk, 2016)

Performance Analysis - HWWTP

Year	Annual TN Load Limit	Equiv. Conc. Limit at 2.4 mgd Design Flow	Actual Average flow	Equiv. Conc. Limit at Actual Flow
2015	50,228 lbs/yr	6.9 mg/l	1.07 mgd	**15.4 mg/l**
2016	**10,422 lbs/yr**	1.43 mg/l	1.10 mgd	**3.1 mg/l**
2017	10,422 lbs/yr	**1.43 mg/l**	0.95 mgd	**3.6 mg/l**

Equiv. Plant Effluent TN Concentration Limits at Design & Actual Flows



12-Month Rolling Average Probability Plot

3-yr TN 95th percentile: **1.96** mg/l

QUESTIONS?

- The report is entitled: *Innovative Nutrient Removal Technologies: Case Studies of intensified or Enhanced Treatment* - EPA 830-R-01-001 – August 2021

- Available for free download at:

https://www.epa.gov/system/files/documents/2021-08/innovative-nutrient-removal-technologies-report-082721.pdf

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