



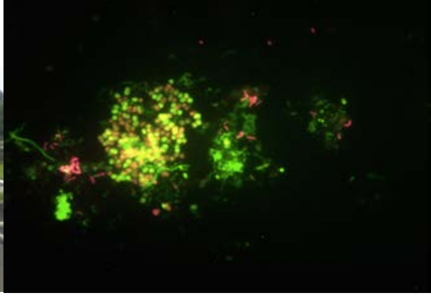

Innovative Nutrient Removal Technologies: Case Studies of Intensified or Enhanced Treatment

ACWA Nutrients Permitting Workshop

Columbus, OH

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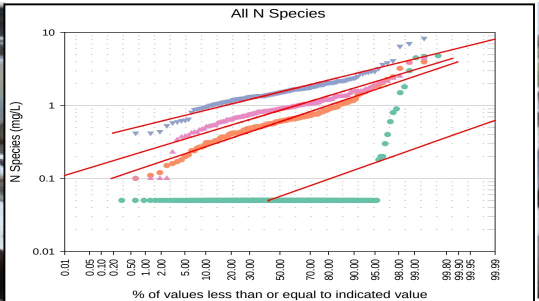
EPA Office of Wastewater Management



Presentation Outline

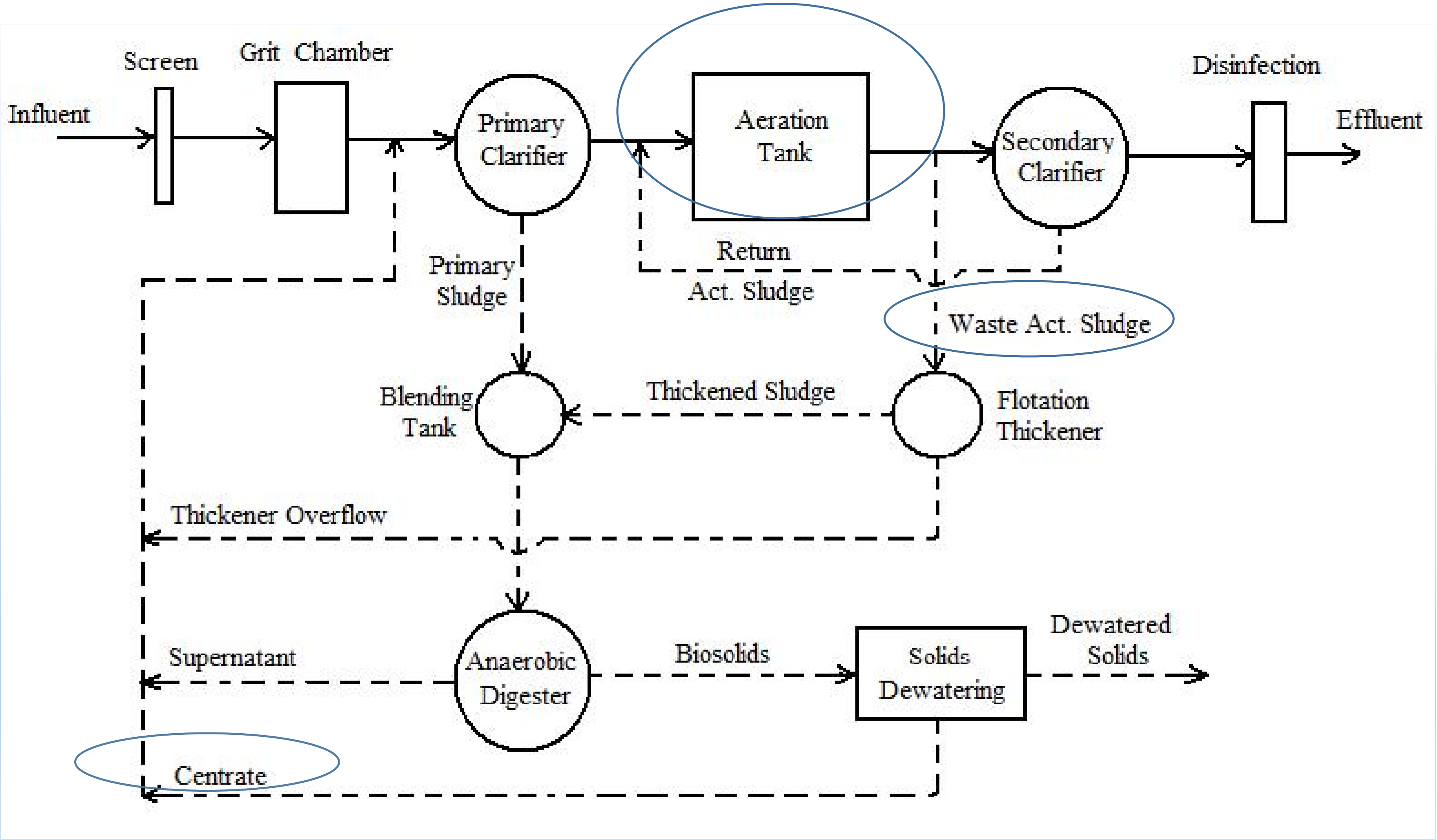
- Nutrient Removal
  - Conventional Removal Mechanisms
  - Innovation

- Previous EPA Reports on Nutrient Removal Technologies

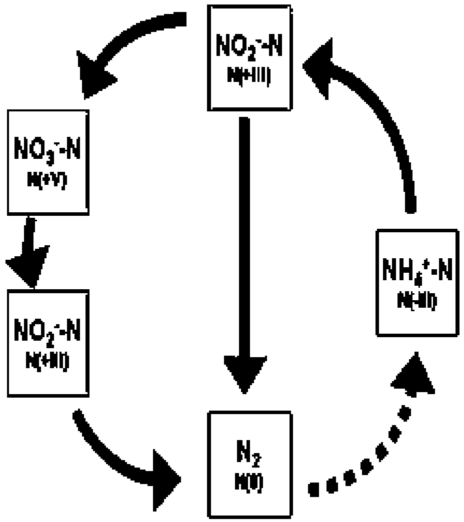
- Innovative Nutrient Removal technologies Case Studies
  - Purpose & Scope
  - Process Performance and Site-specific Impact Analysis
  - Statistical Analysis

- Selected Processes and facilities
  - Removal Mechanisms
  - Expected Benefits

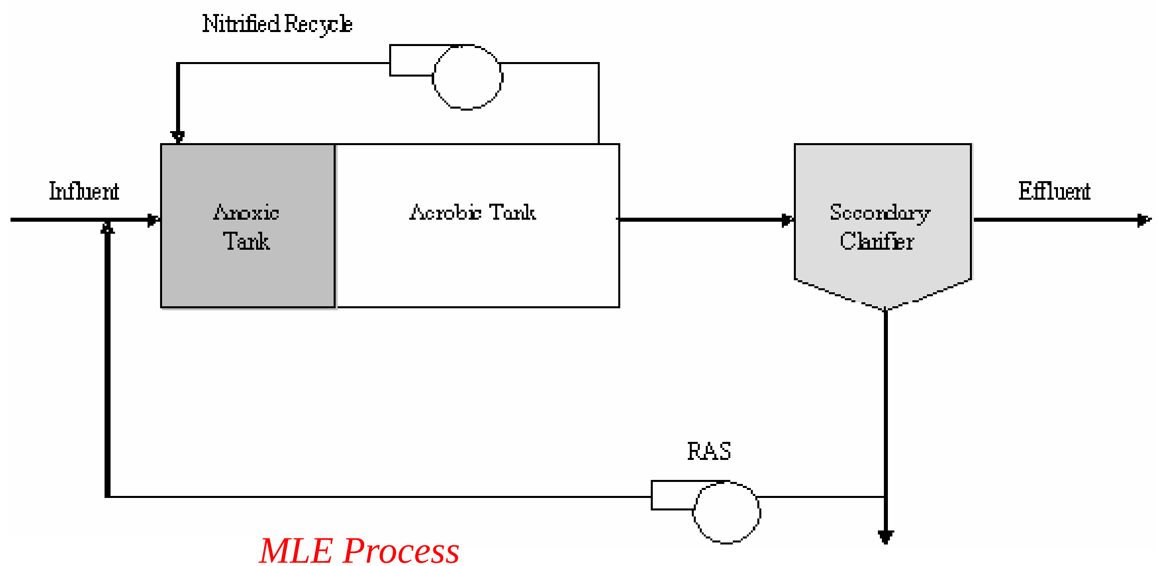
Typical Secondary Treatment Plant Trains



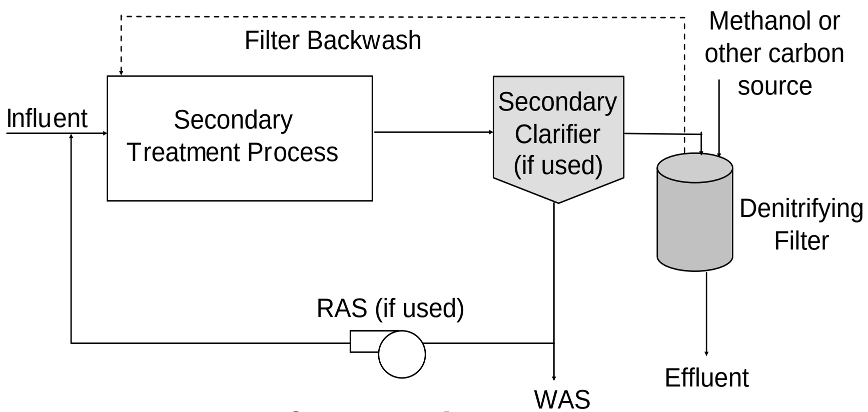
Conventional Biological Nitrogen Removal & Process Examples



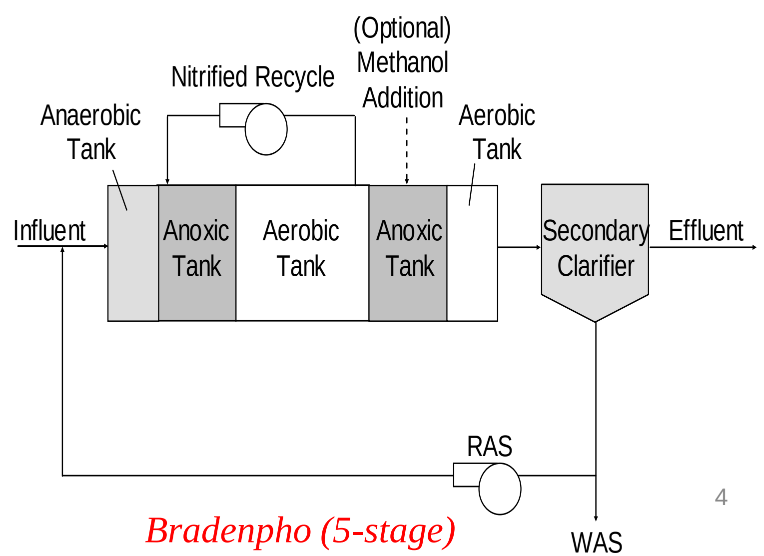
Conventional BNR



MLE Process



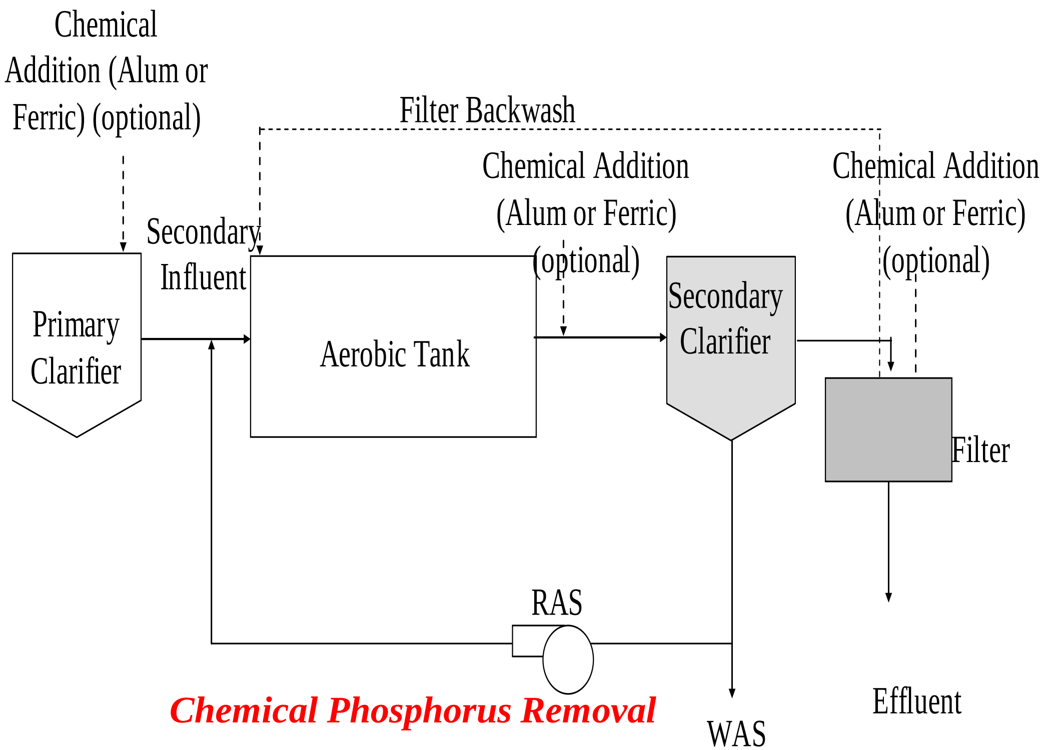
Denitrification Filter



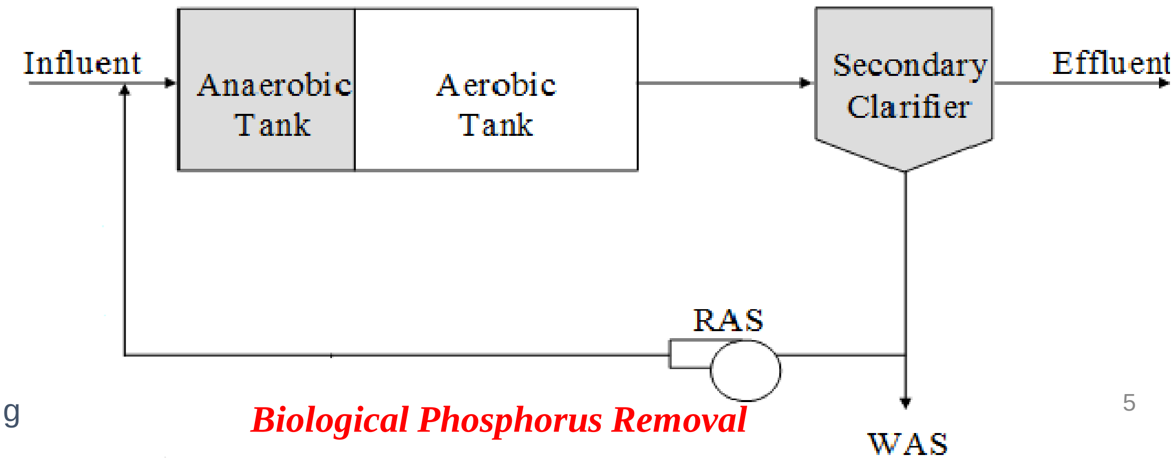
Bradenpho (5-stage)

Conventional Phosphorus Removal

- **Chemical Addition – Metal Salts**
- **Biological Phosphorus Removal (EBPR)**
- **Combination (bio & chem) Removal**
- **Effective Solids Separation is important**



Chemical Phosphorus Removal



Biological Phosphorus Removal

Innovative Nutrient Removal

- Improved and more reliable performance, reduced costs
- Reduction in sidestream nutrient loads
- Reduction of expensive chemical consumption
  - External carbon for PAOs and denitrifiers
  - Metal salts for Chemical phosphorus removal
  - Alkalinity
- Reduction of sludge production (& associated processing and utilization/disposal costs)
- Reduction of energy consumption
- Footprint reduction
- Quick implementation to meet much lower limits
- Efficacy in cold climates

Previous EPA Reports on Nutrient Removal Technologies

Innovative Nutrient Removal Technology Case Studies - Purpose

- In-house study to provide seven to nine detailed case studies of recent innovative nutrient removal processes for Nitrogen or Phosphorus removal.
- Includes innovative processes or significant enhancements to conventional processes.
- Focus on nutrient removal performance and variability, site-specific factors impacting performance, and lessons learned.
- Audience: Regulators and Utilities.
- Supplement OW's efforts to assist Regions and States in implementing nutrient standards.
- Inform utility decision-making on process selection.

Study recently started, data shown is preliminary draft, currently under review.

Innovative Nutrient Removal Technology Case Studies - Scope

- Describe the innovations and their benefits.
- Perform a detailed statistical analysis of performance and variability.
  - *Analysis of a minimum of 1 year (preferably 3 years) of nutrient species monitoring data (Plant and process influent, plant and process effluent, other parameters as needed for case study).*
- Assess operational and existing infrastructure factors that impacted performance positively or negatively such as process control, design flexibility, recycle load management, wet weather flow management, and others where applicable.
- Conduct external peer review and share document with stakeholders.

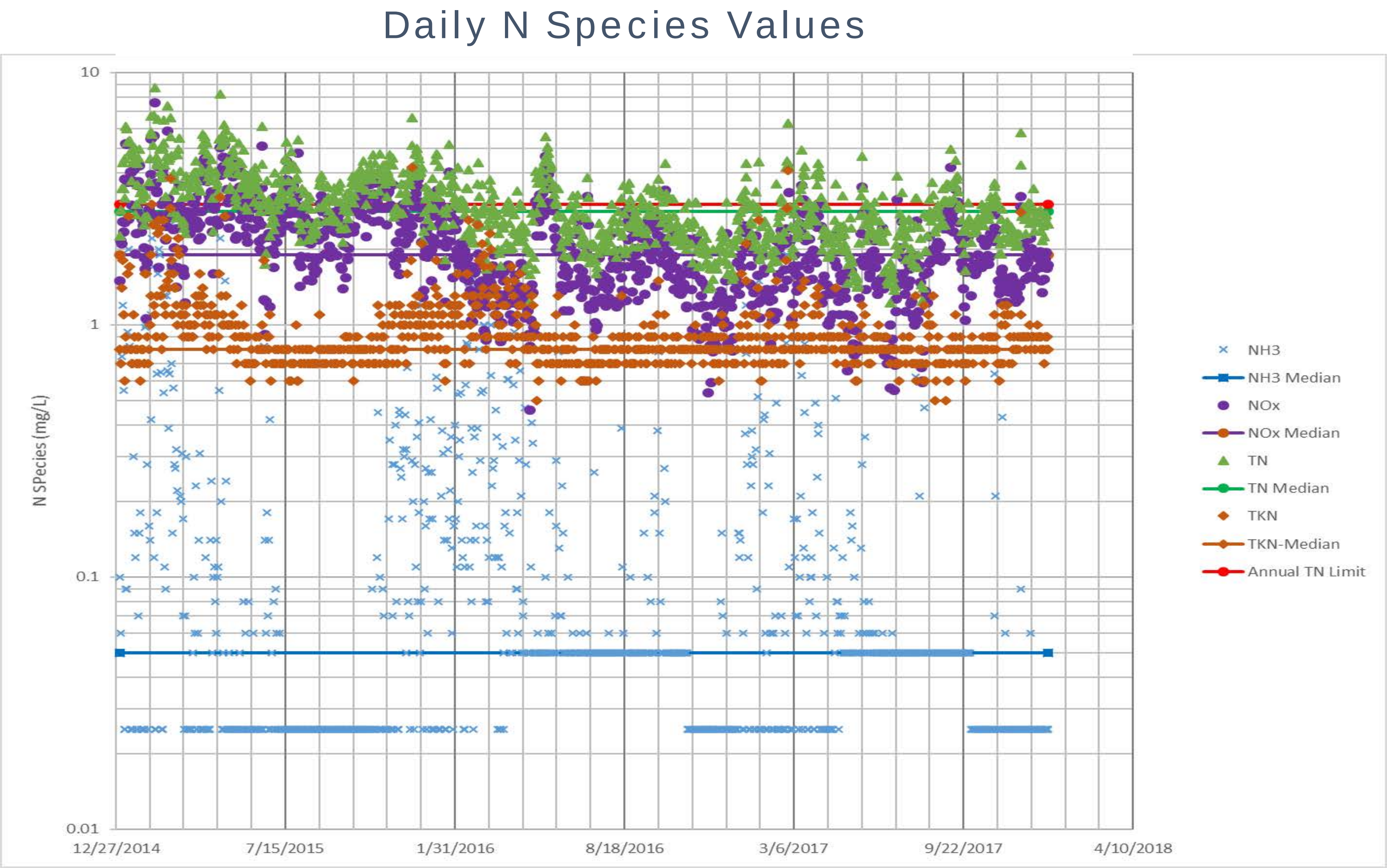
Selected Technologies

Process	Facility	Process	Facility
Side-stream deammonification process - **DEMON®**	Alex Renew AWRRF, Alexandria, VA	Submerged Attached Growth Reactor (**SAGR®**) for Lagoon Low N	Kingsley, IA
S2EBPR - Side-stream RAS and primary fermentate addition for enhanced biological phosphorus removal	Westside Regional Facility, West Kelowna, BC	**BioMag®** magnetite-ballasted mixed liquor process	Mystic WPCF, Stonington, Connecticut
WASSTRIP® Phosphorus Release with OSTARA Pearl® nutrient recovery	F. Wayne Hill Water Resources Center, Gwinnett County, GA	Side-stream deammonification process - **ANITAMox®**	South Durham WRF, Durham, North Carolina
Very **Low TN 4-Bardenpho** Modification	Town of Hillsborough, NC	Others?	

Statistical Analysis Uses

- Understanding achievable performance under conditions it was achieved.
- Determine the variability of the technology to achieve a target effluent limit (useful for facility design features that increase reliability)
- Evaluate the potential risk of exceeding permit limits – number of times per permit cycle, etc.
- Provide consistent parameters for process performance assessment.

Statistical Analysis - Daily series



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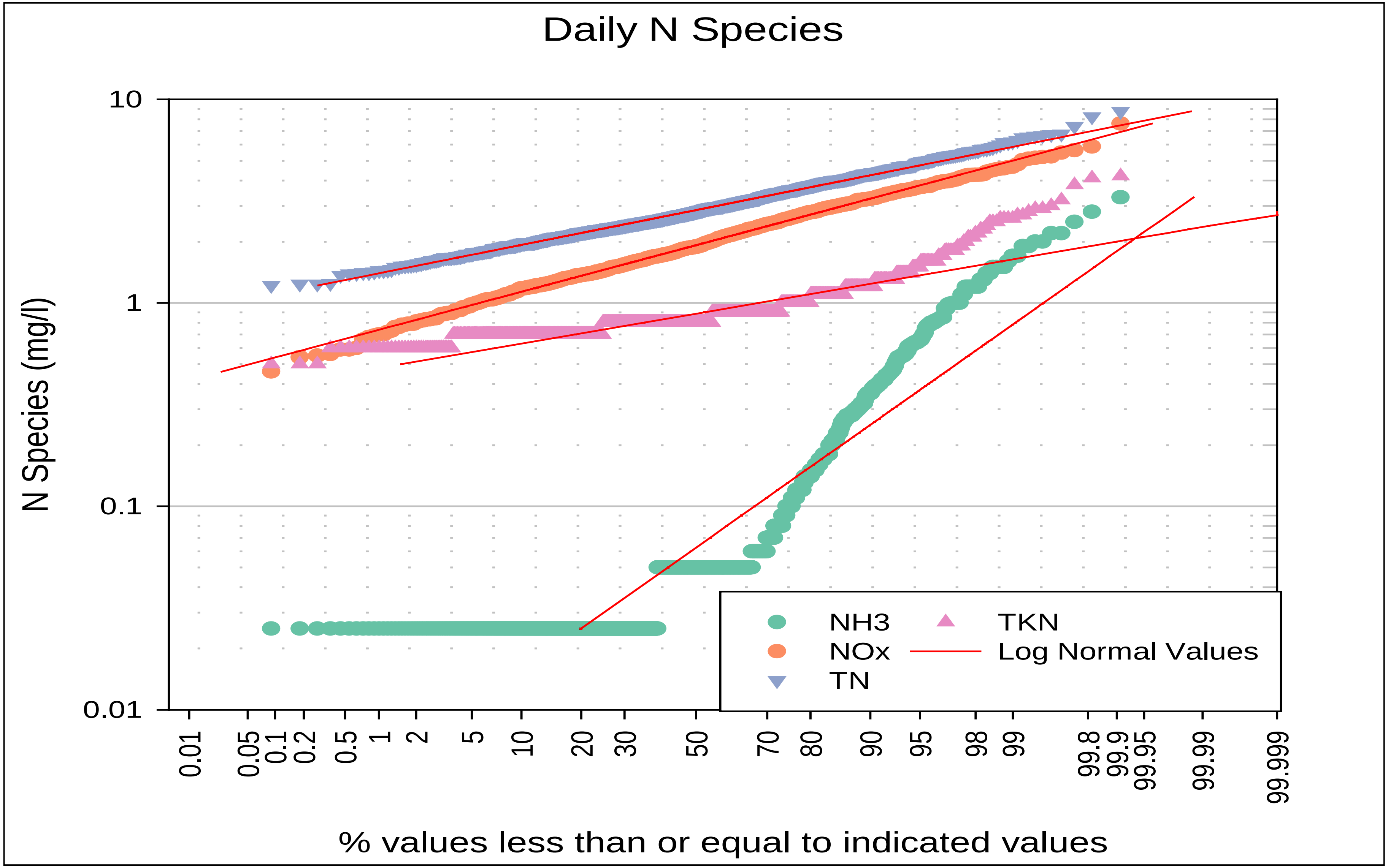
Statistical Analysis – Cumulative Probability



Plant Effluent Concentrations

Study recently started, all data shown are preliminary draft, currently under review

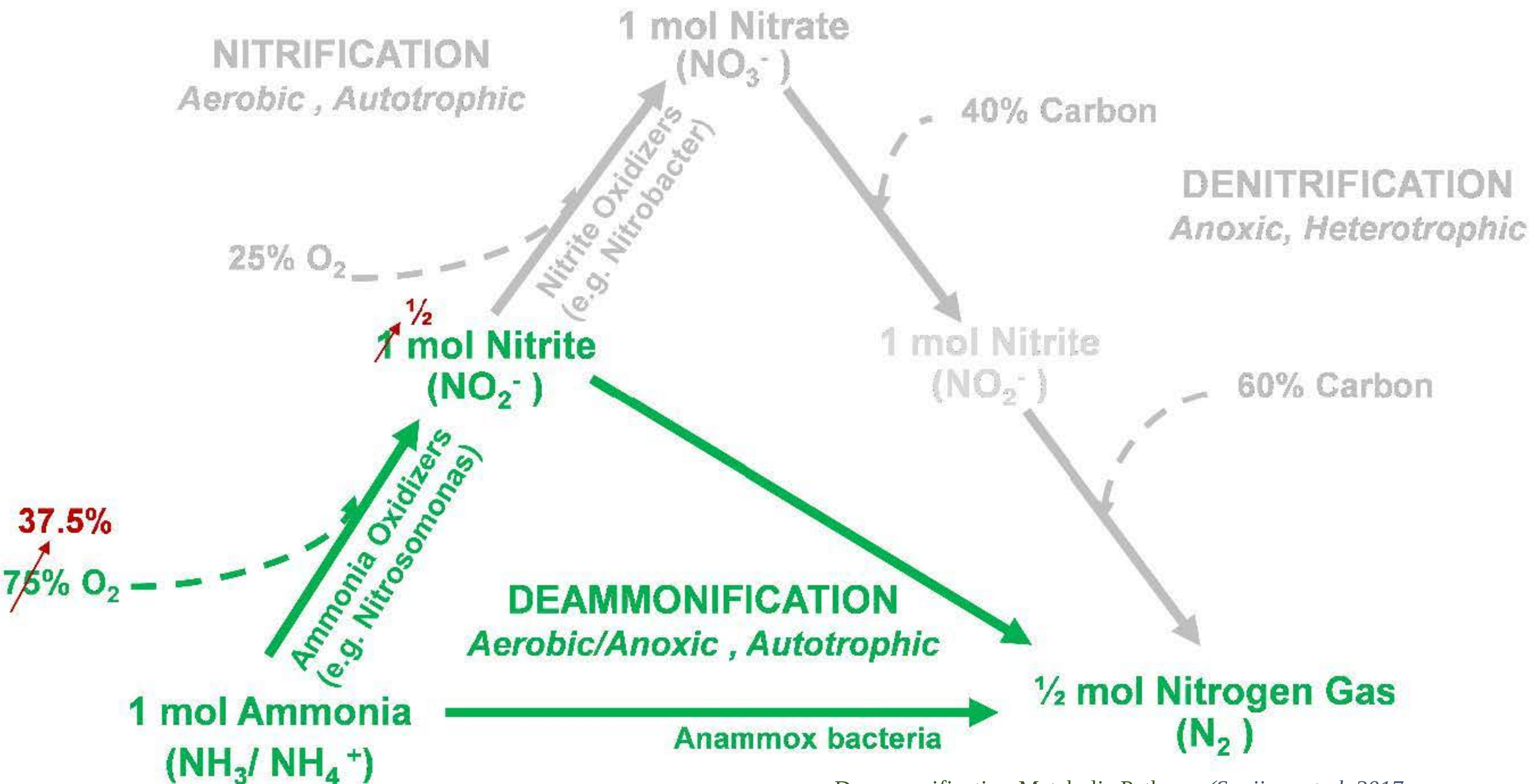
Statistical Analysis
Example Summary Stats & Probability

	NH3 Daily Data	NH3 Weekly Data	NH3 Rolling 30-day Average	NH3 Monthly Averages	NH3 Annual Average
n	1096	156	1067	36	25
Mean	0.146	0.147	0.145	0.148	0.143
Geometric Mean	0.063	0.083	0.097	0.098	0.140
Standard Dev.	0.308	0.190	0.147	0.146	0.031
CV	2.101	1.294	1.013	0.989	0.214
Skew	4.765	2.458	2.028	1.869	-0.080
Minimum	0.025	0.025	0.025	0.025	0.103
Maximum	3.300	0.999	0.793	0.687	0.192

Probability	NH3 Daily Data	NH3 Weekly Data	NH3 Rolling 30-day Average	NH3 Monthly Averages	NH3 Annual Average
n	1096	156	1067	36	25
3.84 (14d)	0.03	0.03	0.03	0.03	0.10
50	0.05	0.06	0.08	0.09	0.15
90	0.36	0.37	0.34	0.35	0.18
95	0.65	0.57	0.48	0.39	0.18
99	1.61	0.89	0.74	0.59	0.19
95/50	13.05	9.90	5.74	4.39	1.22
3.84/50	0.50	0.44	0.30	0.28	0.69

Study recently started, all data shown are preliminary draft, currently under review

Deammonification

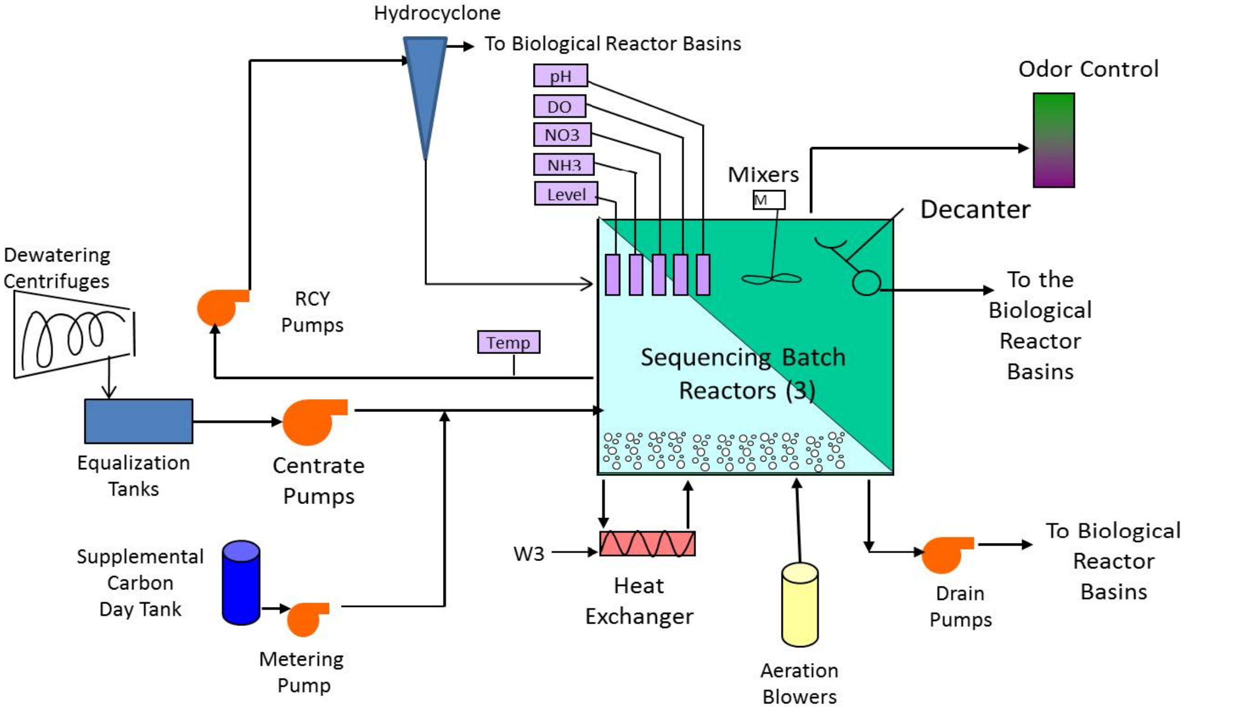


Deammonification Metabolic Pathway *(Sanjines et al, 2017)*

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

Plant Description:

- 54 mgd average annual flow
- BNR either in MLE or step-feed modes. Methanol Addition
- Nutrient limits: 3.0 mg/L TN and 0.18 mg/L TP (Annual Avg.)



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

Process Description:

Centrate pre-treatment (CPT) system uses the DEMON® sidestream deammonification process to remove anaerobically-digested sludge centrate nitrogen.

AlexRenew ARRF, Alexandria, VA
Sidestream Deammonification - DEMON®

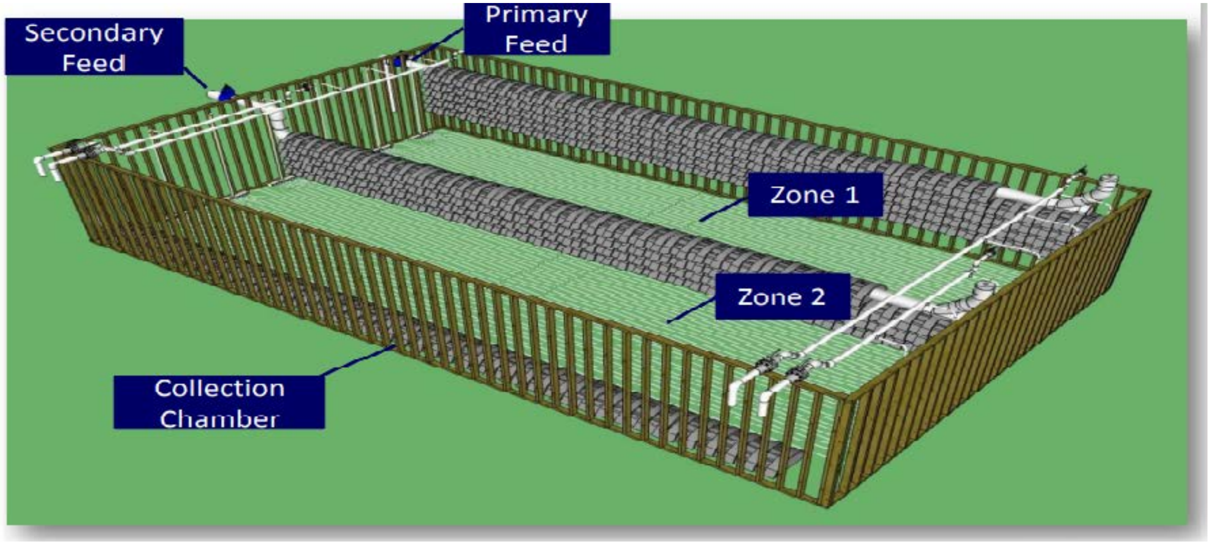
➢ *Potential Performance & Benefits*

- ✓Reliable nitrogen removal from centrate
- ✓Significant reduction of ammonia loading to mainstream BNR
- ✓Significant reduction in mainstream carbon (methanol) addition
- ✓Significant reduction in aeration/energy consumption
- ✓Significant reduction in sludge production

Kingsley Sanitary Treatment Plant
City of Kingsley, IA
Submerged Attached Growth reactor (SAGR ®)

Plant Description:

- 0.3 MGD design flow 3-cell aerated lagoon followed by a 2-stage SAGR process.
- Ammonia-N limit: Jan. high of 11.9 mg/l (30-day avg.) and 20.9 mg/l (daily max), to as low as 2.4 and 3.1 mg/l respectively Aug.
- Objective: <1/<5 mg/l summer/winter



Project Description:

- ✓ SAGR process gravel bed with evenly distributed wastewater flow across the width of the cell. Diffuser aeration throughout the floor.
- ✓ Step Feed procedure used to develop additional bacteria in the secondary bed zone to maintain full treatment through the duration of cold weather

Kingsley STP, Kingsley, IA
SAGR

- ***Potential Performance & Benefits***

  - ✓Effective ammonia removal to low levels even at very low temperatures.
  - ✓low operational complexity and costs compared to mechanical plant conversion.
  - ✓Potential other benefits in effluent BOD5 and TSS reduction.
  - ✓Potential supplementary reduction in E-coli bacteria supporting existing disinfection.

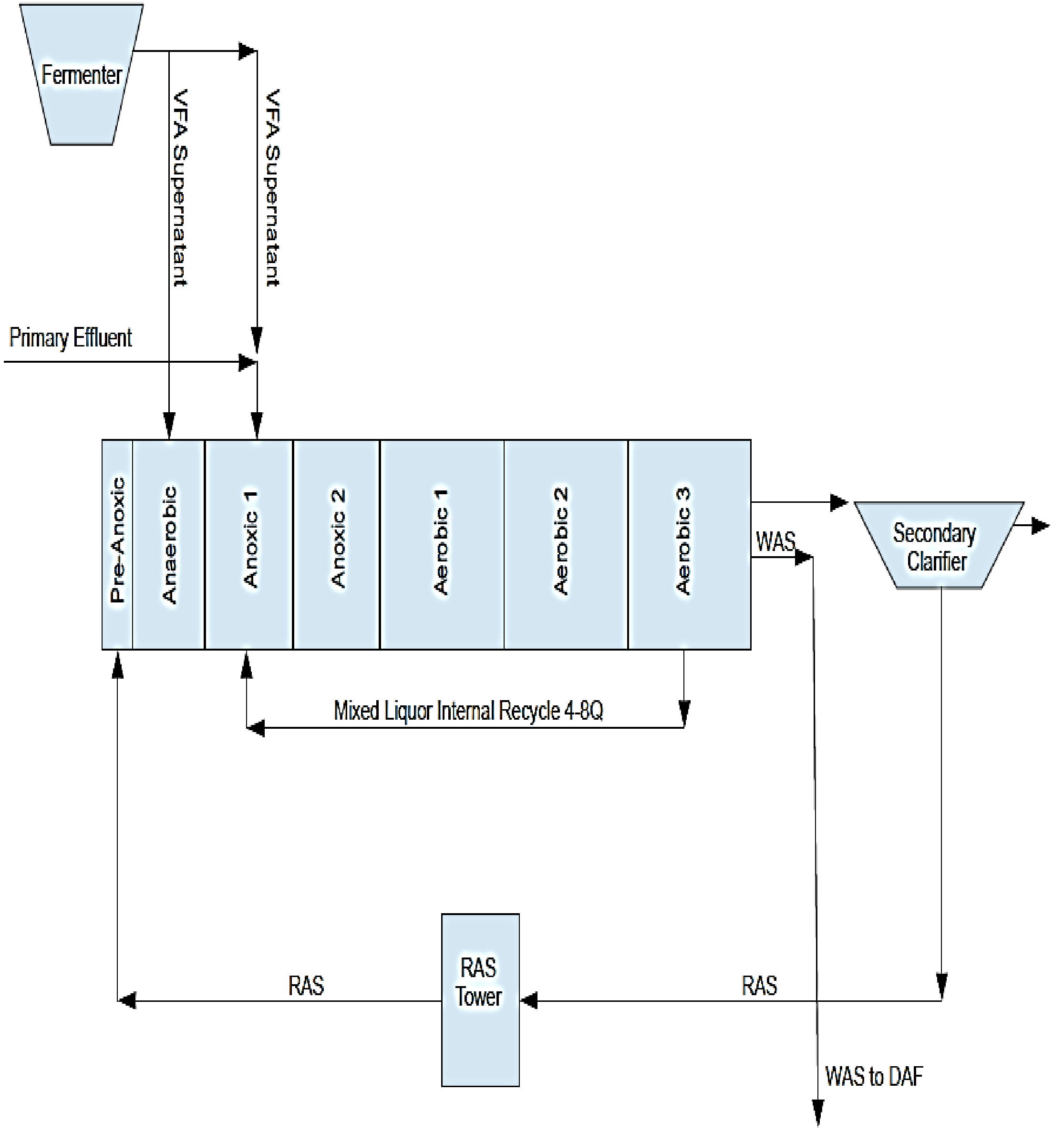
Westside Regional Wastewater Treatment Facility
Regional District of Central Okanagan, Kelowna, BC
Sidestream RAS Fermentation (with Primary Fermentate Addition)

Plant Description:

- 4.4 MGD design Flow – TP annual avg. limit: 0.20 mg/l, TN < 6 mg/L - Daily
- MLE BNR process with sidestream enhanced biological phosphorus removal, Cloth Filters

Process Description:

- ✓ S2EBPR: Primary sludge fermentation with RAS anoxic pretreatment (5-10 min) followed by anaerobic sidestream treatment with a portion of primary fermentate. Remaining fermentate fed to mainstream anoxic zone.



Westside RWTF, Kelowna, BC

S2EBPR - Sidestream RAS Fermentation (with PS Fermentate Addition)

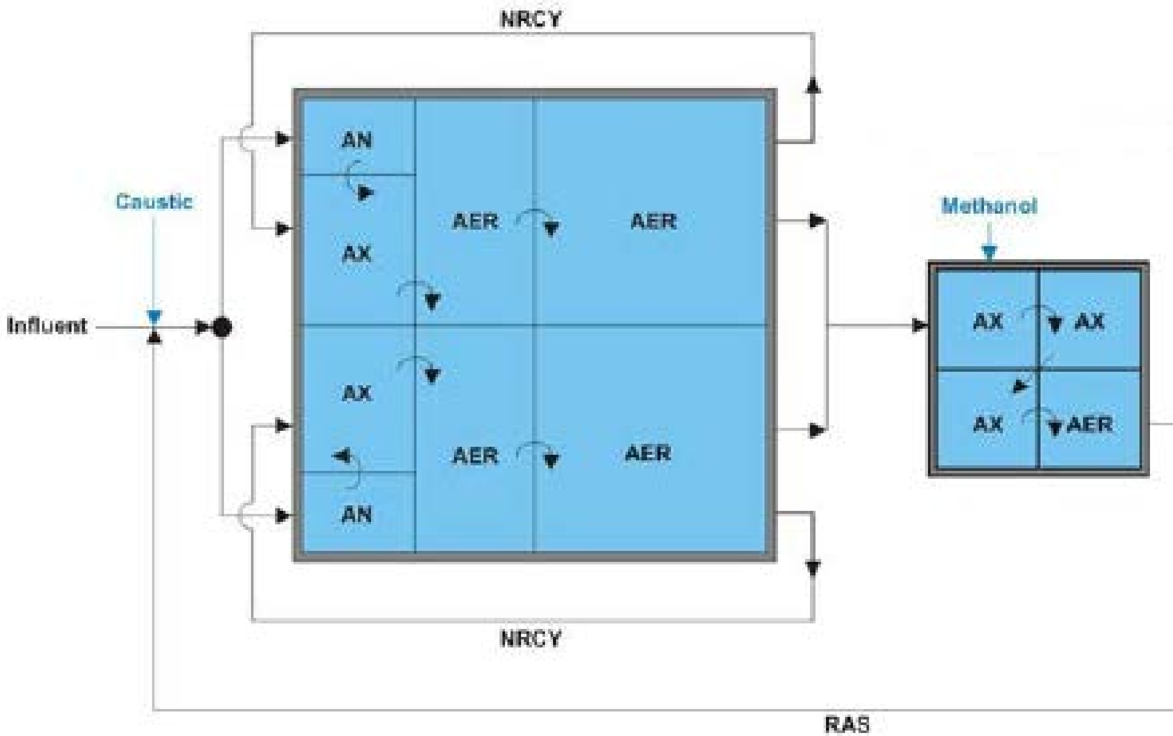
➢ ***Potential Performance & Benefits***

- ✓ Improved P removal and more stable operation (i.e. effluentortho-P consistently low).
  - ❖ Potential positive impact of S2EBPR extended anaerobic HRT (e.g. 16-48 hours) and continuous substrate feed on higher levels and composition of VFAs favoring PAOs over GAOs.
  - ❖ Potential positive impact of lower ORP on abundance of specific fermenting PAOs. *(Gu et. al, 2018, research in progress)*
- ✓ Positive impact on demand for carbon (VFAs) between biological nitrogen (denitrifiers) and phosphorus removal (PAOs) processes.
- ✓ Significant reduction in external carbon addition
- ✓ Significant reduction in metal salt (Alum) addition for P-trim.
- ✓ Reduction in RAS retention time compared to RAS only anaerobic zone

Hillsborough Wastewater Treatment Plant
Hillsborough, NC
Low TN modification – 5-Stage Bardenpho BNR

Plant Description:

- Permitted plant capacity: 3.0 MGD
- 5-Stage BNR, Denite filters
- 0.99 MGD Avg. Flow (2017)
- Design flow: 2.4 MGD
- TN Permit Limit: 10,422 lbs/yr *(1.43 mg/l at design flow)*
- TP: 2.0 mg/l (quarterly avg.)



Process Modification 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

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

ORIGINAL

MODIFIED

Zone	Volume (MG)	% of Volume Allocated	NRCY % of Inf	Detention Time (hours)	Volume (MG)	% of Volume Allocated	NRCY % of Inf	Detention Time (hours)
AN	0.125	6%		2	0.125	6%		2.4
1st AX	0.375	17%	200%	2.5	0.875	39%	900%	2.2
AE	1.5	67%		24.4	1	44%		18.8
2nd AX	0.1875	8%		3	0.1875	8%		2.3
Reair	0.0625	3%		1	0.0625	3%		0.8
Total	2.25	100%		29.2	2.25	100%		39.2

Original Reactor Modifications (Mahagan & Bilyk, 2016)

➢ *Potential Performance & Benefits*

✓Significant reduction in effluent TN limits

✓Mostly Stable operation

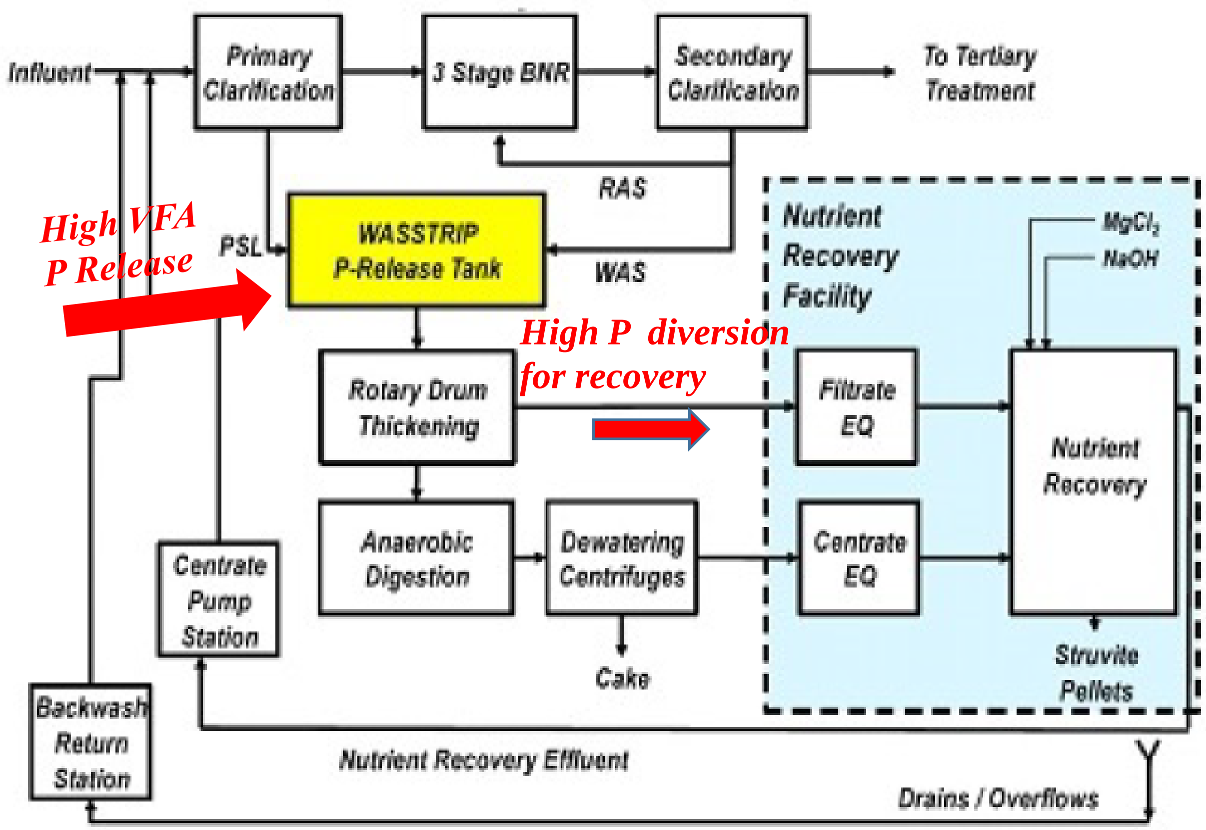
✓Significant reduction in carbon (methanol) addition

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

Plant Description:

- 60 MGD plant
- EBPR and chemical trim to meet a TP limit of 0.08 mg/L

✓Receives sludge from22 mgd Yellow River WRF (significant additional phosphorus loading and recycle).



(Adapted from Latimer et al, 2017)

Process Description:

Implement OSTARA Pearl® struvite precipitation for P (and some N) recovery and prevent struvite deposits in the dewatering centrifuges and upstream of dewatering

F. Wayne Hill WRC
WASSTRIP & OSTARA Pearl®

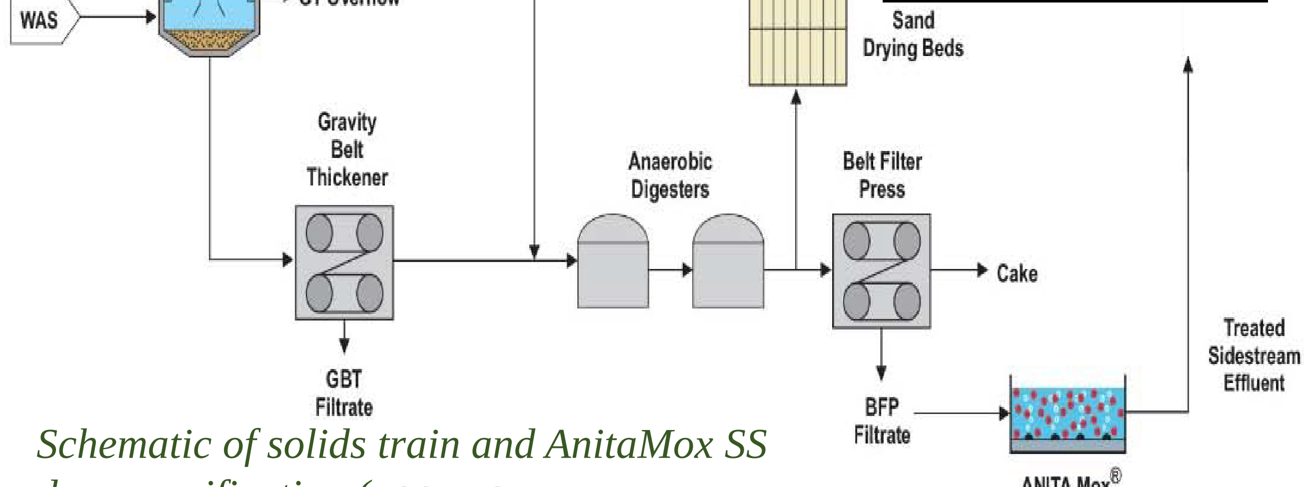
- ***Potential Performance & Benefits***

  - ✓Resolution of nuisance struvite formation and associated need for high pressure blasting of centrate pipes.
  - ✓WASSTRIP tank (PS &WAS) is achieving good P-release with relatively short HRT.
  - ✓Increased Nutrient recovery (PO4-P and TP)
  - ✓Significant reduction in Alum addition to achieve very low effluent TP.
  - ✓ Lower and more consistent effluent TP
  - ✓Improvement in dewatered biosolids cake solids content (likely impact of increase in Monovalent to Divalent Cation Ratio)

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

Plant Description:

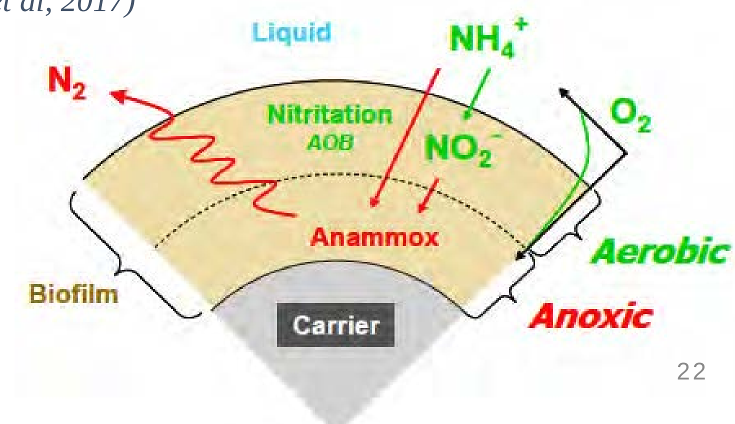
- 20 mgd design flow
- 5-stage BNR
- Nutrient limits: equiv. 3.0 mg/L TN and 0.18 mg/L TP (@ design flow)
- Repurposed two abandoned aerobic digesters for AnitaMox



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

Project Description:

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



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

- ***Potential Performance & Benefits***

  - ✓Significant nitrogen removal from filtrate (Ammonia and TN).
  - ✓Significant reduction of ammonia loading to mainstream BNR.
  - ✓Significant reduction in aeration/energy and sludge production.
  - ✓Reduction in final effluent TN.
  - ✓Most likely tolerates higher DO and nitrite levels (> 5mg/l).

Contact Information

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