# More Than Just Energy Savings

## Understanding the Benefits of Low DO Operation

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# Low Energy Process Intensification

New low energy technologies are being developed: AGS, MABR, PN/A, AnMBR.

WRRF looking at low capital investment to achieve BNR and reduce energy.

As an alternative to new technologies, WRRF have focused on new process control and operational approaches.

Application of low DO BNR in activated sludge facilities has led to many success stories.

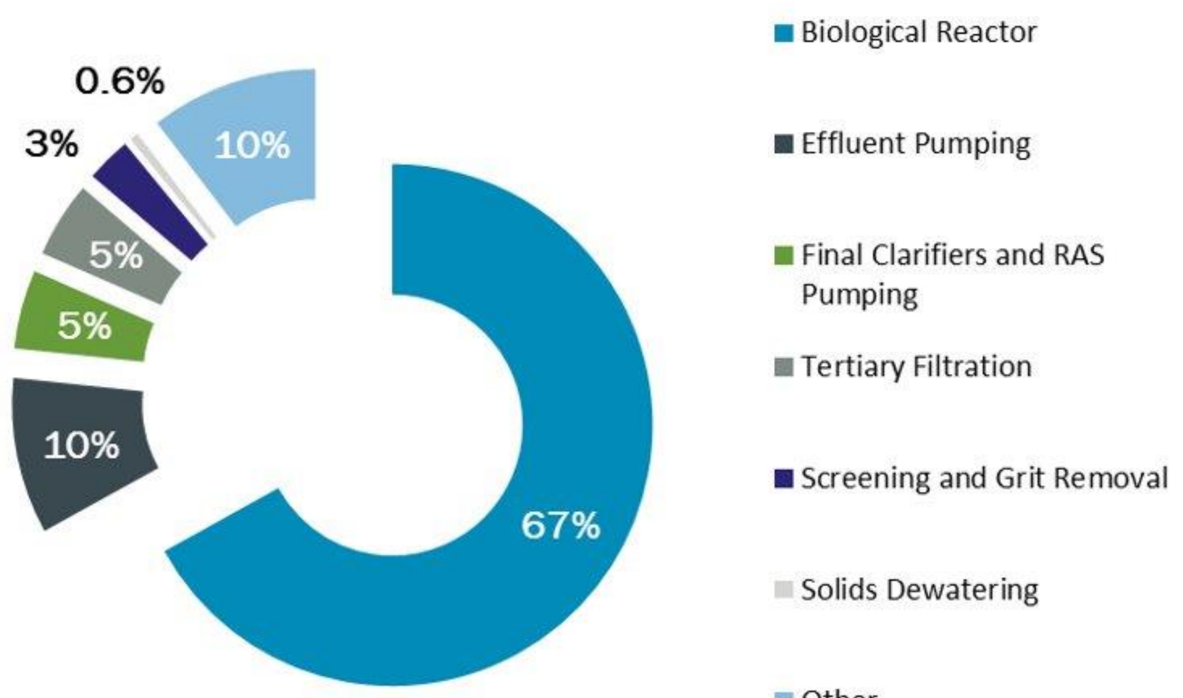
# WRF No. 5083 - Advancing Low Energy Biological Nitrogen and Phosphorus Removal

# Aeration and Process Intensification Opportunities

## Low DO-based Operation – why is it important?

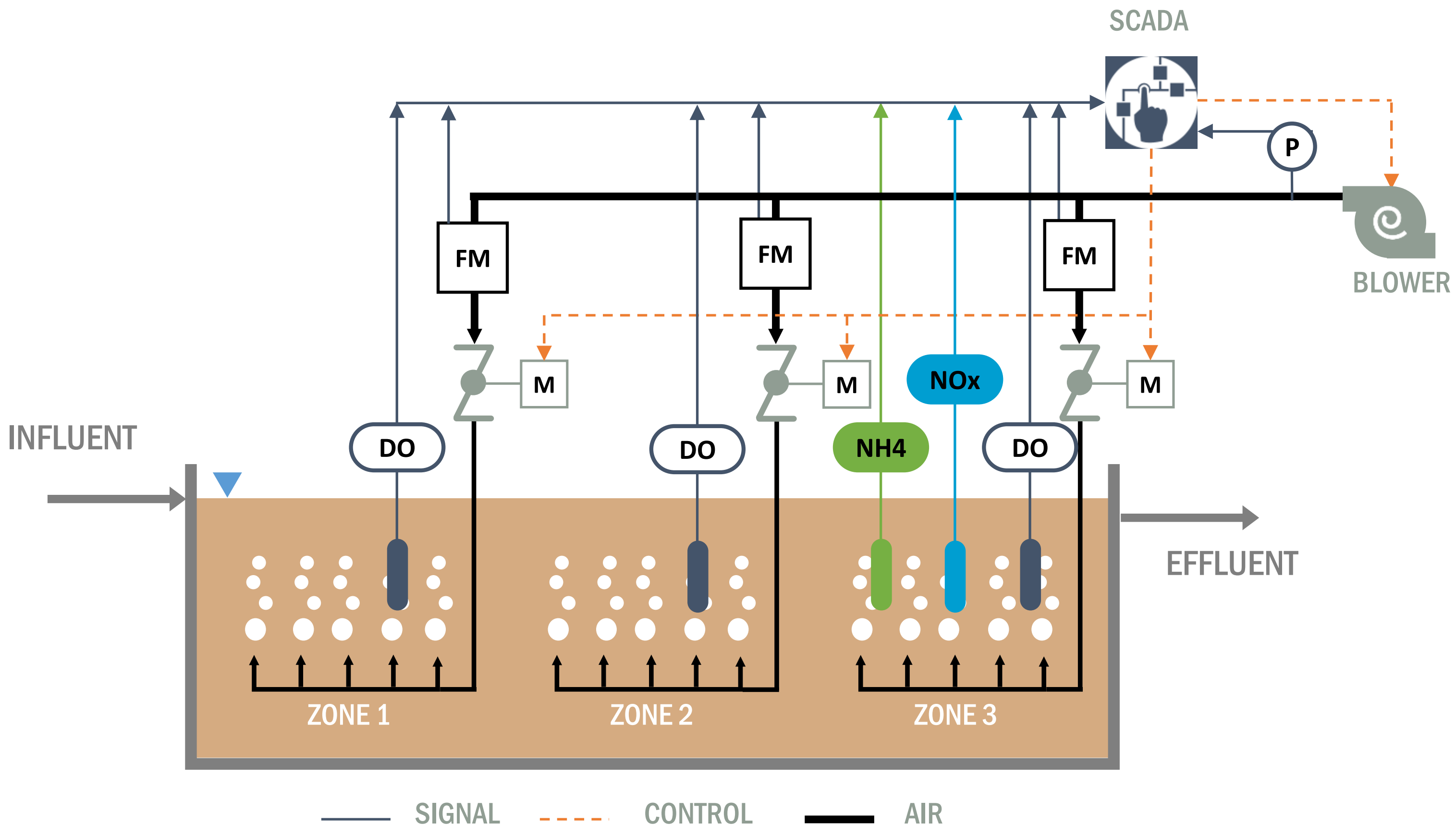
**Benefits of Advanced Aeration Controls**

- Energy savings
- Carbon and oxygen requirements are curbed
- Simultaneous nitrogen removal (including shortcut SND)
- Simultaneous nitrogen and phosphorus removal
- ABAC, AvN™, ORP, DO set points



# Diffused Aeration Control

- DO control with manual DO setpoints
- Ammonia based aeration control (ABAC)
- Ammonia versus NOx-N (AvN) control



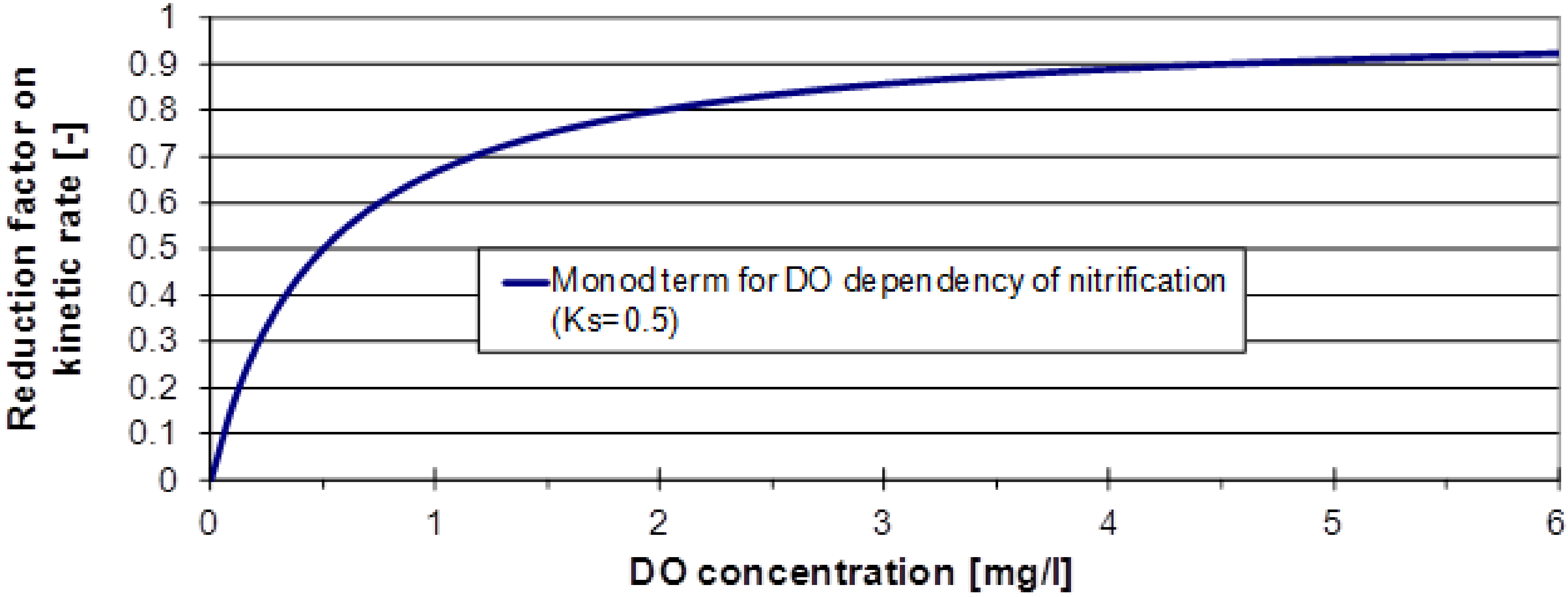
# Nitrification Fundamentals

## Nitrification requirements

- **Sufficient** provision of **dissolved oxygen**
- **Ammonia** as substrate (+ essential nutrients)
- Sufficiently long **aerobic sludge retention time**
- Sufficient **mass of nitrifiers**

# Nitrification Fundamentals

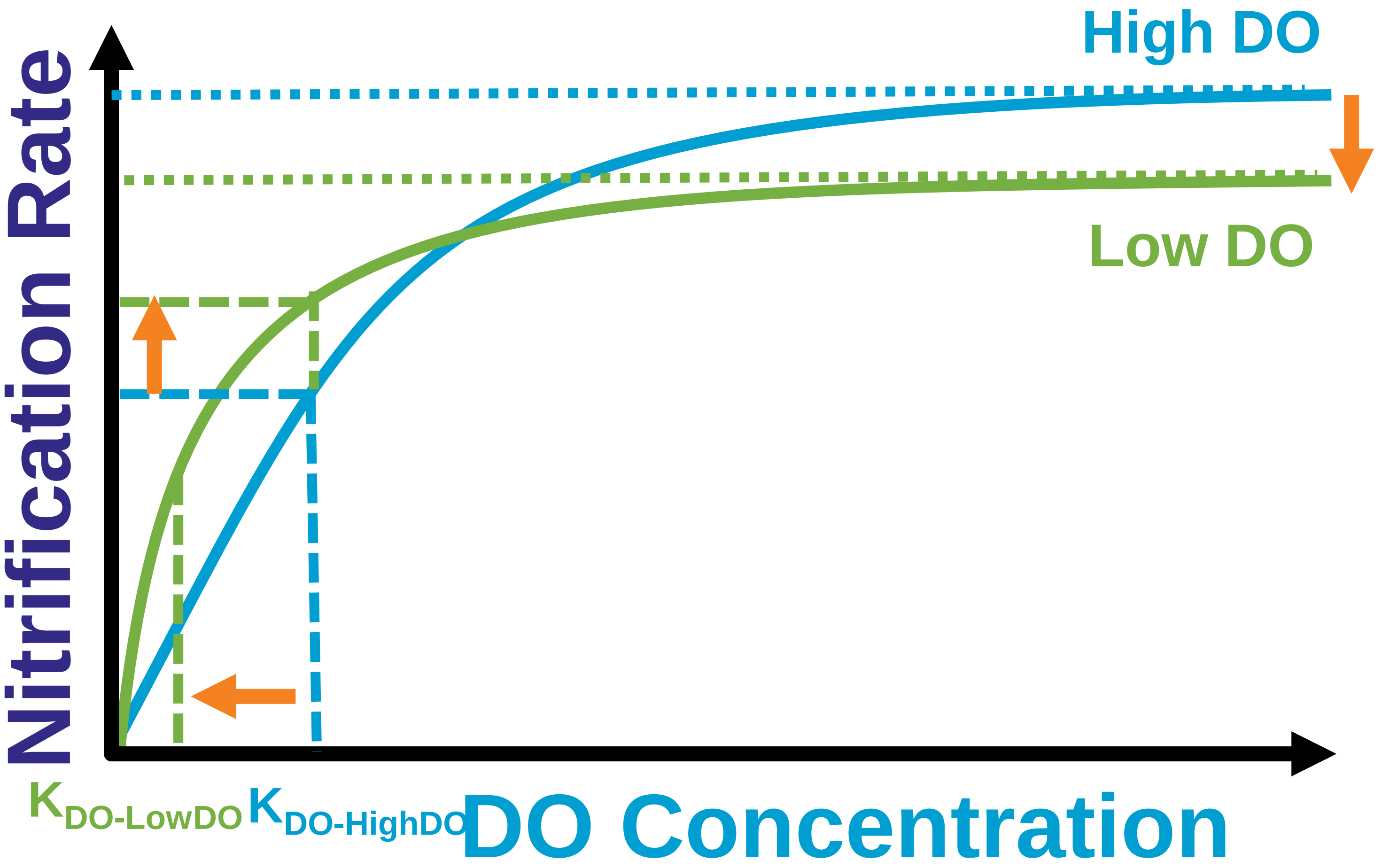
## Nitrification Kinetics – DO Constraints




At 2 mg DO/L: ca. 80% of max. Rate
At 0.3 mg DO/L: ca. 30% of max. Rate

# Nitrification Fundamentals

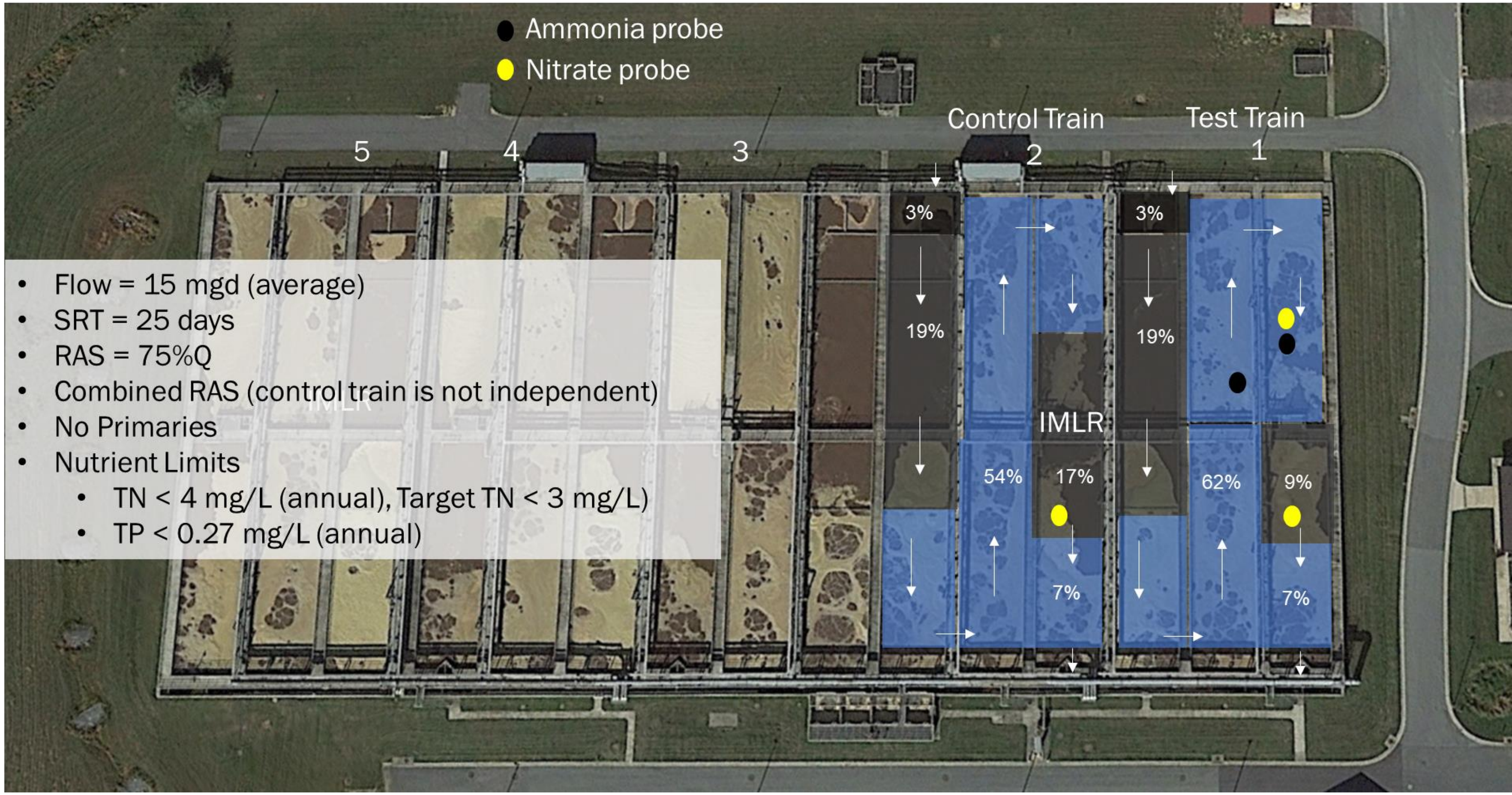
## Nitrification Kinetics – Effect of adaptation




- Maximum nitrification rate is reduced by approximately 20-30%
- Apparent $K_{DO}$ decreases
- Rates at low DO higher for low DO-adapted biomass
- Requires biomass adaptation and acclimation

# Full-Scale Observations

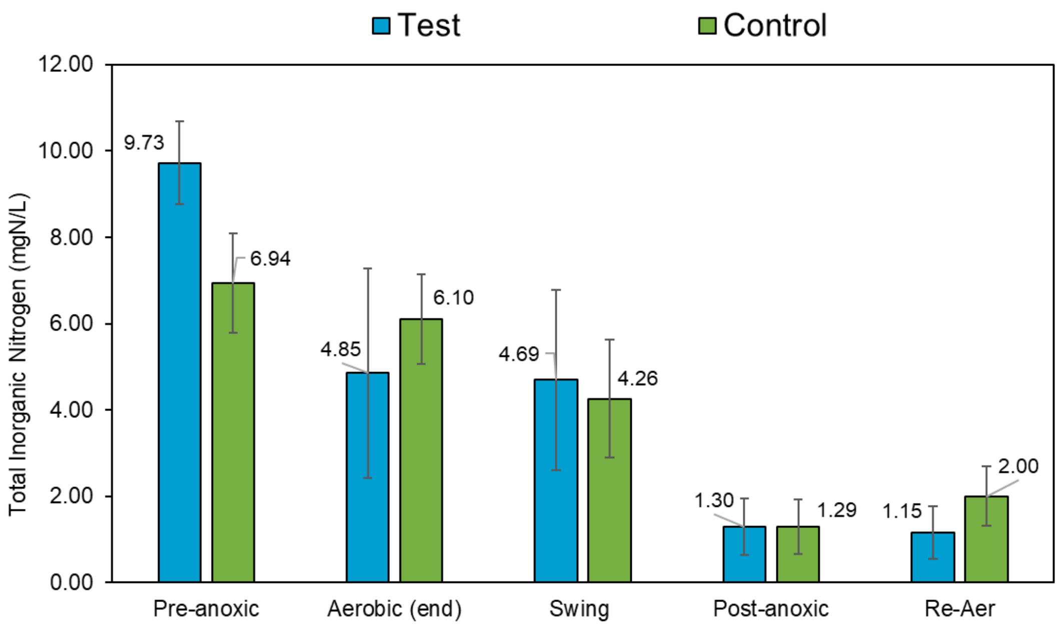
# Plant 1



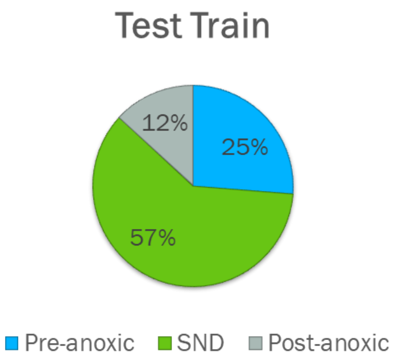

- Flow = 15 mgd (average)
- SRT = 25 days
- RAS = 75%Q
- Combined RAS (control train is not independent)
- No Primaries
- Nutrient Limits
  - TN < 4 mg/L (annual), Target TN < 3 mg/L)
  - TP < 0.27 mg/L (annual)

| Operations | Test Train | Control Train |
|---|---|---|
| ABAC | Yes | Constant high DO |
| IMLR (%) | 200 | 400 |
| Avg DO (mg/L) | 0.35 | 1.6 |
| Post anoxic zone | SZ1 aerated; SZ2 anoxic | Both SZ1 and SZ2 anoxic |
| Methanol (gal/d) | 0 | 50 |

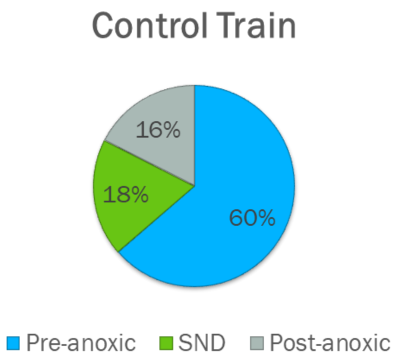
# Plant 1



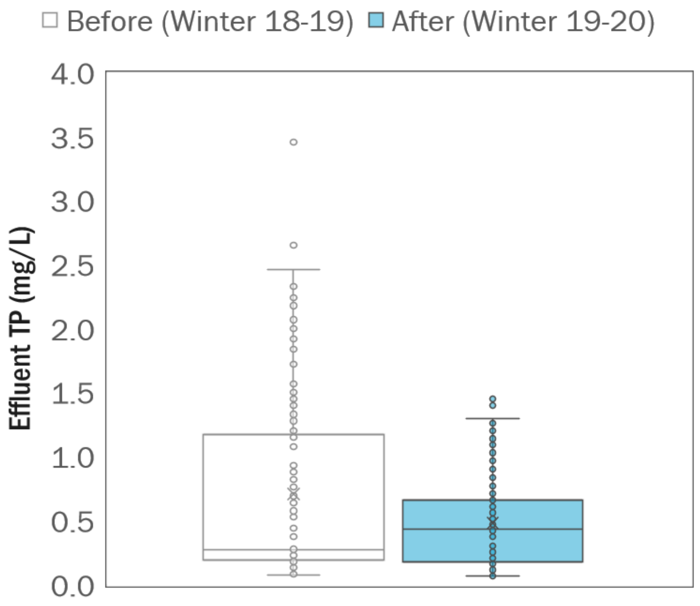
Test
Control
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Total Inorganic Nitrogen (mgN/L)
9.73
6.94
4.85
6.10
4.69
4.26
1.30
1.29
1.15
2.00
Pre-anoxic
Aerobic (end)
Swing
Post-anoxic
Re-Aer

Test Train
12%
25%
57%
Pre-anoxic
SND
Post-anoxic

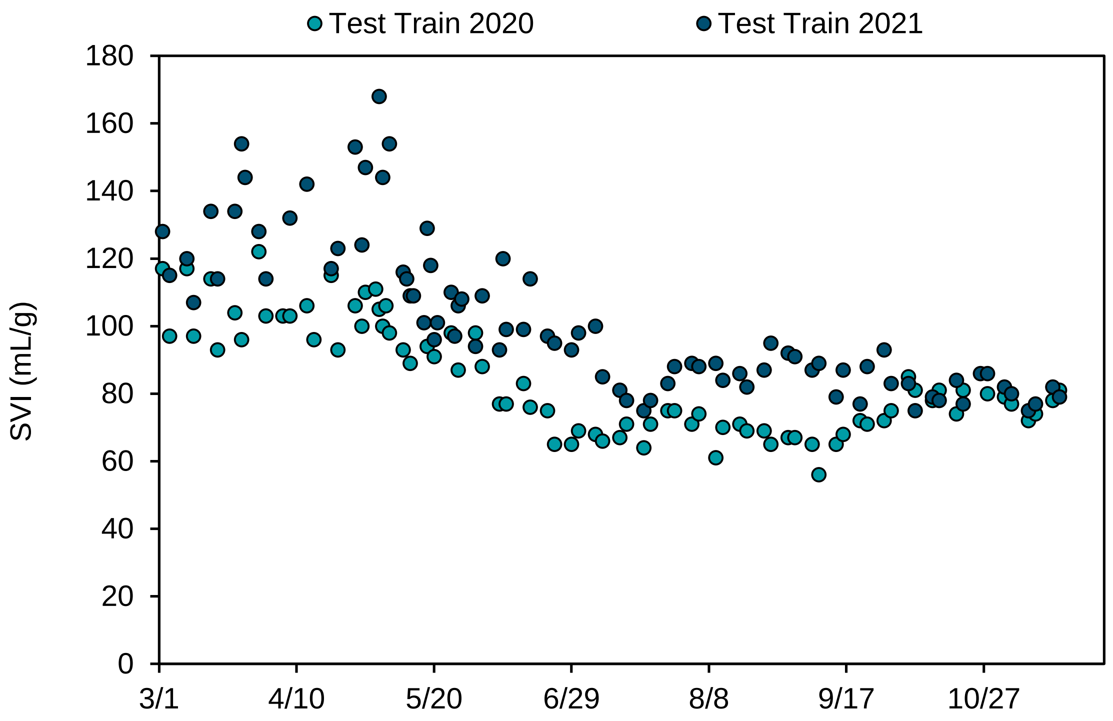



Control Train
16%
18%
60%
Pre-anoxic
SND
Post-anoxic

Before (Winter 18-19)
After (Winter 19-20)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Effluent TP (mg/L)

# Plant 1




Results of Microscopic analysis

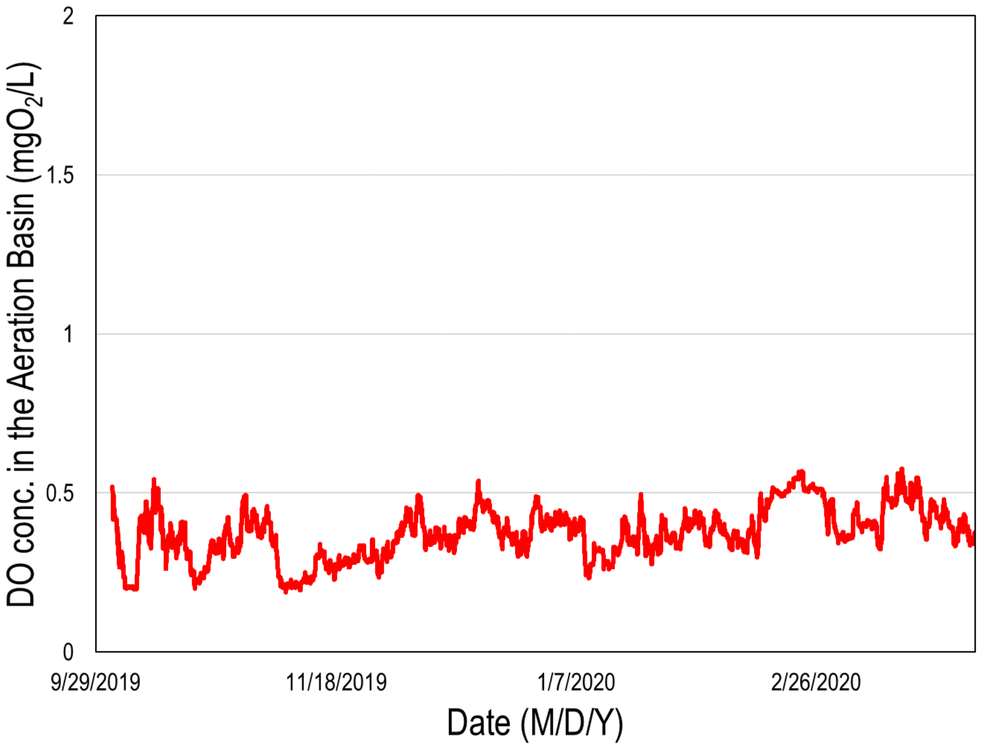
| Morphotype/ Indicator Organism | Rank | Abundance |
|---|---|---|
| Actinomycetes | 1 | Very Common-Abundant |
| Zoogloea | 2 | Common-Very Common |
| Type 1851 | 3 | Common |
| Type 0675/0041 | 3 | Common |
| Type 0914 | 3 | Common |
| Thiothrix | 4 | Some |
| Type 021N | 4 | Some |

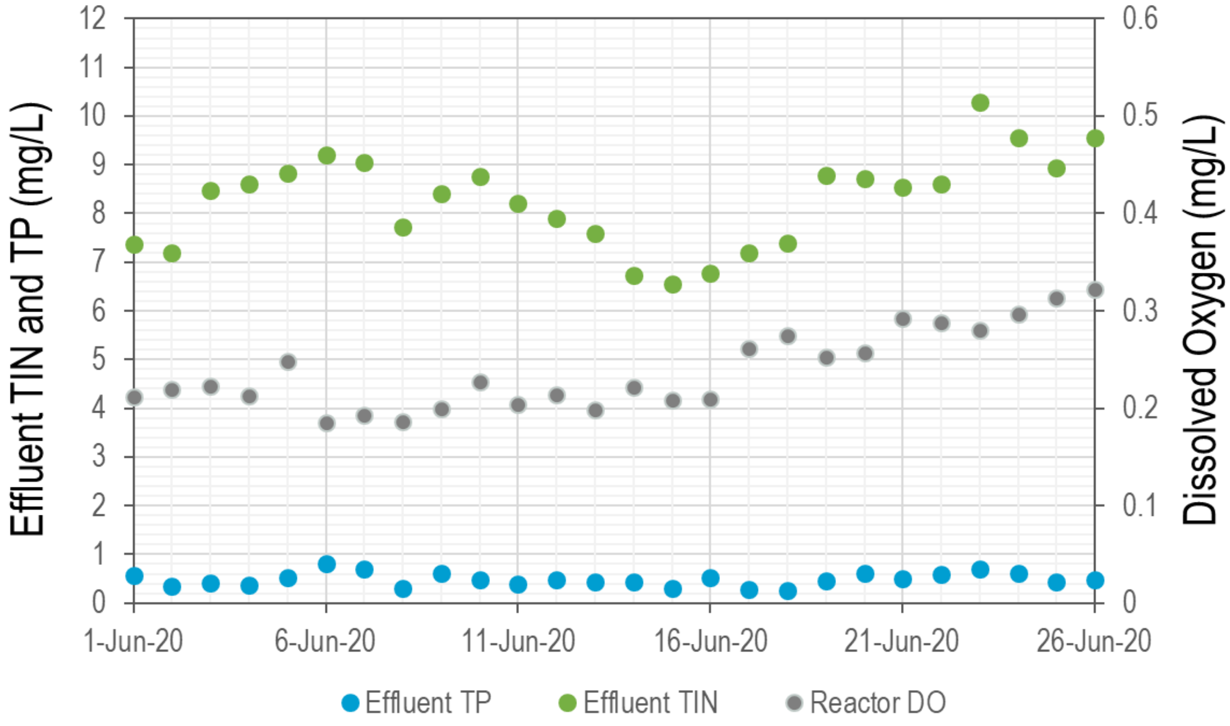
- ✓ No low DO filaments were identified
- ✓ There was no evidence that lower DO operation contributes to poor settling characteristics

# Southwest Water Reclamation Facility
## City of St. Petersburg, Florida


- High-rate AO process
- 2-way step feed to biomass control
- Low DO operation to
- inDENSE for process intensification

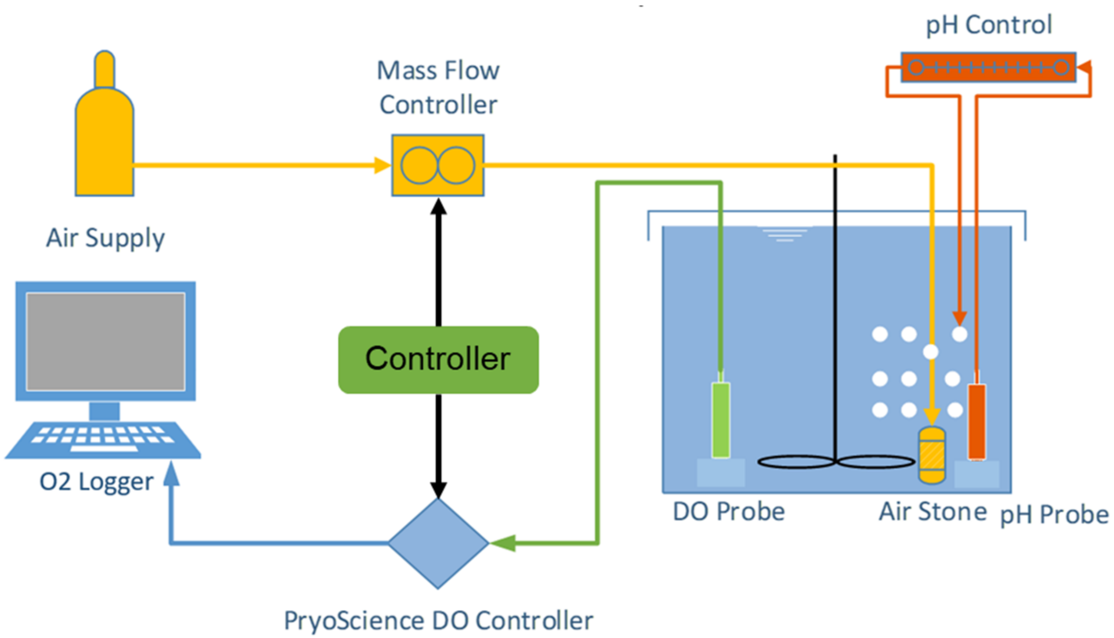
# Southwest Water Reclamation Facility

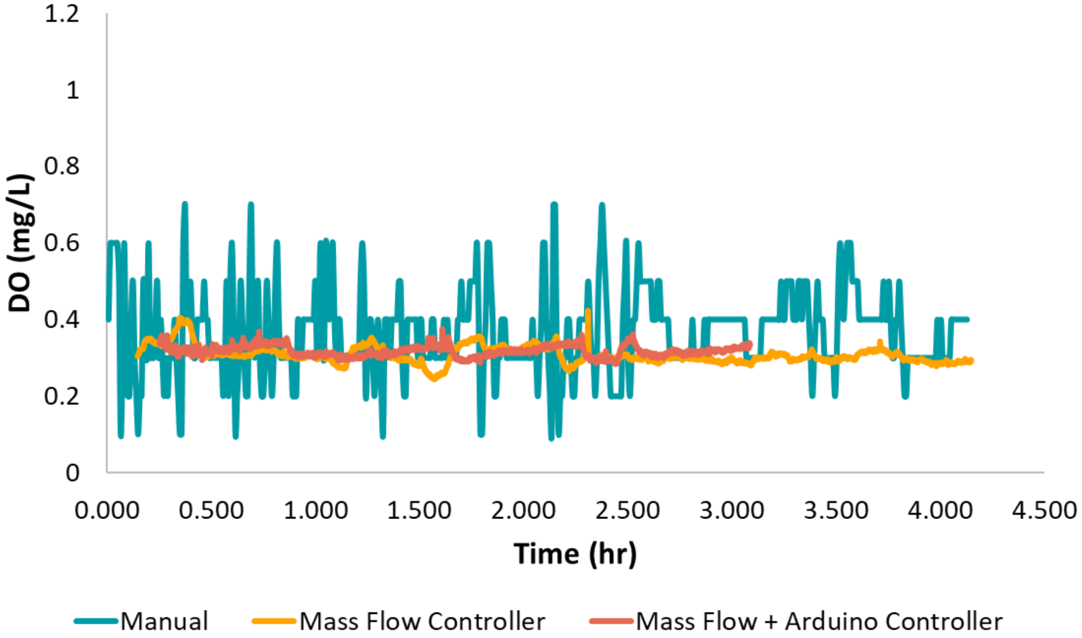


# Kinetic Testing

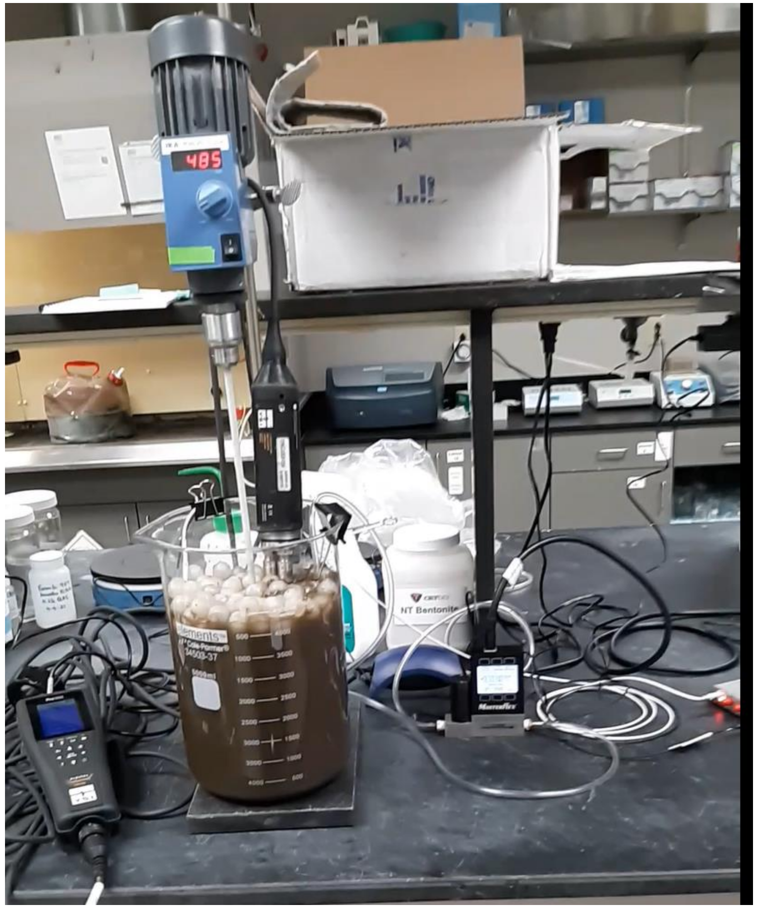
# Low DO Control



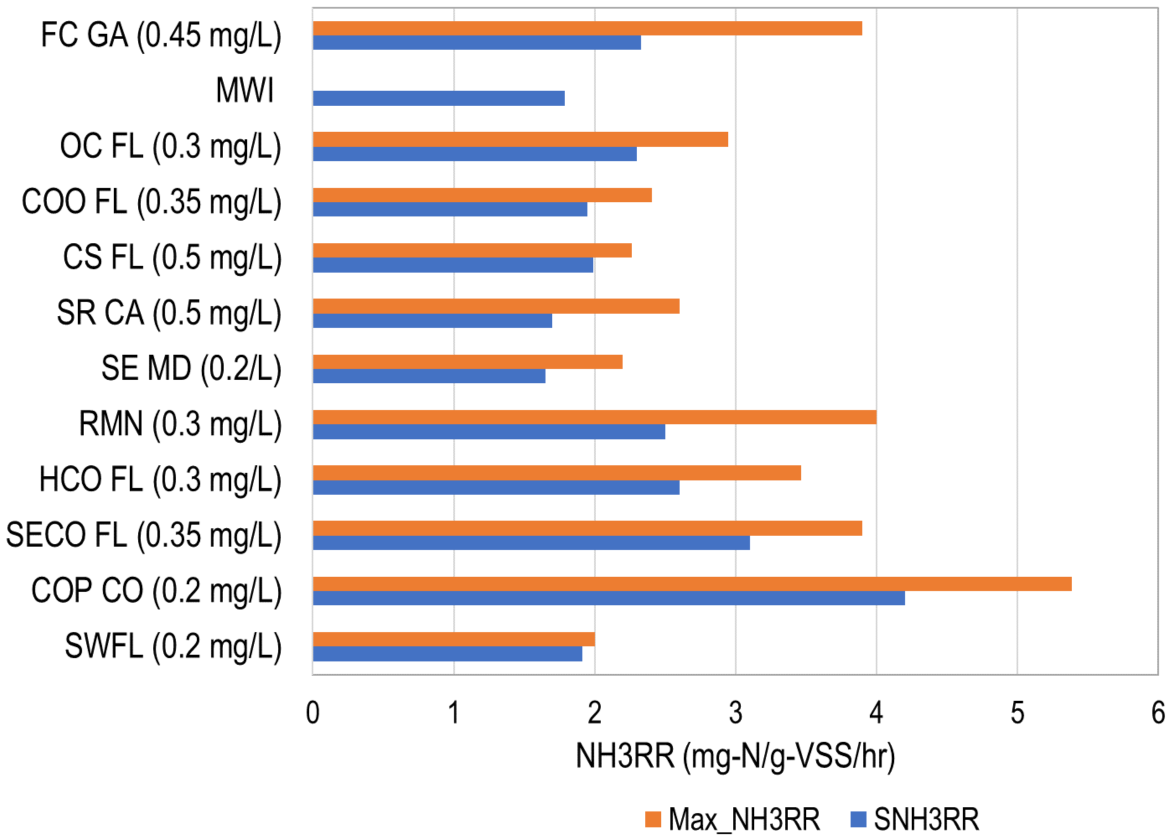




| Control Mechanism | Mean | SD (%) |
|---|---|---|
| Manual | 0.36 | 30% |
| Mass Flow | 0.31 | 7% |
| Mass Flow + Arduino | 0.32 | 4% |

# Nitrification Rates



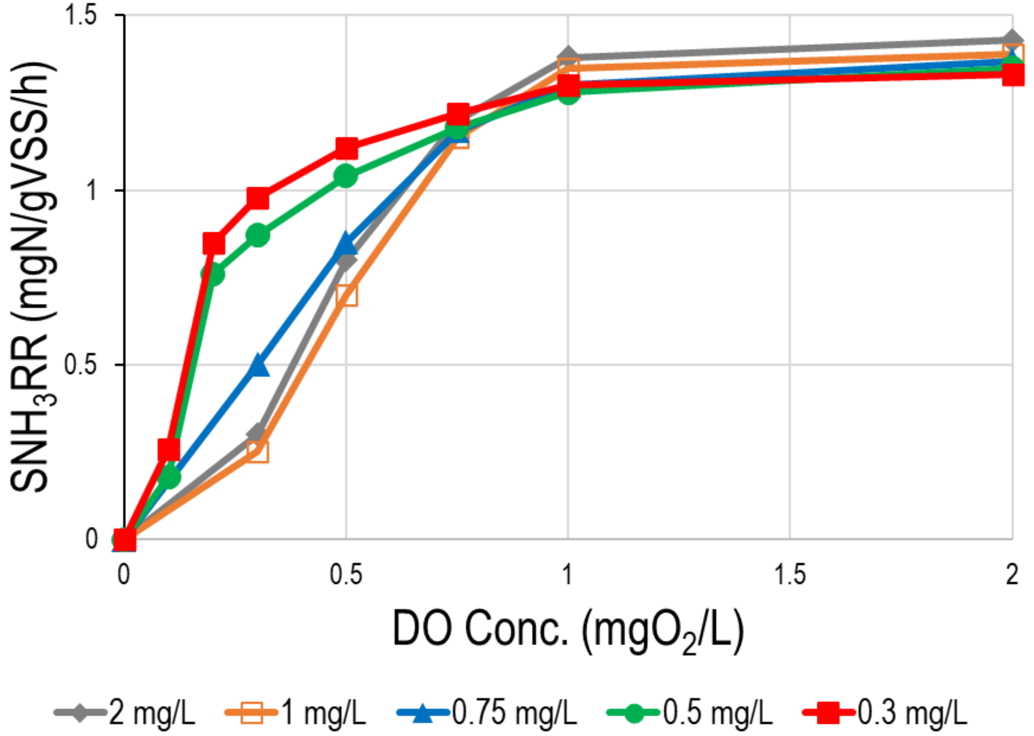
Nitrification Test Setup

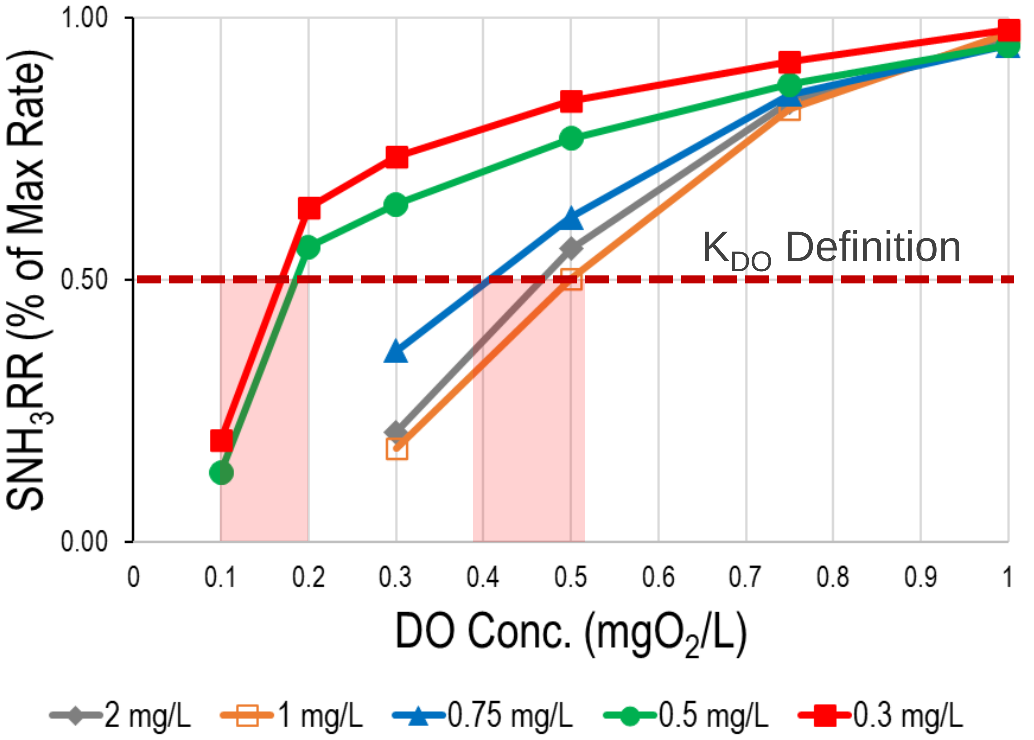



Average Low DO Rate Approximately 80% of Max Rate $NH_3RR$

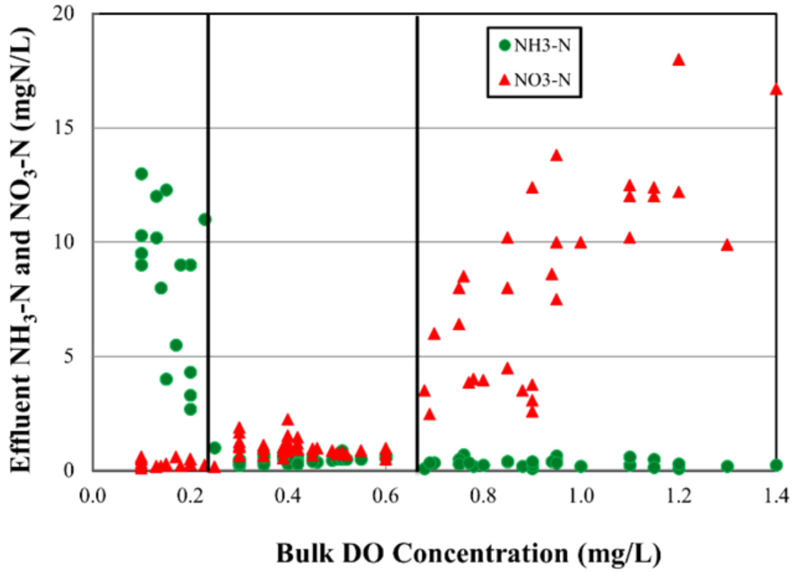
# Nitrification KDO Testing

- Sludge samples collected from full-scale facility at various DO setpoints after 2-3 weeks of acclimation at each DO setpoint
- Nitrification rate testing was performed at various DO concentrations (0-2 mg/L) in the batch reactor

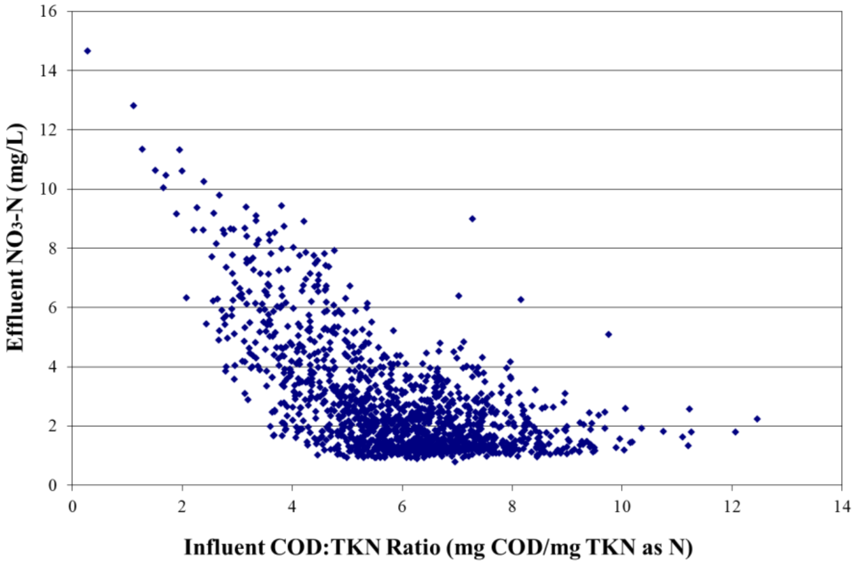


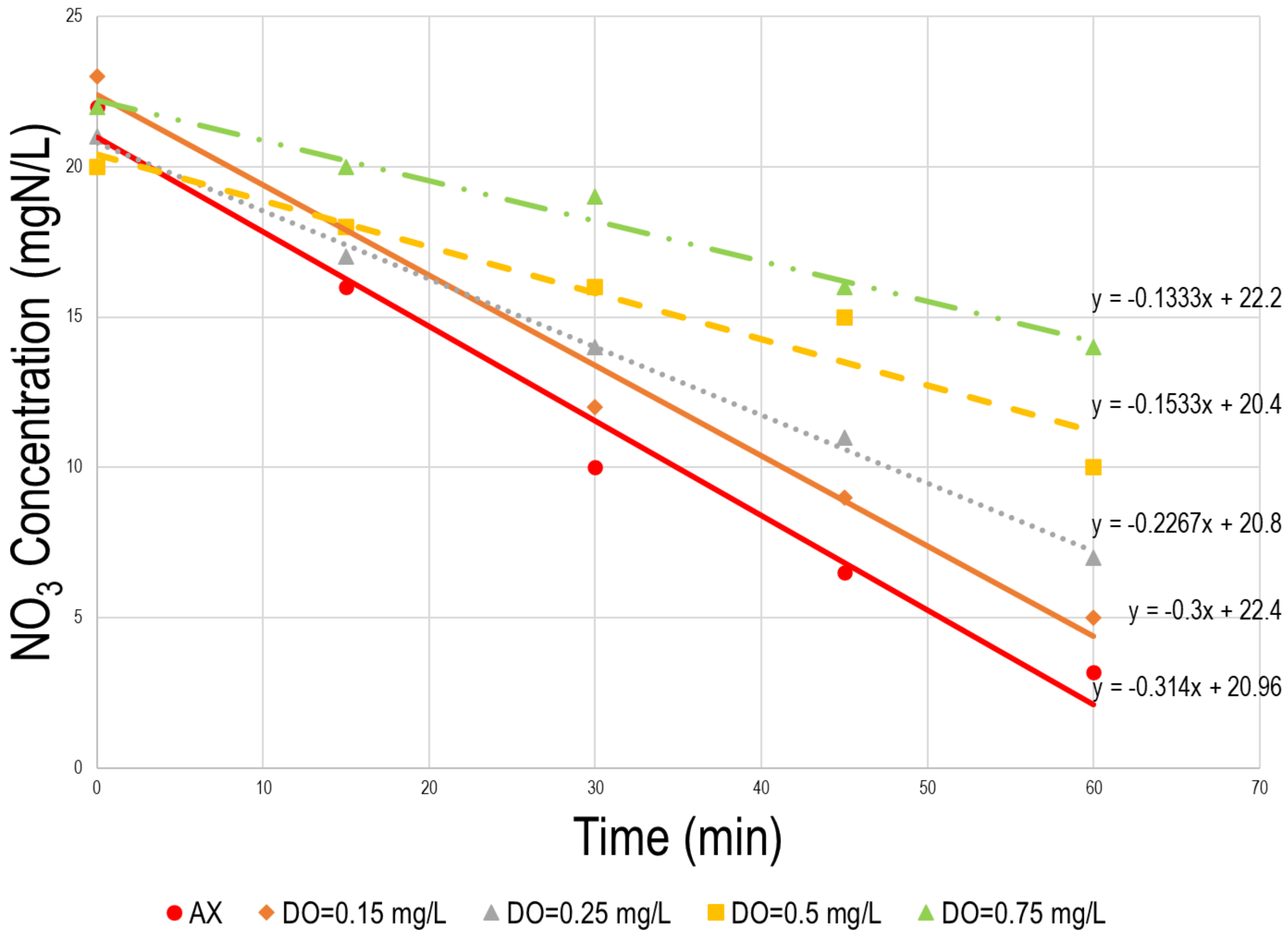
# SND Rates



NH3-N
NO3-N
Effluent NH3-N and NO3-N (mgN/L)
Bulk DO Concentration (mg/L)

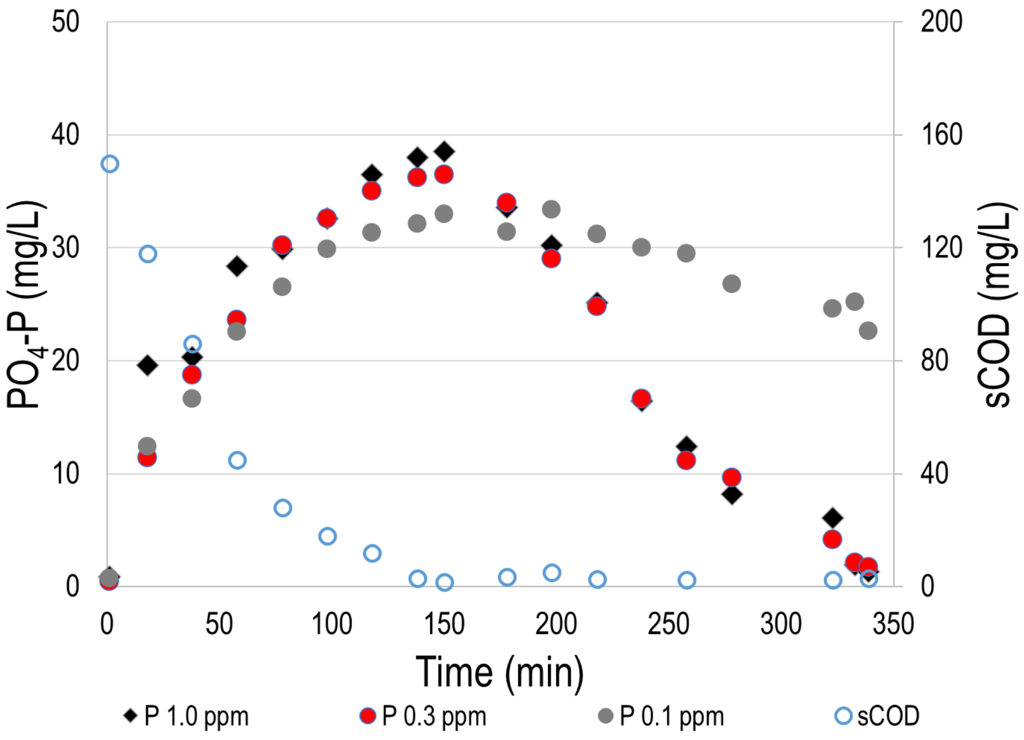



Effluent NO3-N (mg/L)
Influent COD:TKN Ratio (mg COD/mg TKN as N)

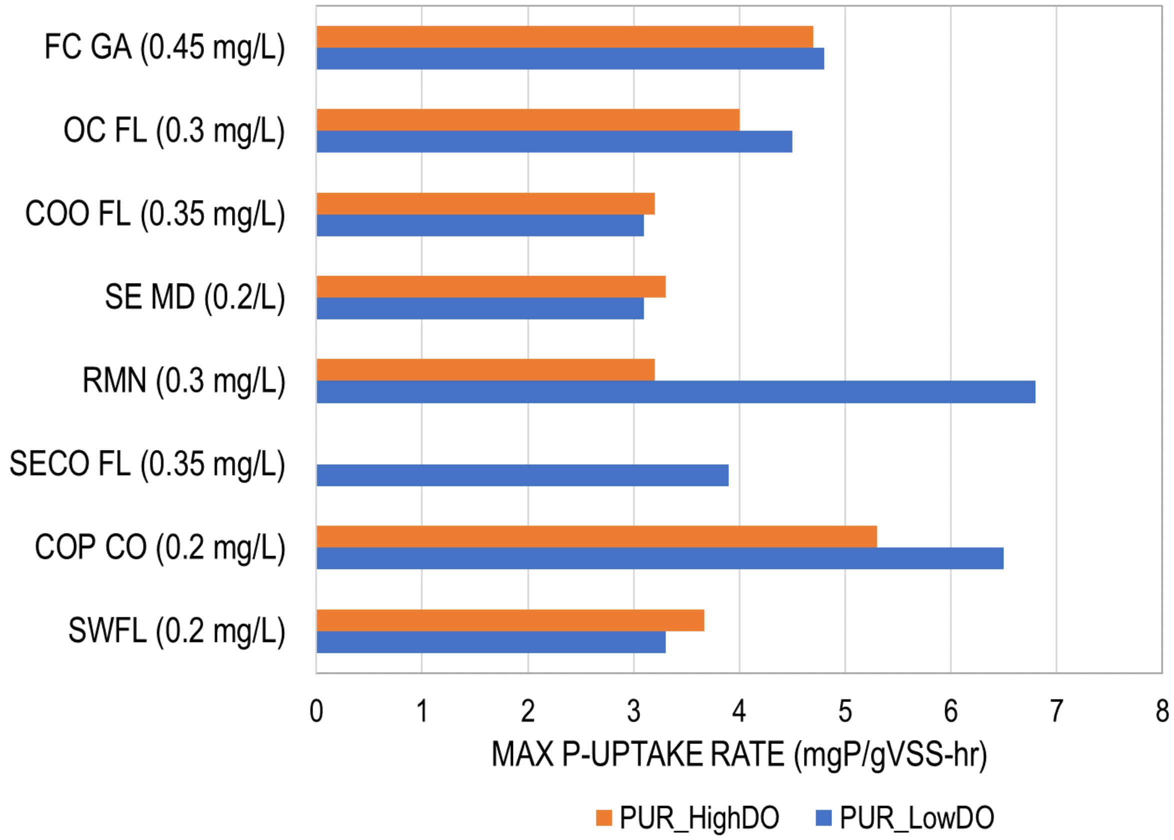



y = -0.1333x + 22.2
y = -0.1533x + 20.4
y = -0.2267x + 20.8
y = -0.3x + 22.4
y = -0.314x + 20.96
NO3 Concentration (mgN/L)
Time (min)
AX
DO=0.15 mg/L
DO=0.25 mg/L
DO=0.5 mg/L
DO=0.75 mg/L

# Biological Phosphorus Uptake Rates



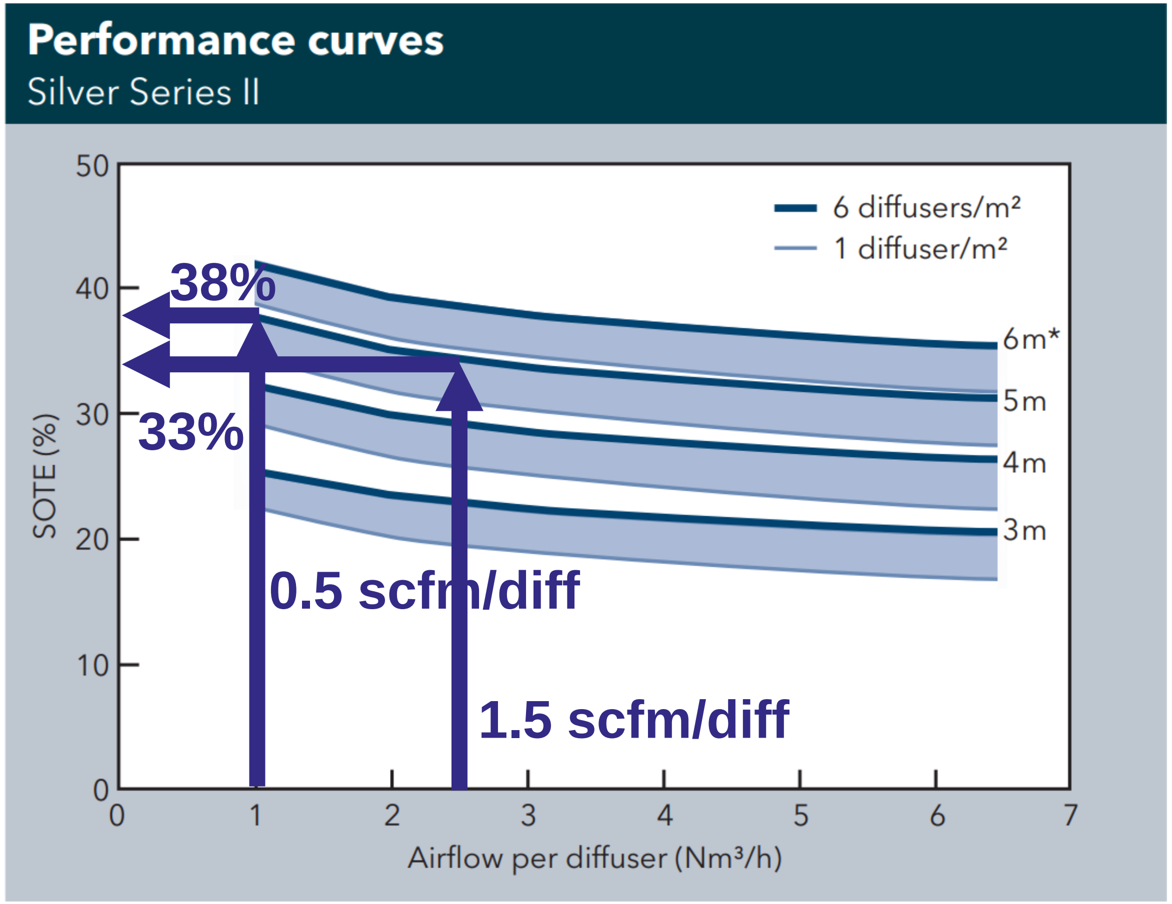

| Rate (mgP/gVSS/hr) | High DO | Low DO |
|---|---|---|
| Max P Release | 13.23 ± 1.92 | 14.16 ± 1.61 |
| Max P Uptake | 5.53 ± 1.85 | 6.52 ± 1.92 |
| P:VFA | 0.41 ± 0.05 | 0.56 ± 0.04 |




Low DO seems to slightly improve PUR within the DO values evaluated

# Mechanical Benefits of Low DO Operation

- Lower diffuser flux results in higher oxygen transfer efficiencies
- Lower head losses in distribution piping and valving
- Allows operating at lower blower discharge pressures
- Higher driving force to dissolve oxygen into water




*Xylem Aeration Products – Sanitaire Silver Series II Diffusers* **Submergence*

# Summary

- Low DO nitrification rates are approximately 80% of maximum rates
- Nitrification $K_{DO}$ is lower in low DO systems
  - Design for aeration system turndown
- SND occurs between 0.2 to 0.6 mg/L
  - Substrate dependent
- Low DO seems to improve BioP

# Thank you.

# Questions?

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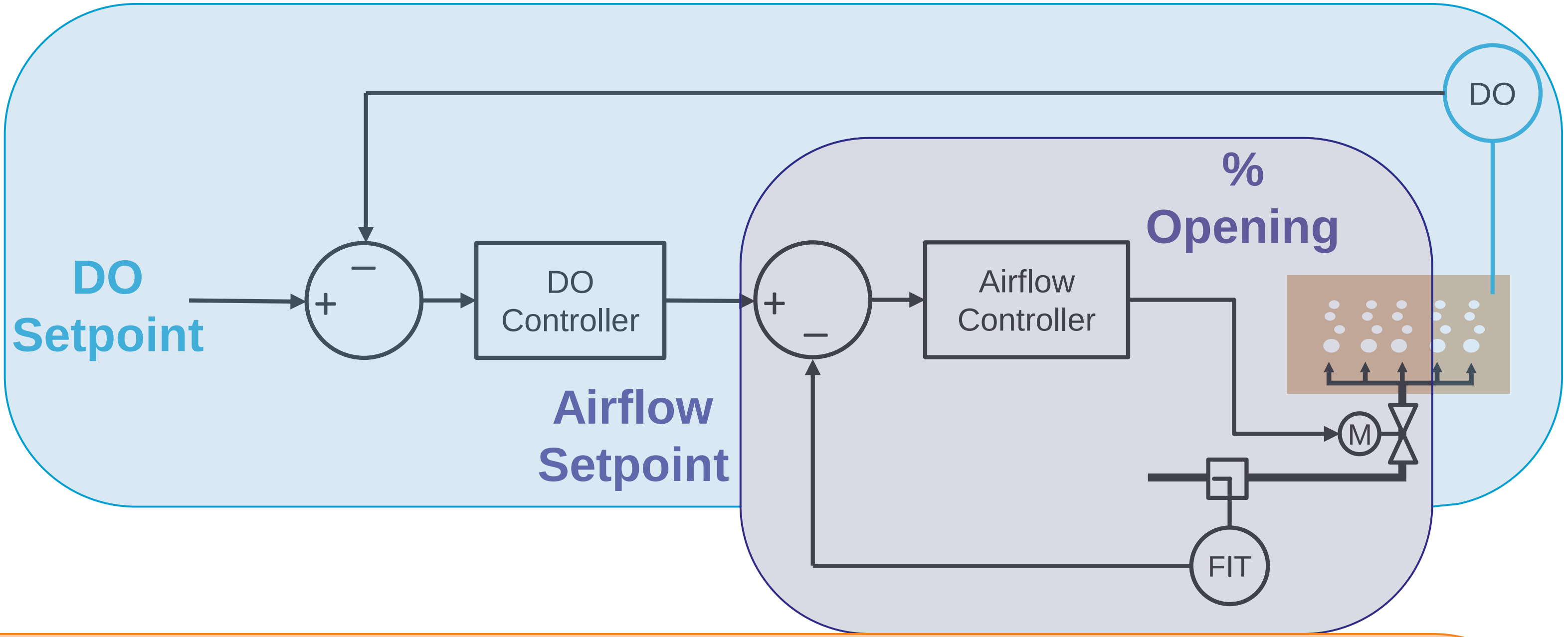
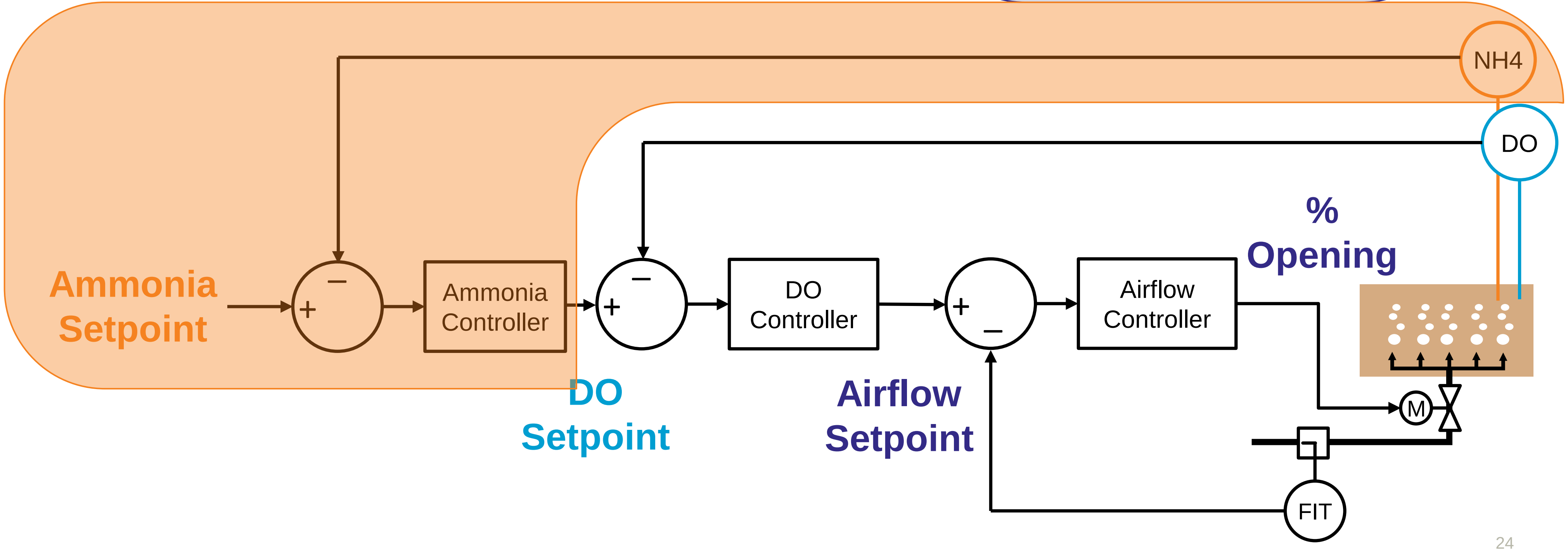
Brown AND Caldwell

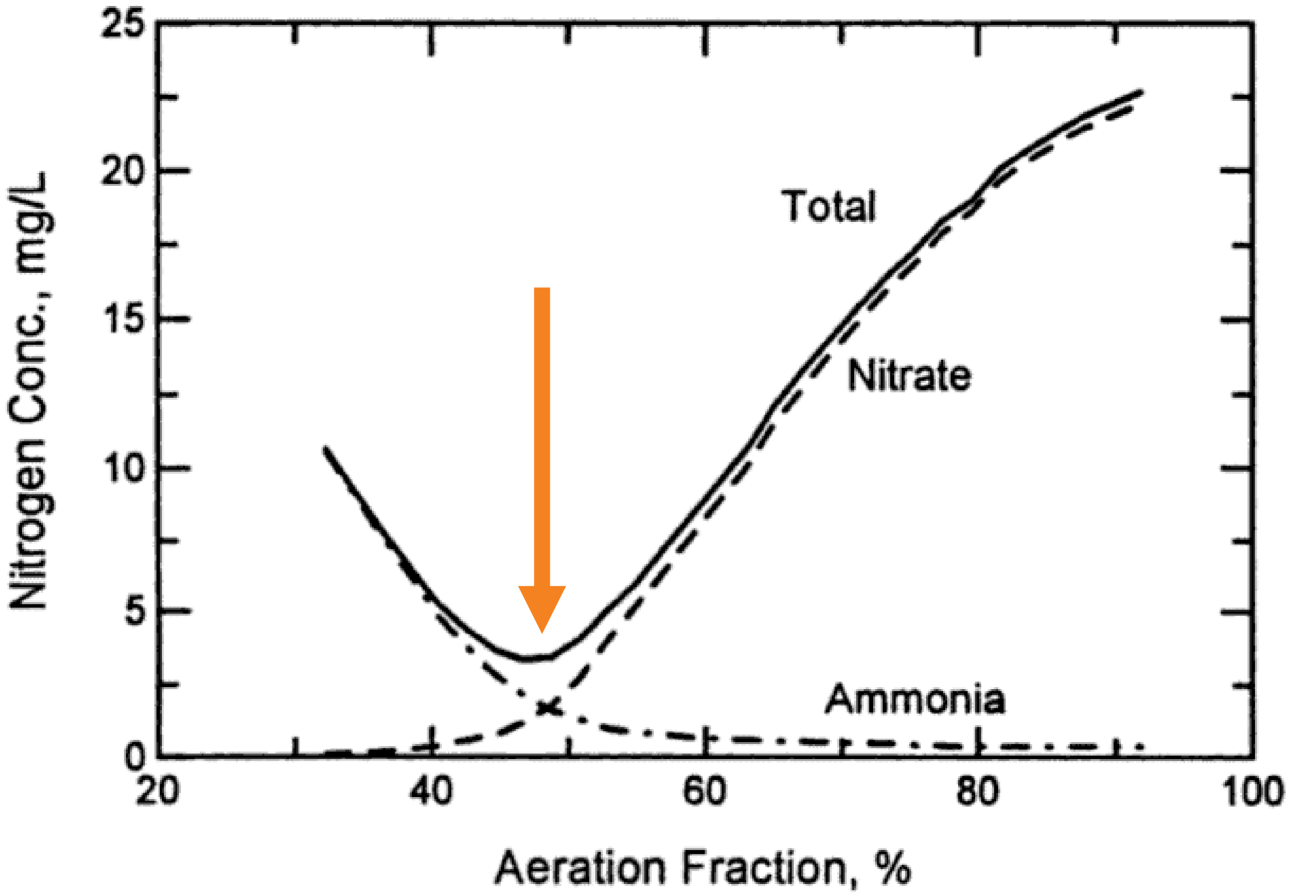
# Cascading DO Control




# ABAC



# Ammonia versus NOx-N Control




*Batchelor, B (1983). Simulation of single-sludge nitrogen removal. Journal of Environmental Engineering*

- Target effluent ammonia to NOx-N ratio of 1 to maximize nitrogen removal
- Intermittent aeration with high DO and variable aerobic fraction (difficult to implement full-scale)
- Continuous aeration with variable DO setpoint