Advances in Nutrient Removal – Process Updates

NJWEA Annual Conference

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May 12, 2014

Agenda

- Nitrogen removal
- Enhanced Biological Phosphorus Removal (EBPR)
- Combined Nitrogen and EBPR
- Innovative Approaches

Natural and Artificial Selection

Nutrient Removal with Activated Sludge

- Understanding treatment process goals
- Providing the appropriate environmental conditions to develop a healthy population of the needed microorganisms and control their behavior
  - Provide advantages to the desired populations
  - Provide disadvantages to those not desired
- Environmental conditions:
  - Appropriate chemistry: pH; alkalinity
  - The right balance of: carbon; oxygen; nitrogen; phosphorus
  - Temperature
  - Solids retention time
  - Hydraulic retention time

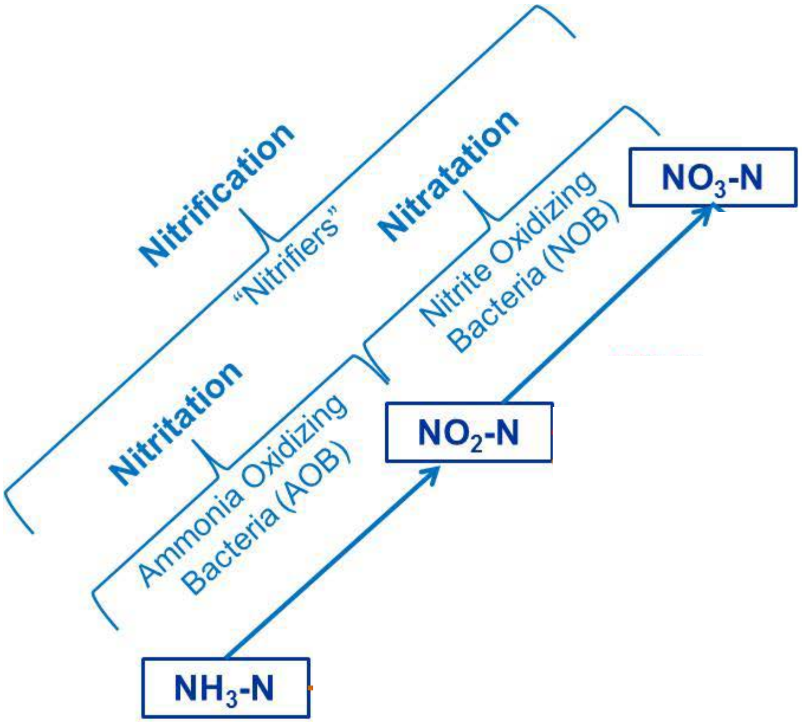
Nitrogen Removal

Tiers of Treatment – Effluent Total Nitrogen

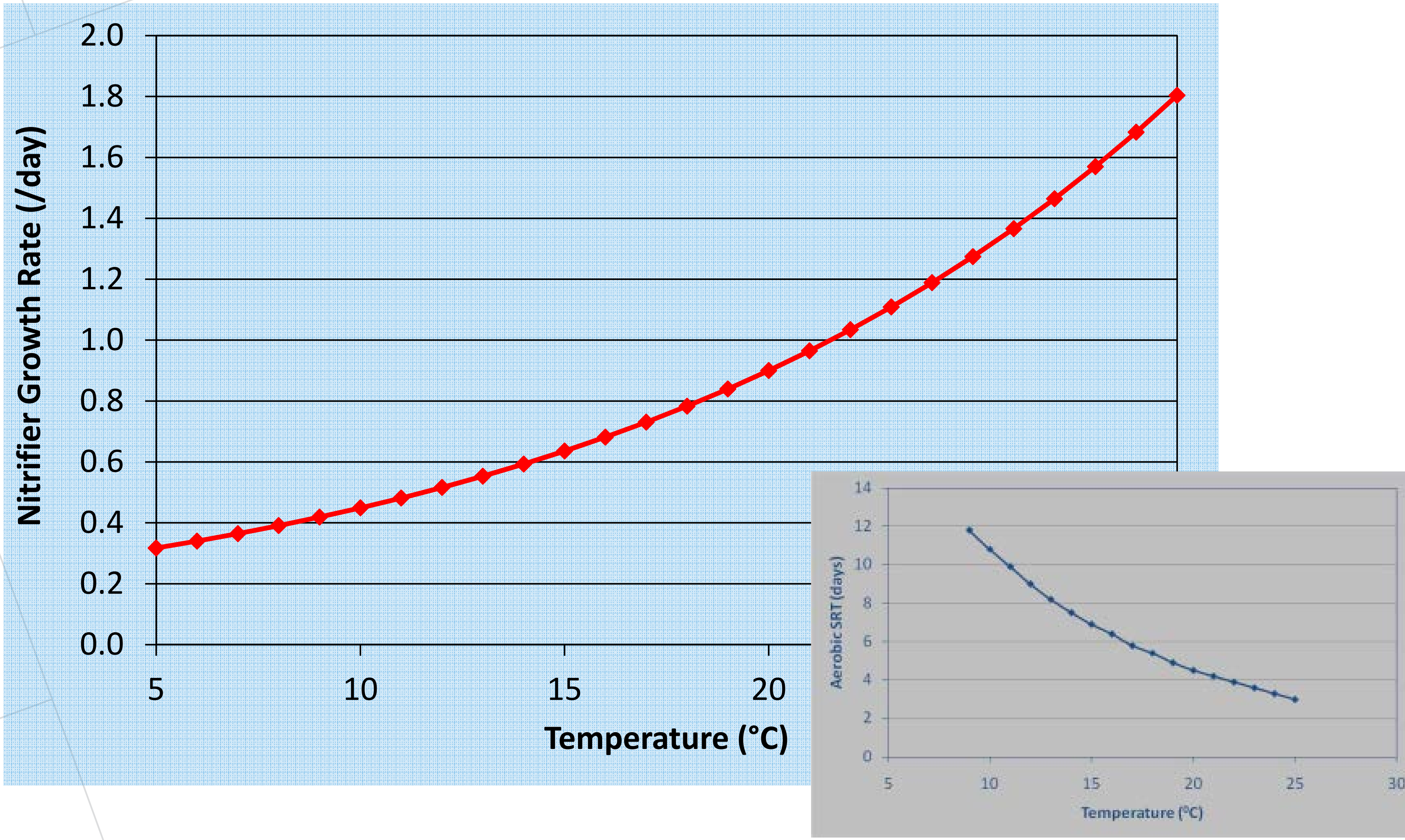
- Tiers of Treatment
  - 8 mg/L TN – "Easy"
  - 5 mg/L TN – Readily do-able, but a challenge
  - 3 mg/L TN – "Limit of Technology", and can be very difficult
- Process configurations of the activated sludge process have developed to address these increasingly stringent levels of treatment

Nitrification

- Conversion of ammonia-N to nitrite-N and then nitrate-N
- Environmental conditions for nitrification:
  - Ammonia-oxidizing and nitrite-oxidizing biomass
  - need adequate solids retention time (SRT) at given temperature
  - Oxygen: 4.6 mg O_2 / mg N nitrified
  - Suitable pH
  - Adequate alkalinity



Environmental Considerations: Nitrification Rate and Temperature



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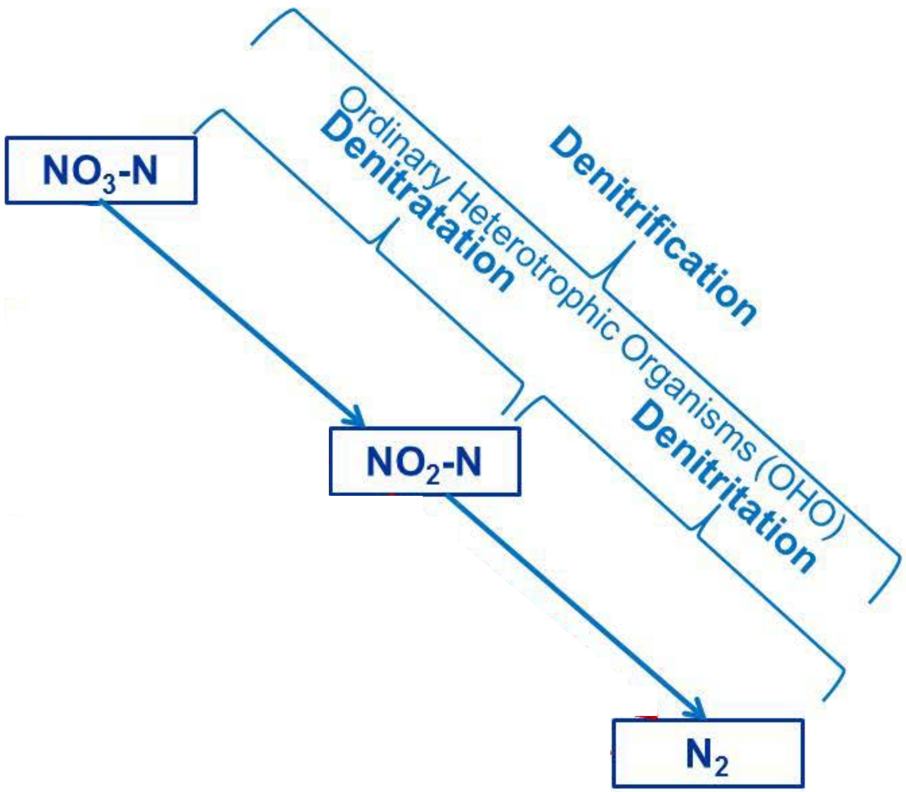
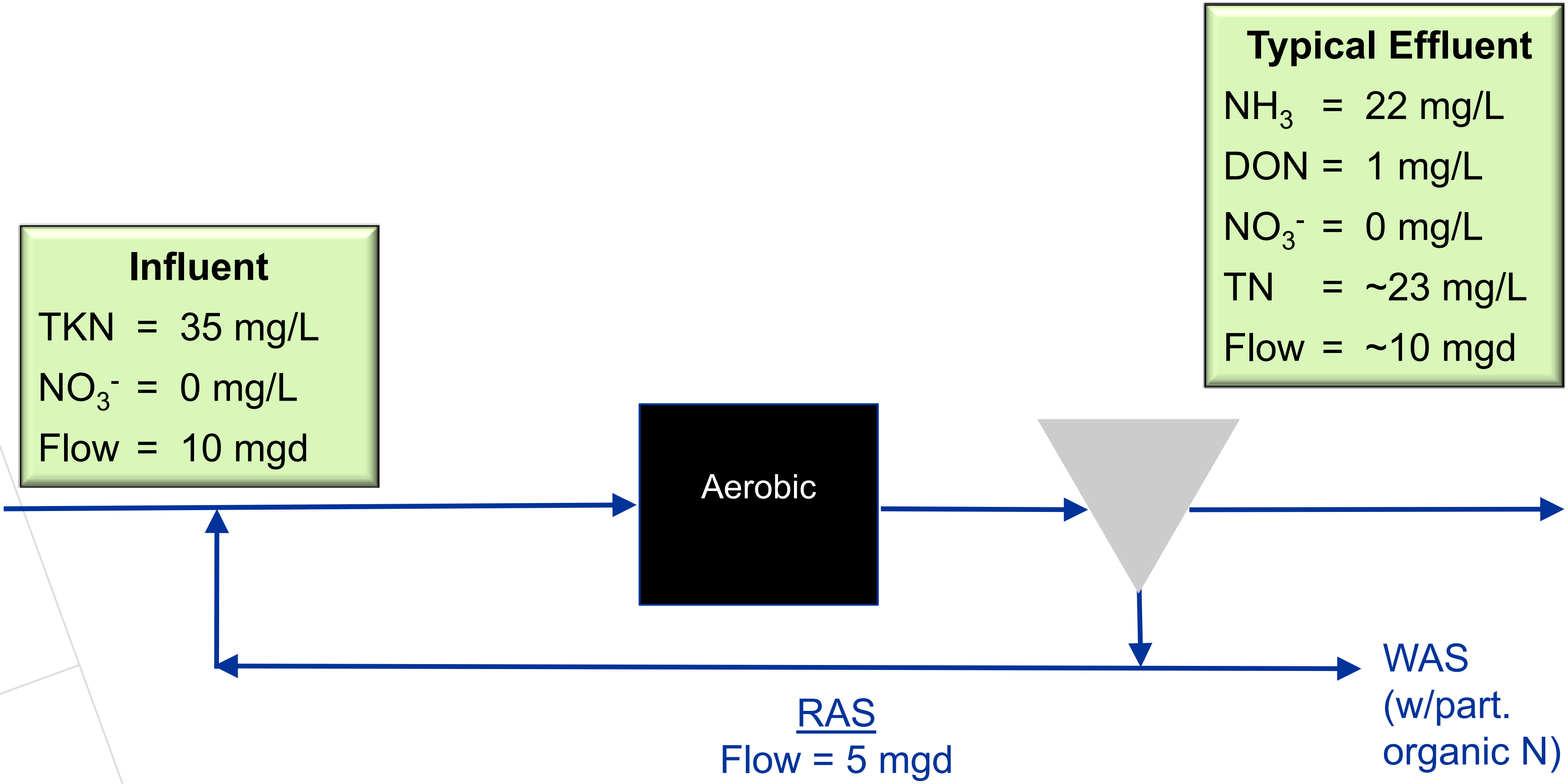
Denitrification

- Conversion of nitrate-N to nitrogen gas (N_2)
- Environmental conditions for denitrification:
  - Denitrifying organisms (ordinary heterotrophs)
  - Carbon needed
  - Low or no oxygen: nitrate-N used as electron acceptor

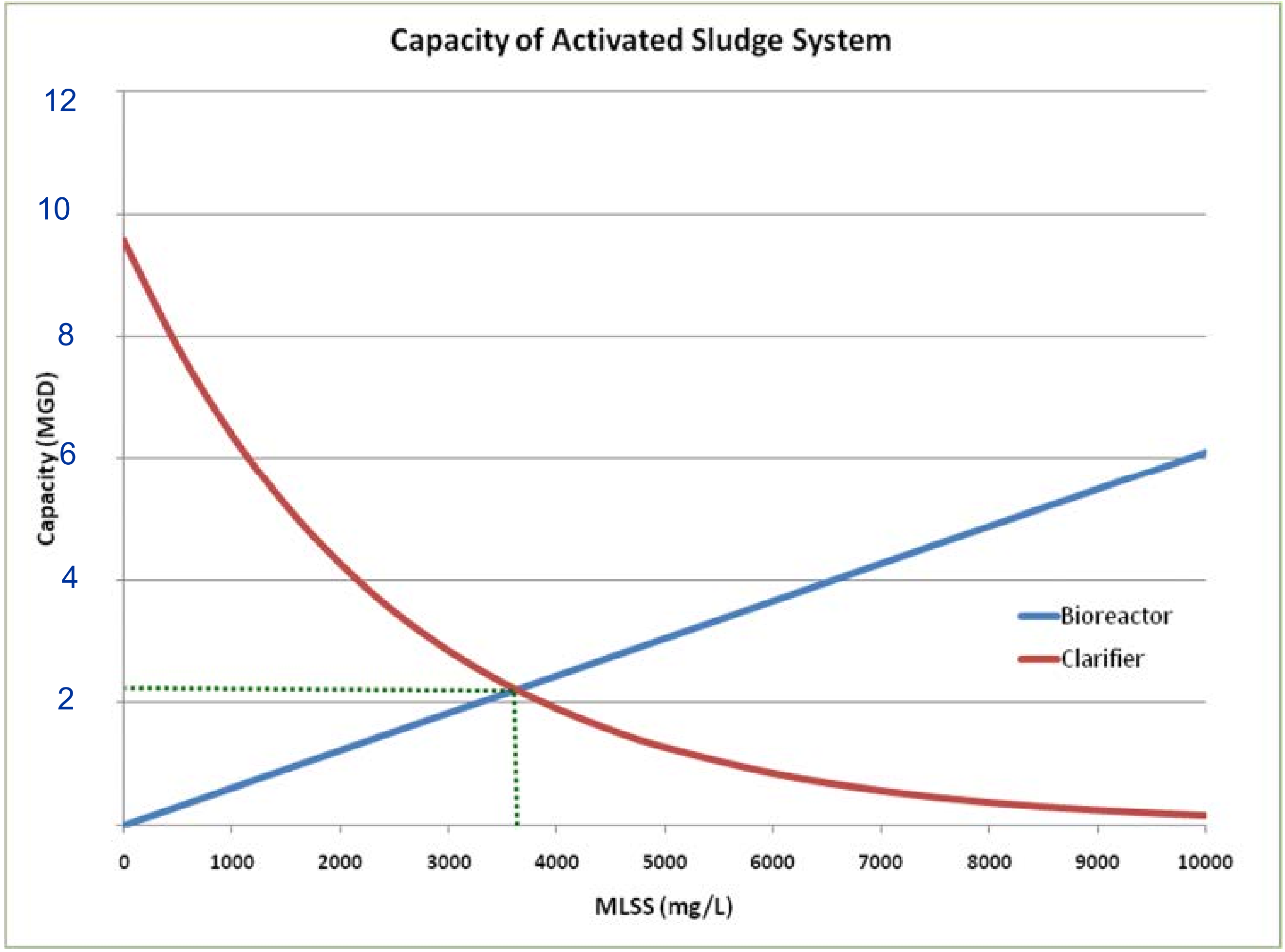


Activated Sludge for Secondary Treatment

- Short aerobic SRT



Activated Sludge Process Capacity at Constant SRT



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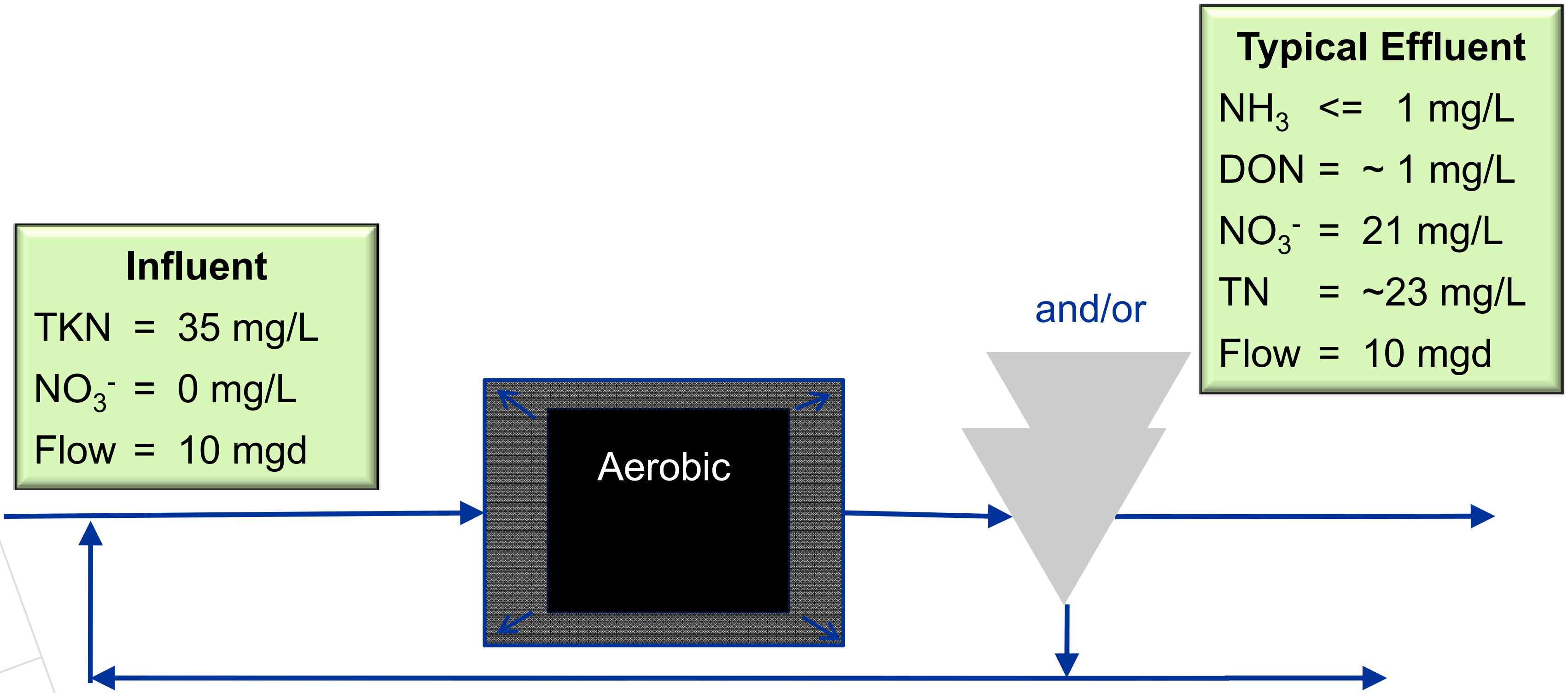
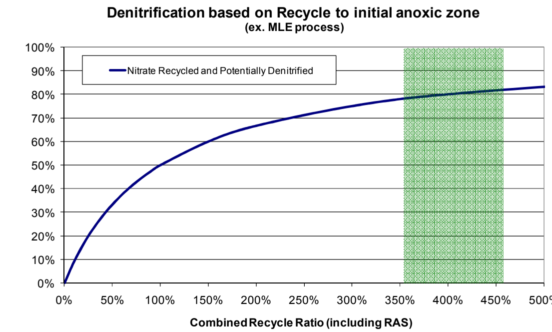
Nitrification
Long SRT (more biomass) Needed



First Tier of TN Removal
Denitrification - MLE



Influent

TKN = 35 mg/L

NO_3^- = 0 mg/L

Flow = 10 mgd

Effluent

NH_3 = 1 mg/L

DON = 1 mg/L

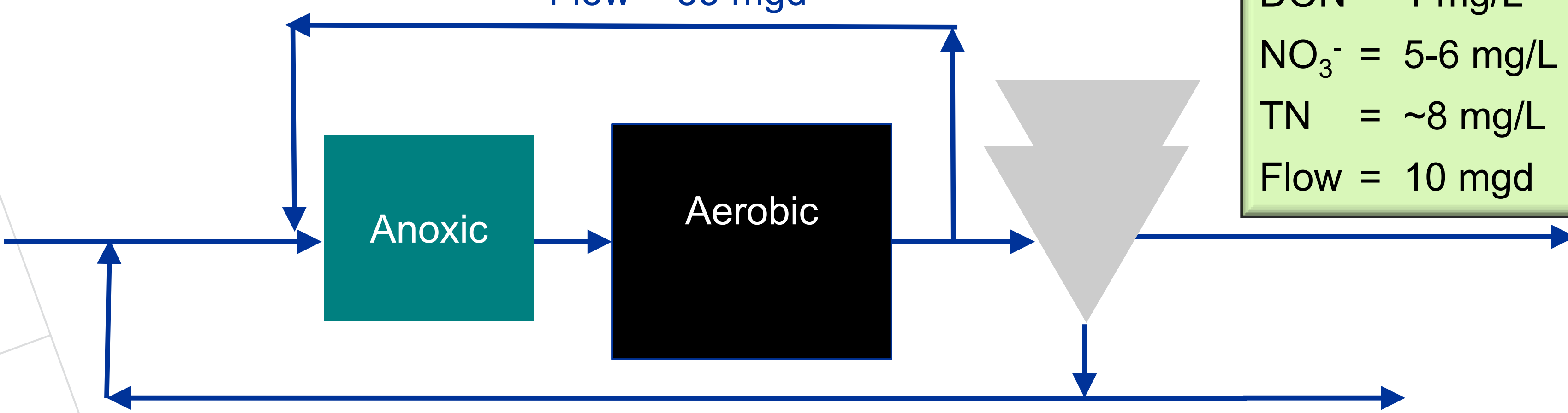
NO_3^- = 5-6 mg/L

TN = ~8 mg/L

Flow = 10 mgd

IR

Flow = 35 mgd



Tier 1 of Nitrogen Removal
Denitrification – Step-Feed

Influent

TKN = 35 mg/L

NO_3^- = 0 mg/L

Flow = 10 mgd

Effluent

NH_3 = 1 mg/L

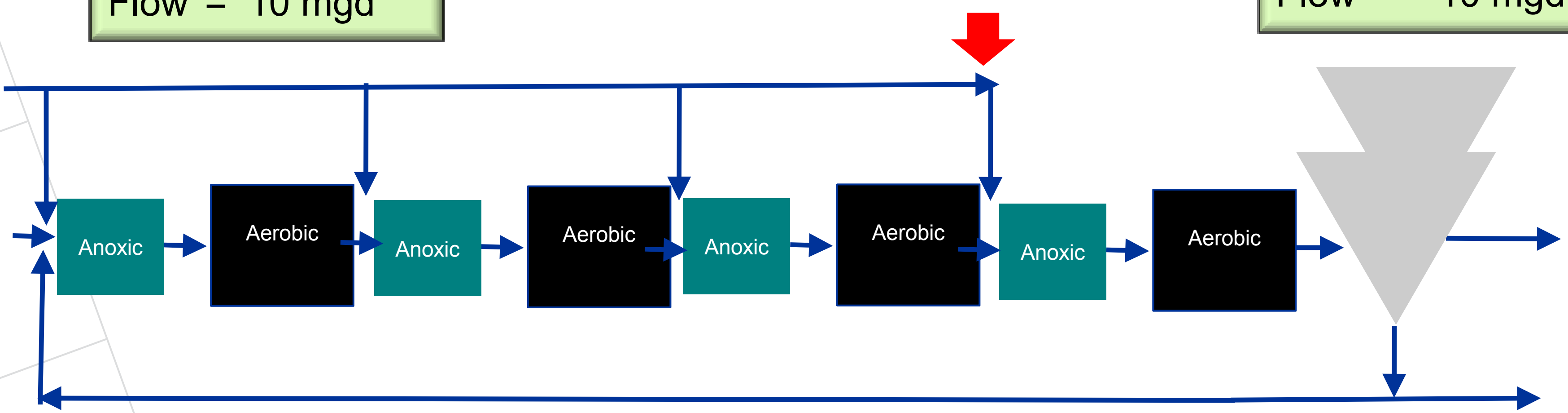
DON = 1 mg/L

NO_3^- = 4-5 mg/L

TN = ~8 mg/L

Flow = ~10 mgd

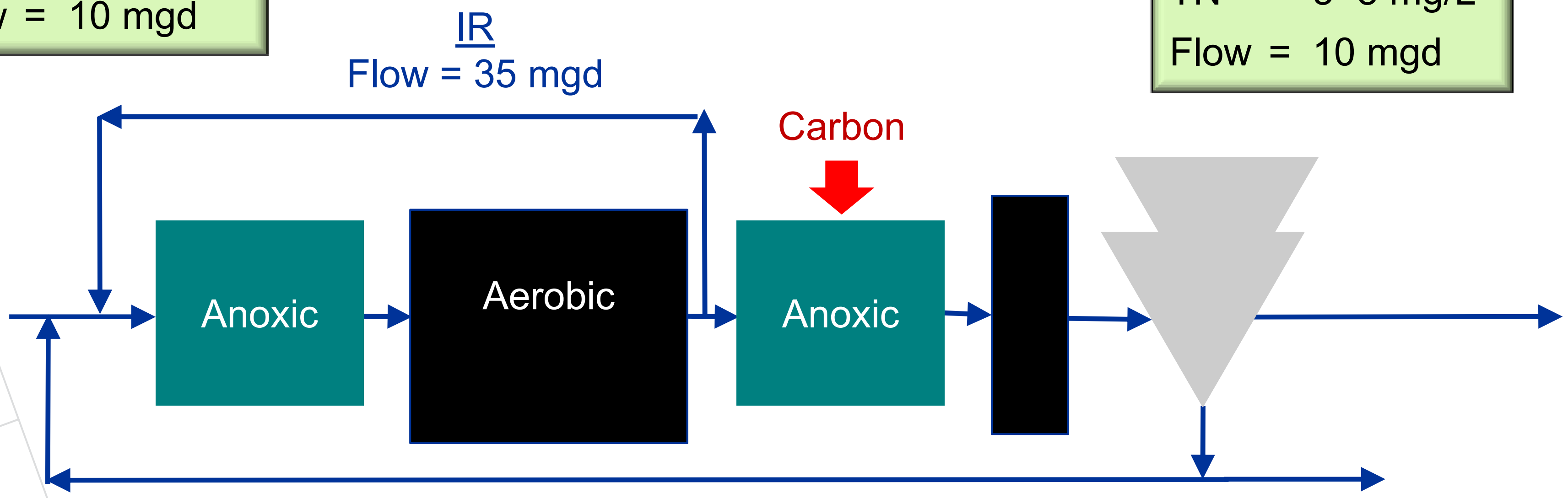
Carbon?



Tier 2 of Nitrogen Removal
4-stage system

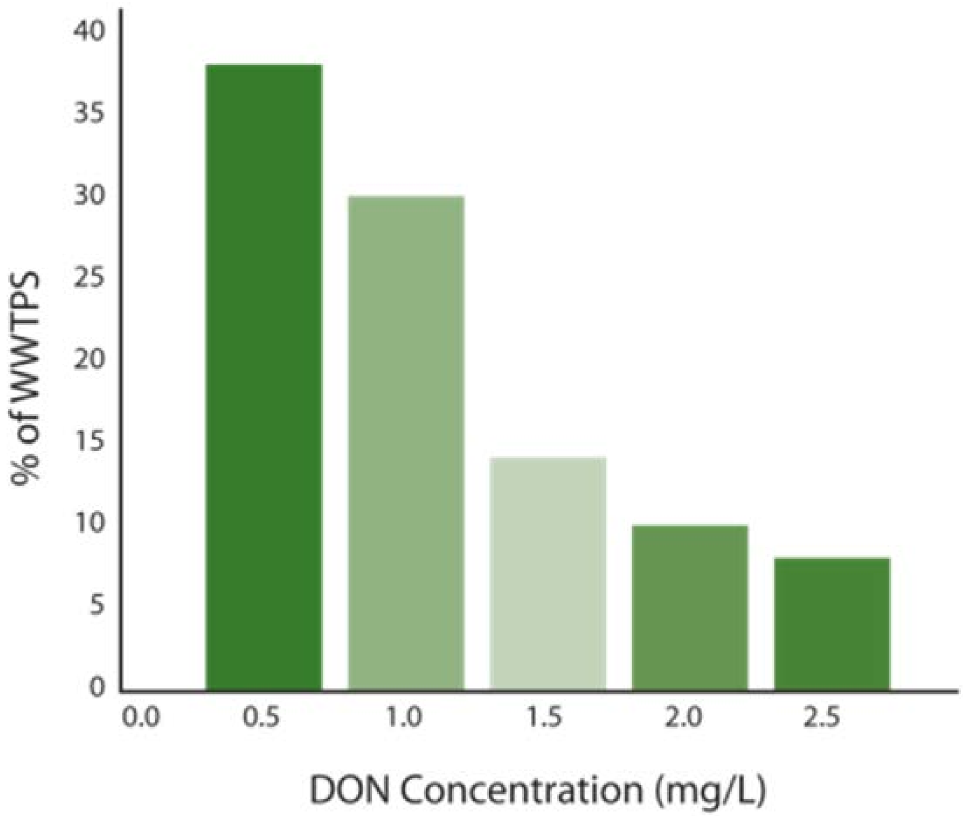
Influent
TKN = 35 mg/L
NO_3^- = 0 mg/L
Flow = 10 mgd

Typical Effluent
NH_3 = 1 mg/L
DON = 1 mg/L
NO_3^- = 1 mg/L
TN = 3~5 mg/L
Flow = 10 mgd



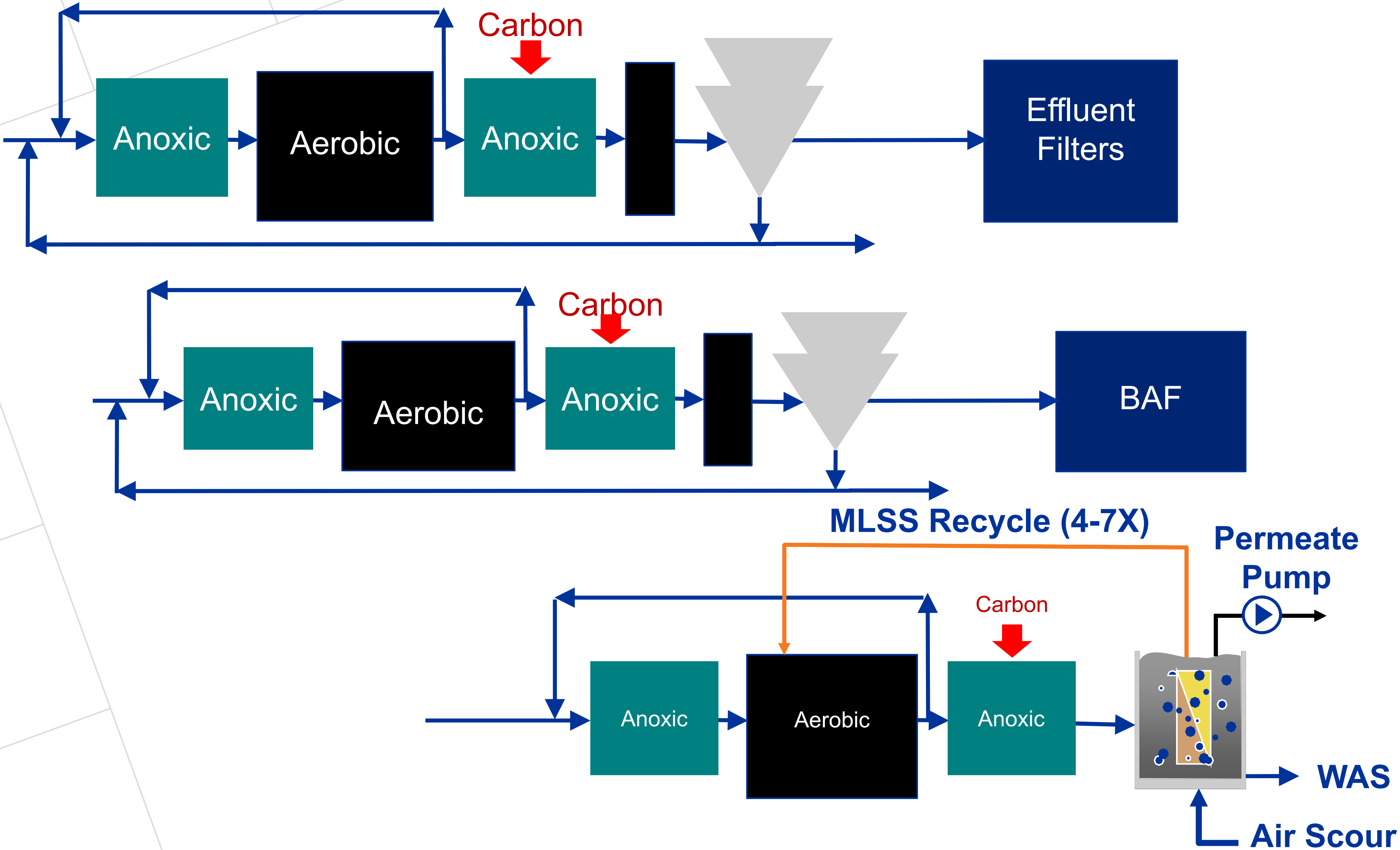
Tier 3 Process Considerations: Effluent rDON

- Effluent DON = TKN not converted to ammonia in biological WW treatment process
- Some may be slowly biodegradable “recalcitrant” or “refractory” (rDON)
- Some produced in process



Summary of effluent dissolved organic nitrogen (DON) concentration (0.45 µm filtration) from 188 Maryland and Virginia wastewater treatment plants (Pagilla, 2007)

Tier 3 Nitrogen Removal Activated Sludge Options

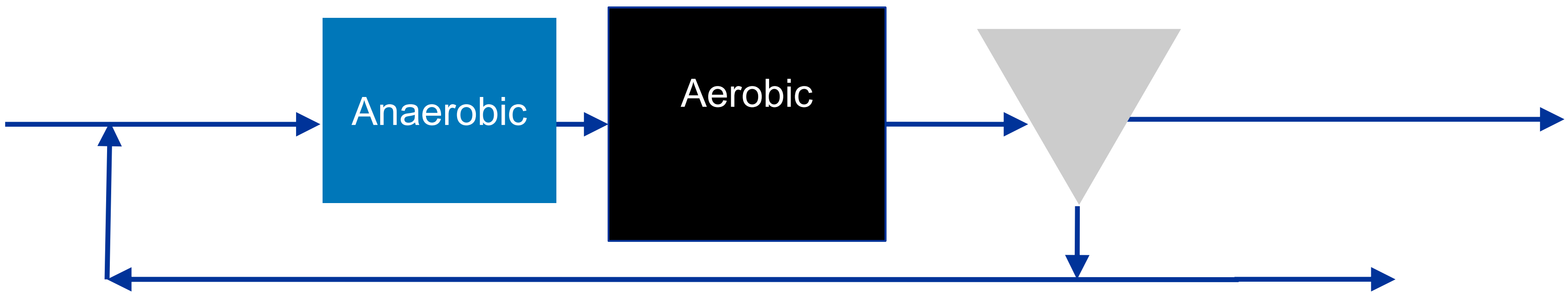


Enhanced Biological Phosphorus Removal (EBPR)

Tiers of Treatment – Effluent Total Phosphorus

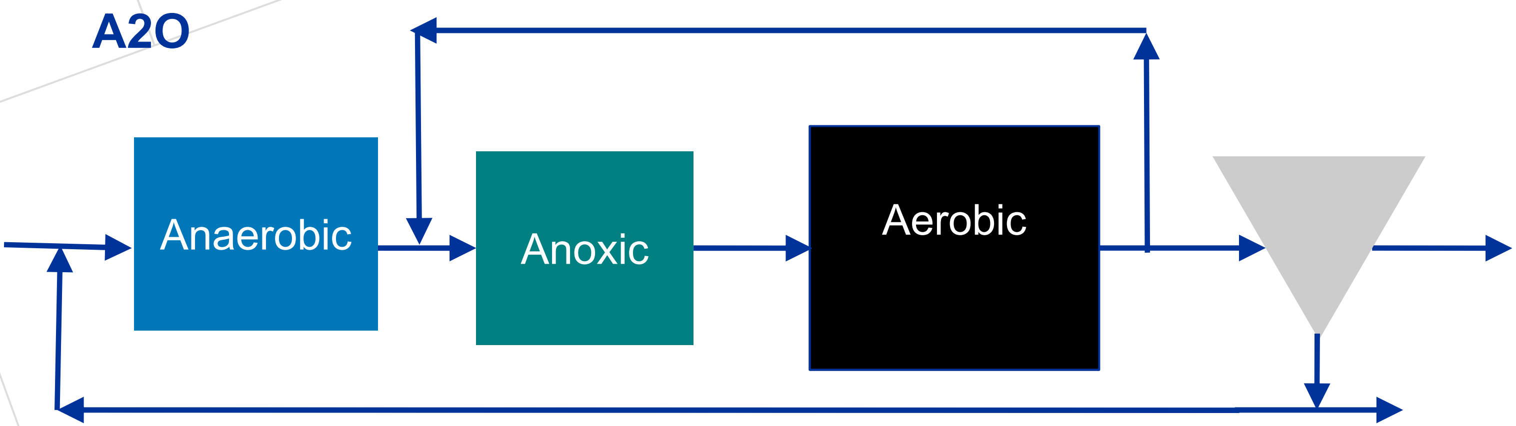
- Tiers of Treatment
  - 1 mg/L – Readily do-able with EBPR (when environmental conditions are right)
  - 0.2 mg/L – Typically requires chemical addition and effluent polishing
  - 0.1 mg/L – Chemical addition and advanced tertiary treatment
- EBPR: Conversion of soluble P into a solid form and removal of the solid
- Environmental conditions for EBPR:
  - Anaerobic and aerobic phases
  - Volatile Fatty Acids (VFAs) – carbon source in influent
  - Factors that favor Phosphorus Accumulating Organisms (PAOs)

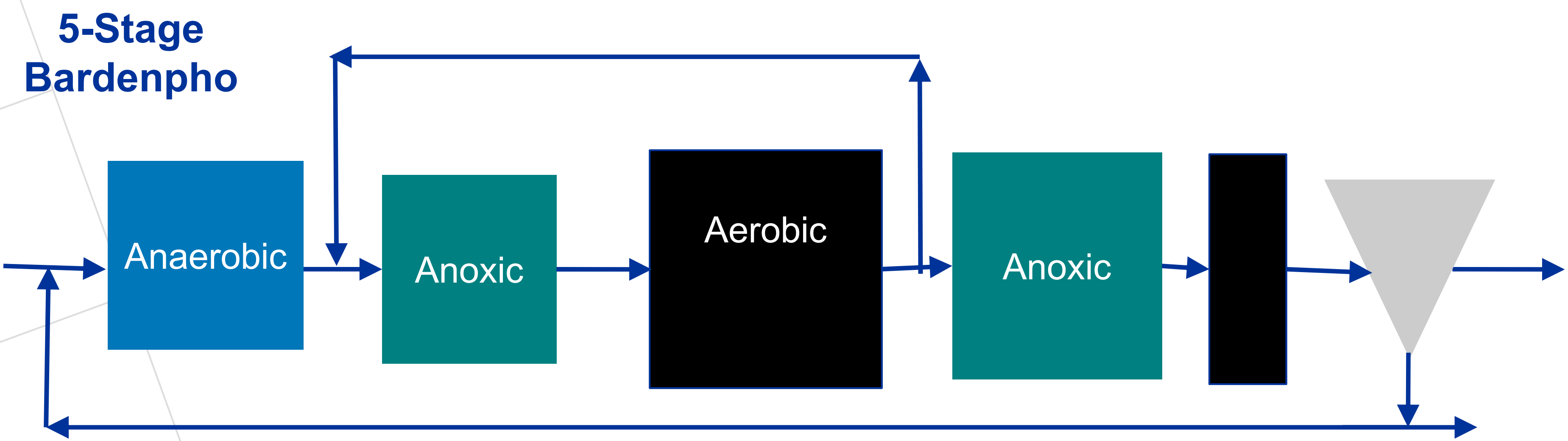
Enhanced Biological Phosphorus Removal with A/O to 0.5 – 0.75 mg/L TP



Combined Nitrogen and EBPR

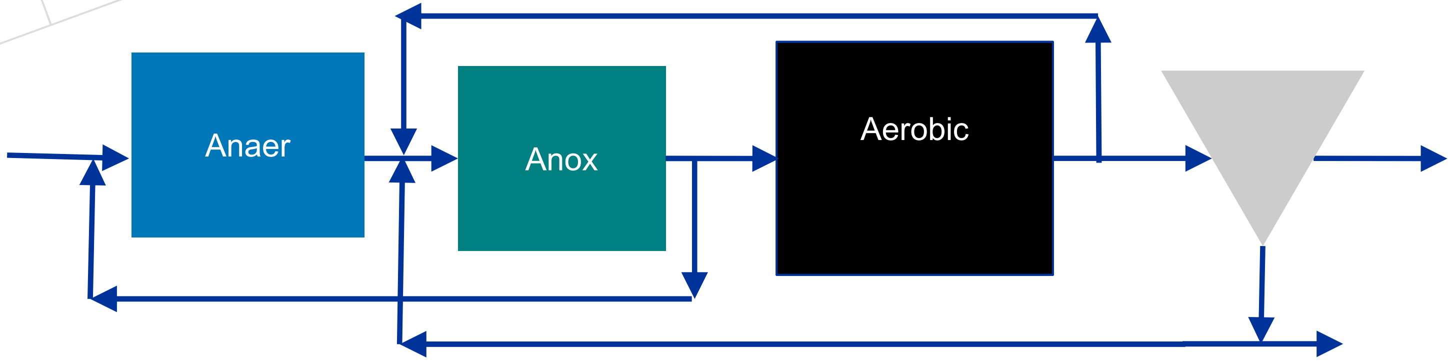
Configurations for both TN and TP Removal



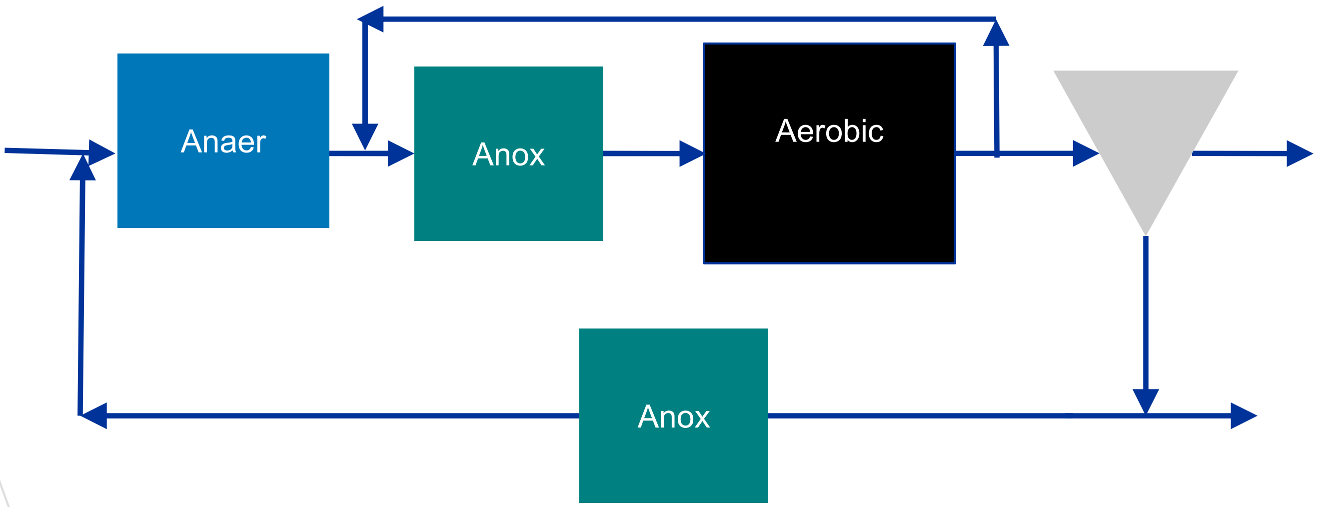


Configurations for both TN and TP Removal

UCT

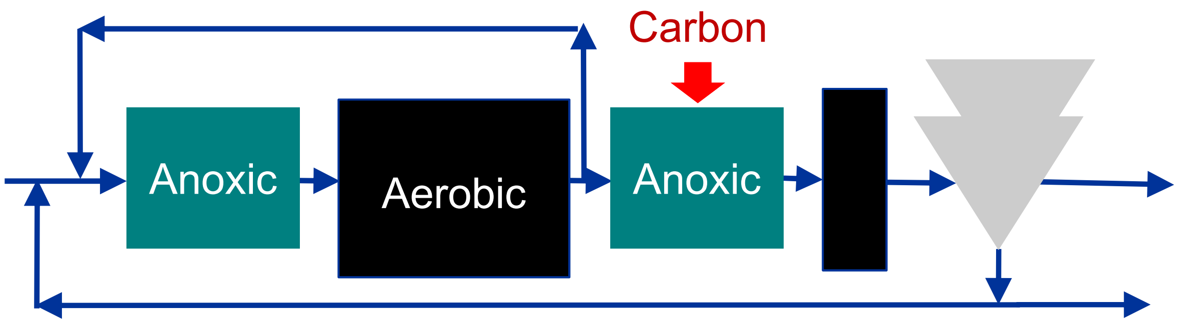


Johannesburg Process

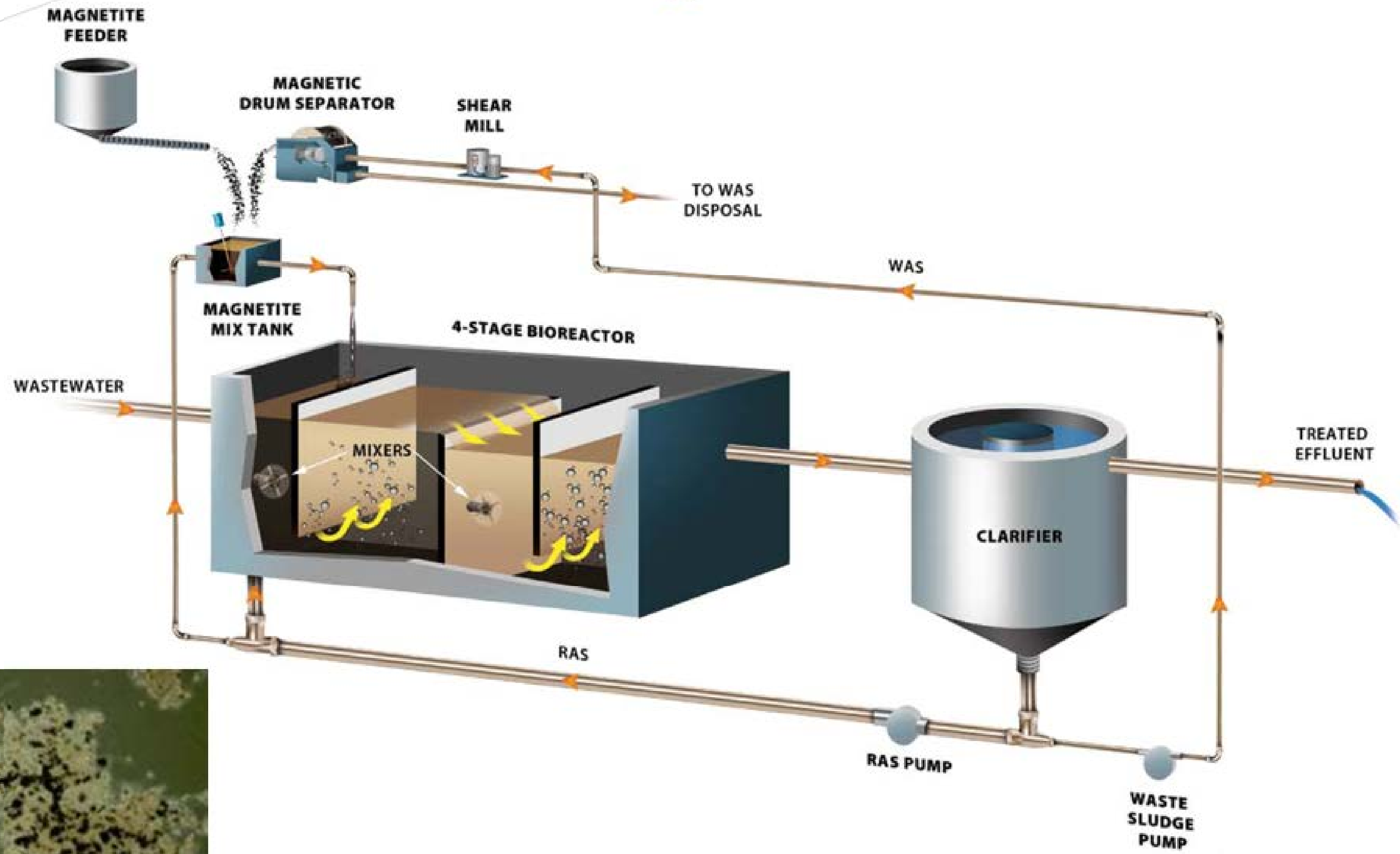


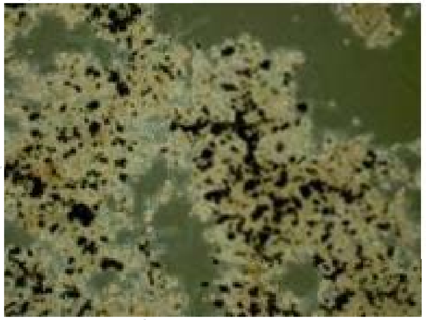
Innovative Approaches

Integrated Fixed-Film Activated Sludge (IFAS)



Suspended Growth Options/Variations
BioMag





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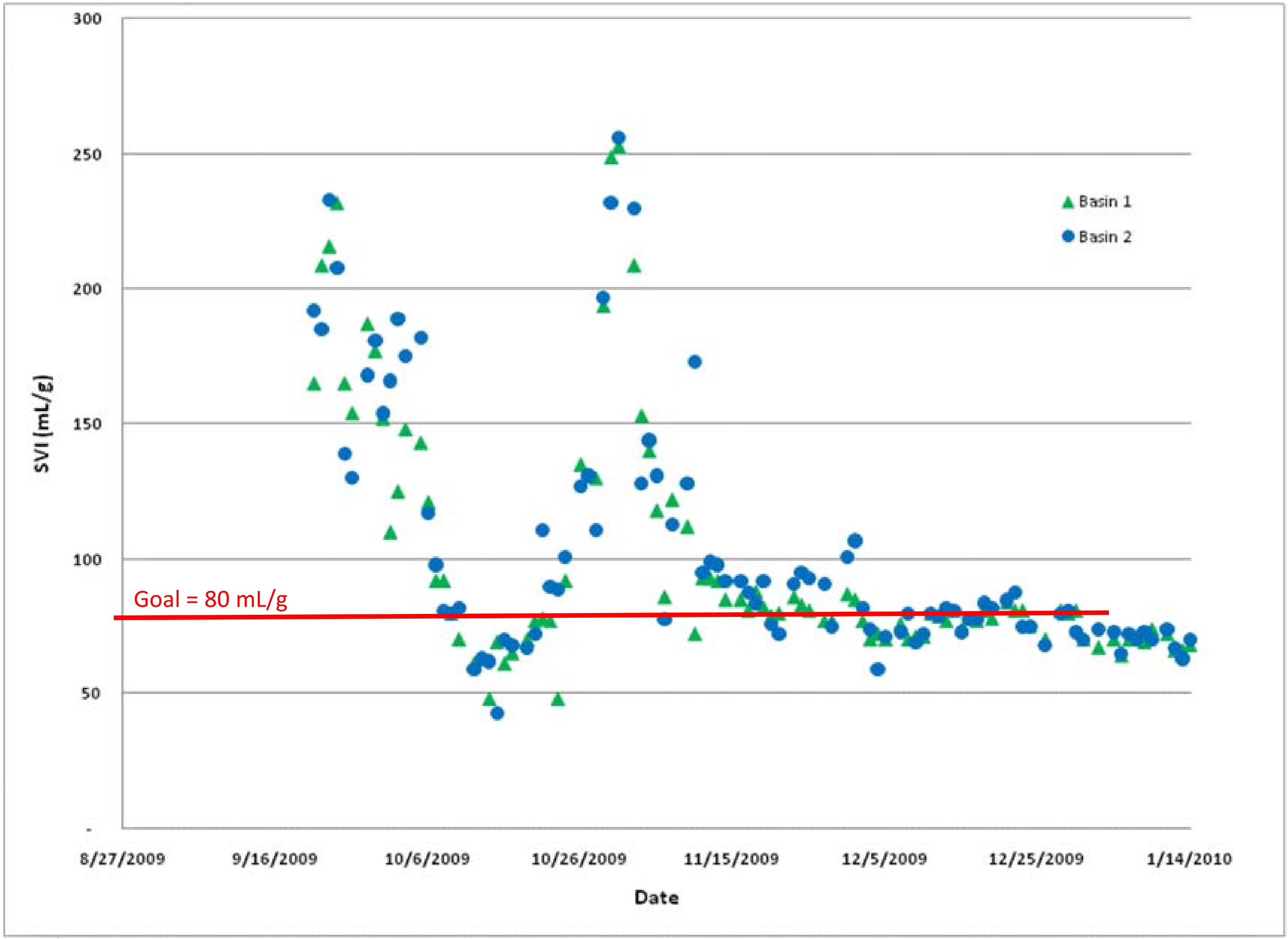
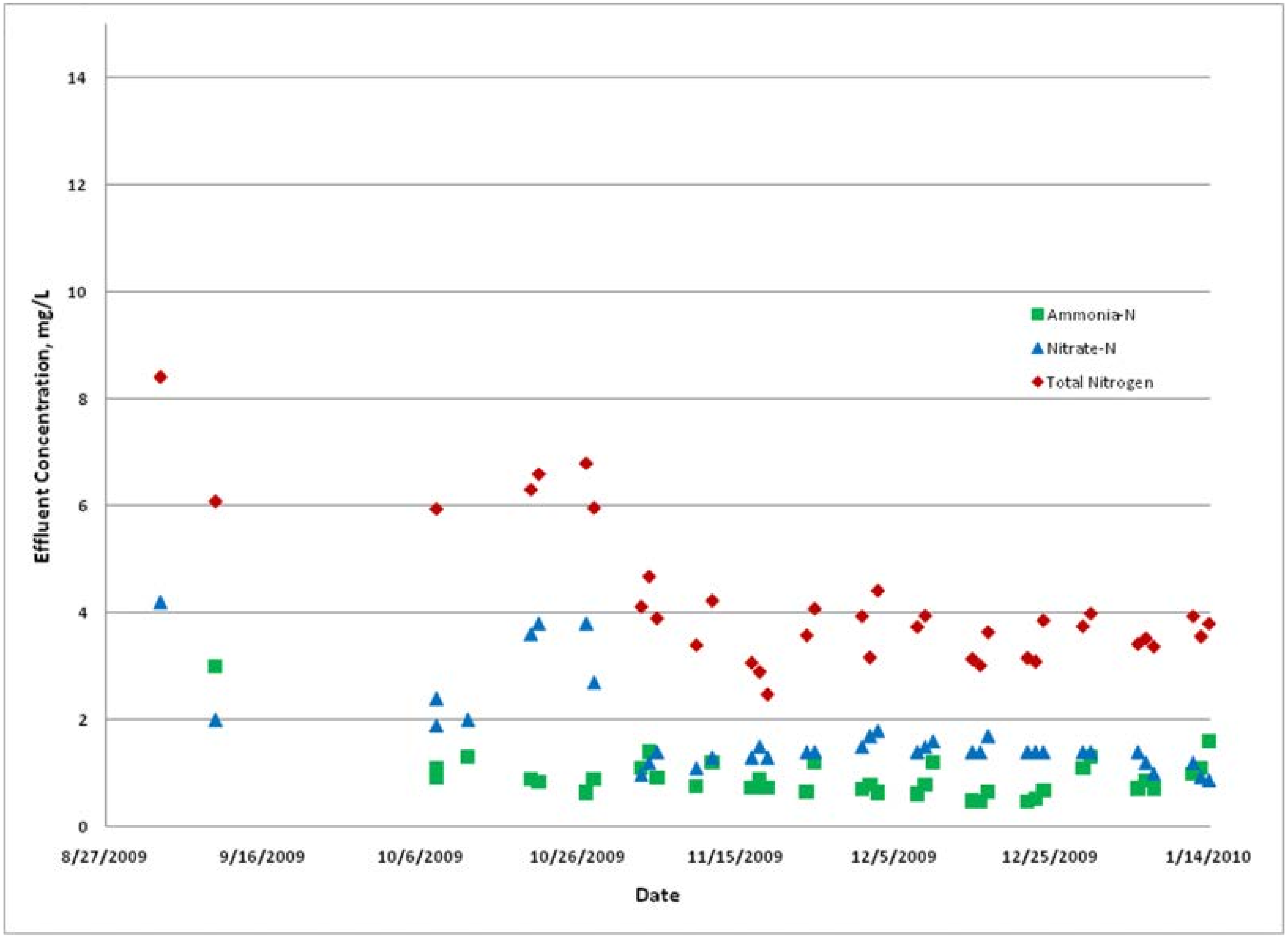
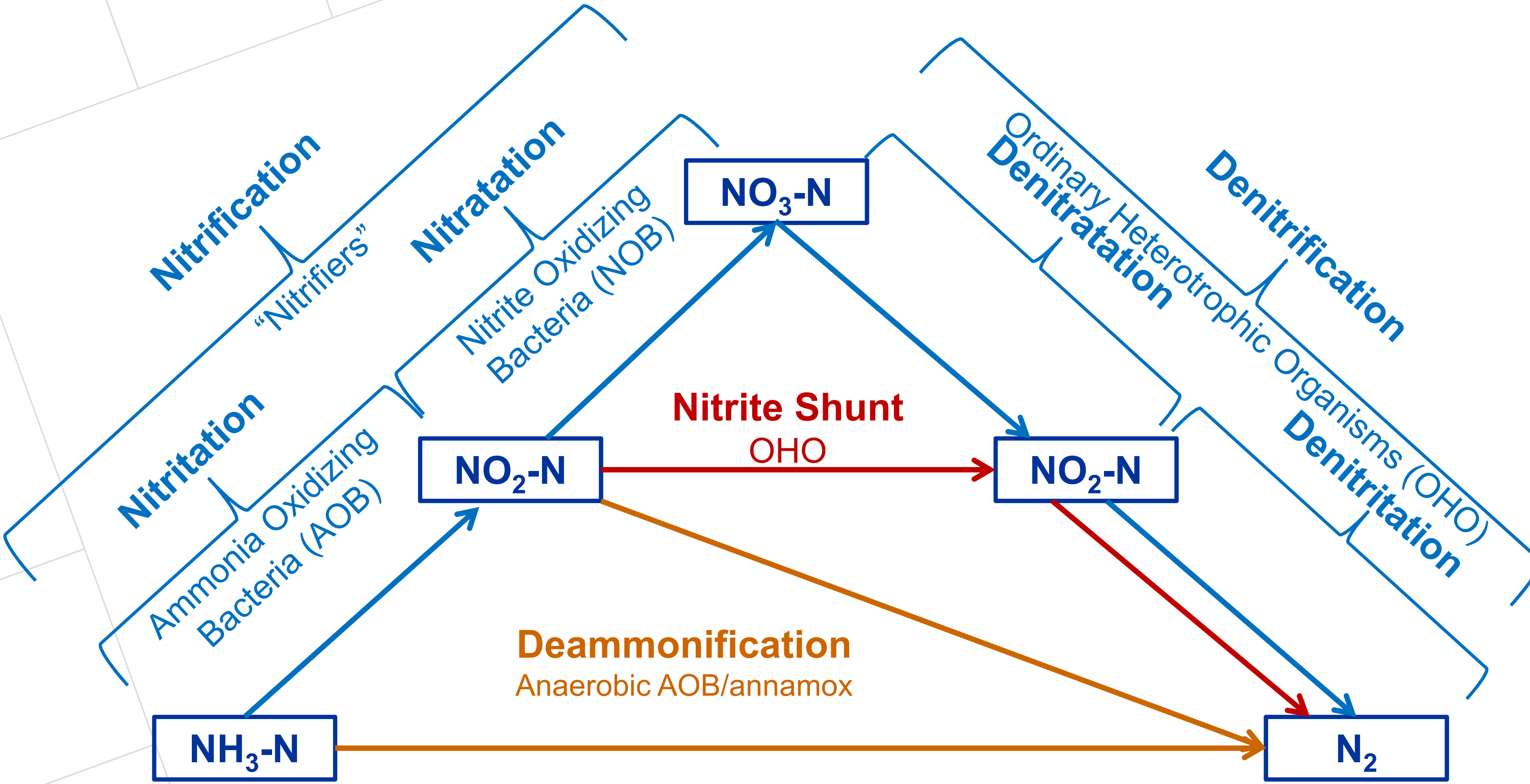
Biomass Settleability – SVI Variation



Effluent Total Nitrogen



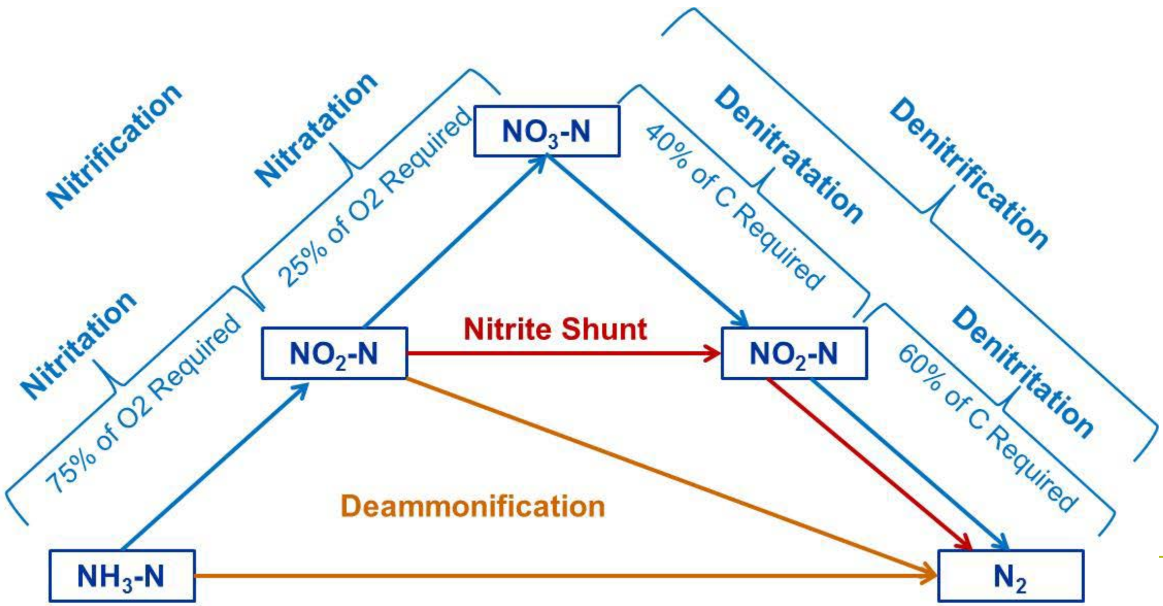
The Future of BNR (nitrogen)



Reference: Based on Stinson, et. al. 2013

Benefits of Nitrite Shunt and Deammonification

- Nitrite Shunt
  - 25 percent reduction in oxygen required
  - 40 percent reduction in carbon demand
  - Reduction in sludge production
- Deammonification
  - 63 percent reduction in oxygen required
  - 90 percent reduction in carbon demand
  - Reduction in sludge production



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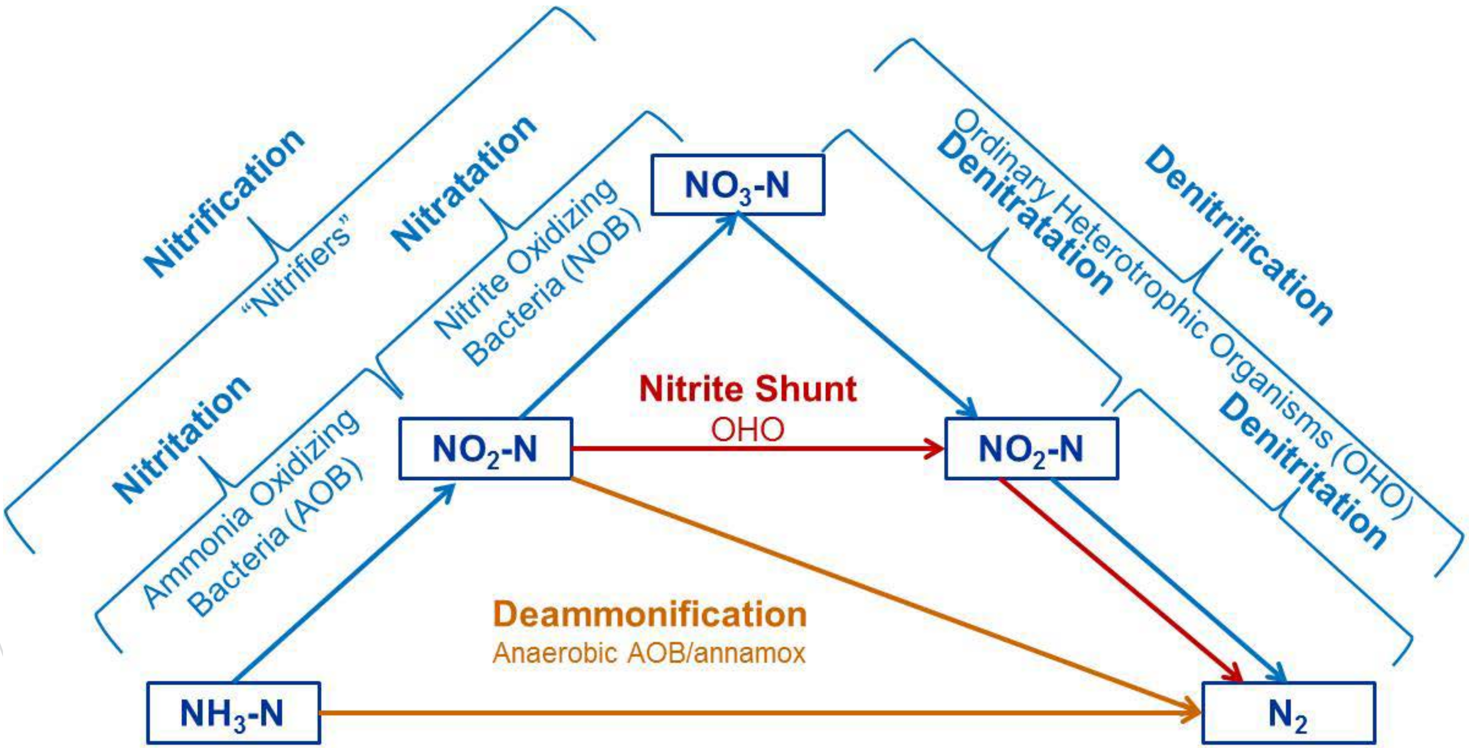
Challenges to Achieving Mainstream Nitrite Shunt and Deammonification

- Low nitrogen concentrations
- Low temperatures
- Providing the right carbon: nitrogen ratio



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Questions?

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