DEAMMONIFICATION PROCESS
Energetic Requirements

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Background

Constraint of two opposing objectives:

- Increasingly stringent standards for nutrient removal
- Desire for energy self sufficient WWTP (anaerobic digestion)

Digested supernatant namely centrate or filtrate is:

- Contributes to up to 25% of TN load in the secondary treatment but only represents 2% of the plant total hydraulic load.
- Highly N-concentrated up to 1,200 mg/l
- Unfavorable COD:N ratio for heterotrophic denitrification

Impact of side stream

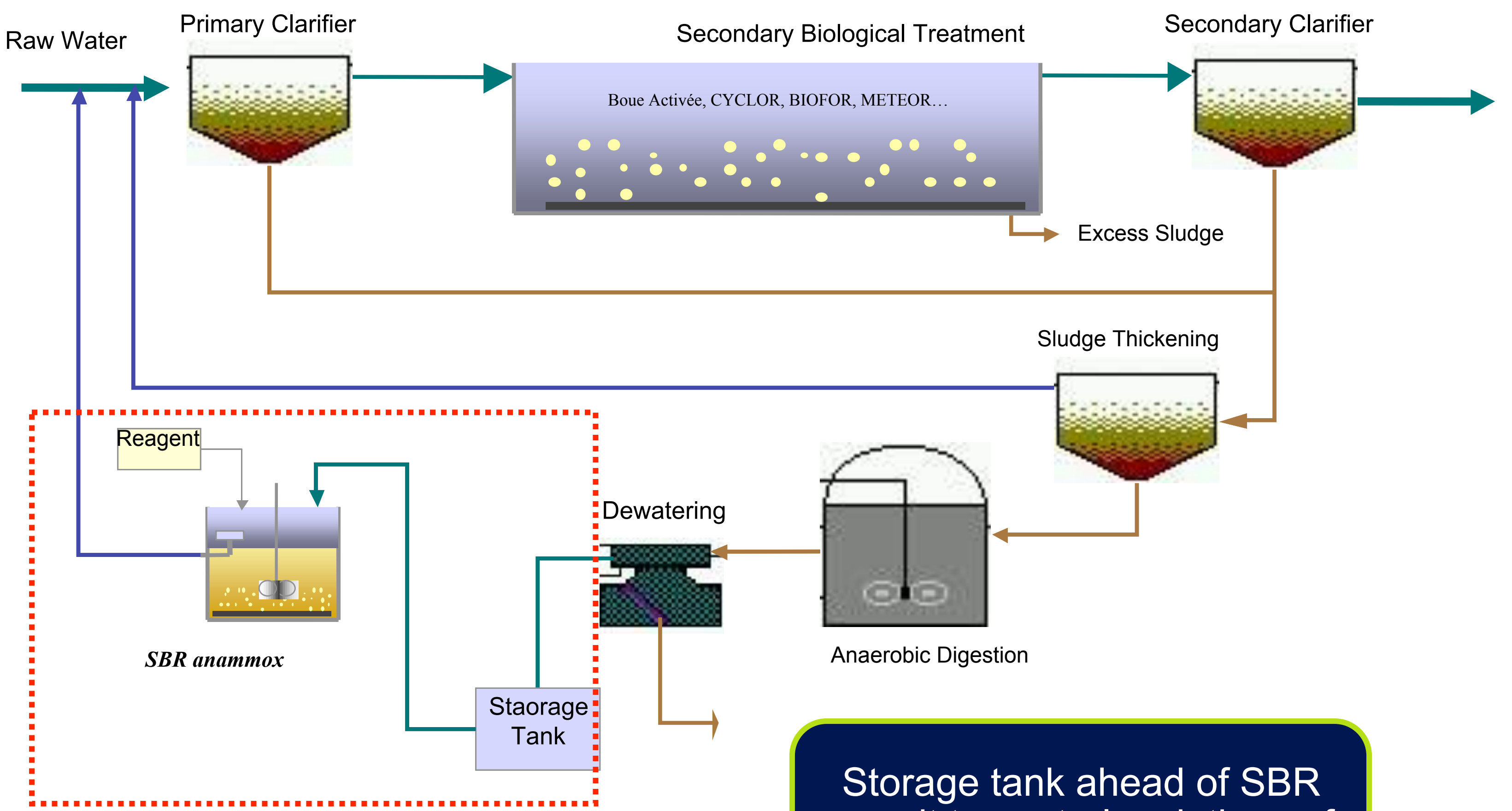
Consequence:

- Additional volume of aeration and endogenous tanks for the main treatment line
- Increased oxygen (nitrification) and external carbon source needs (denitrification)
- Risk of non-compliance with effluent standards.

Solution:

- Separate the sidestreams treatment of N-concentrated from main streams treatment.
- Cleargreen™ deammonification process reduces treatment electrical requirement.
- High temperature → favorable for slow growing bacteria like anammox.

Where does Side Stream Deammonification fit?



Storage tank ahead of SBR permit to control variations of ammonia-N load and TSS

What is SBR anammox process?

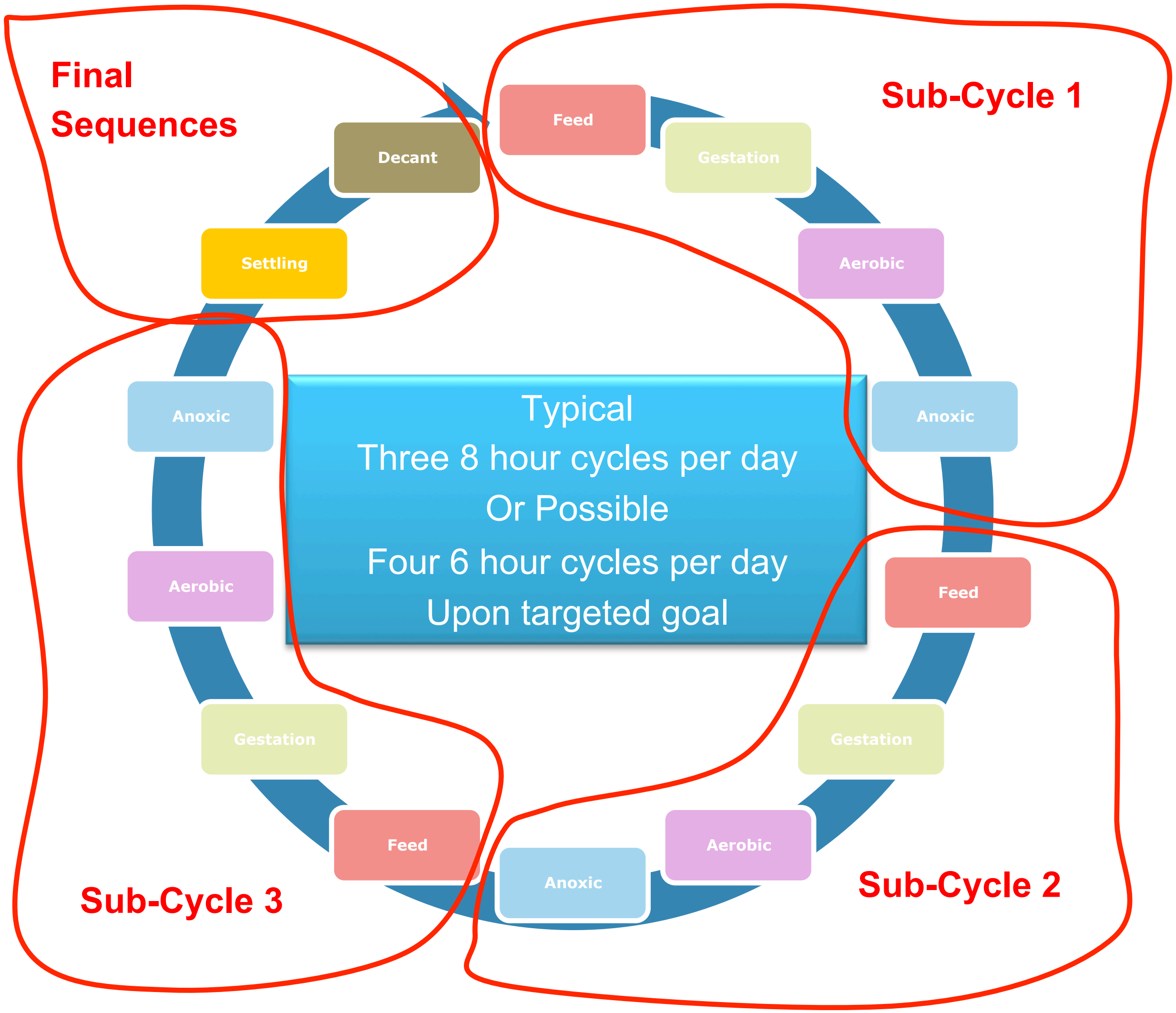
Cyclic

Low

Energy

Ammonia

Removal



What are SBR anammox process advantages?

Cyclic

Low

Energy

Ammonia

Removal

- ✓ More than 50% less oxygen demand: aeration energy savings
- ✓ 0% external carbon demand: chemicals cost savings
- ✓ 25 to 30% less sludge production
- ✓ 20 to 40% reduction in biological treatment volumes

What are SBR anammox biological reactions?

Cyclic

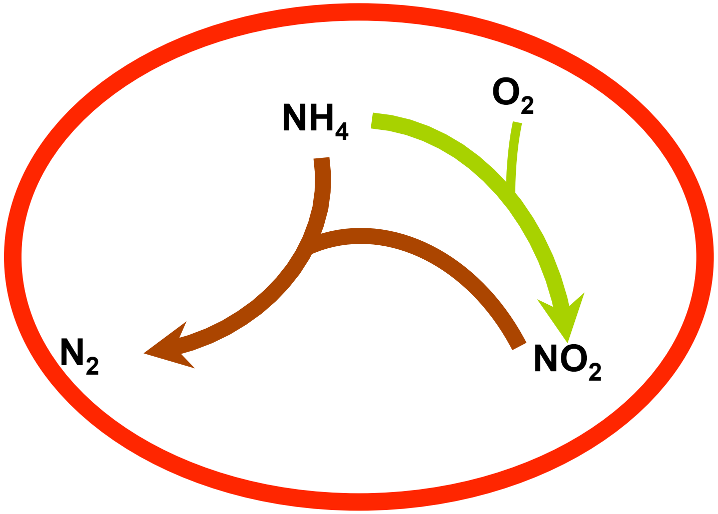
L ow

Energy

Ammonia

Removal

- ✓ Partial Nitritation
- ✓ Anaerobic Ammonium Oxidation (Anammox)
- ✓ Together = Deammonification



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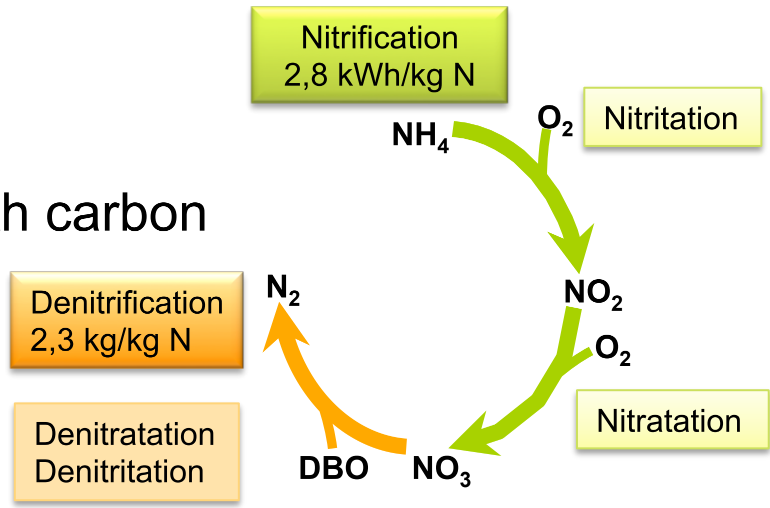
Conventional nitrogen treatment energy requirements

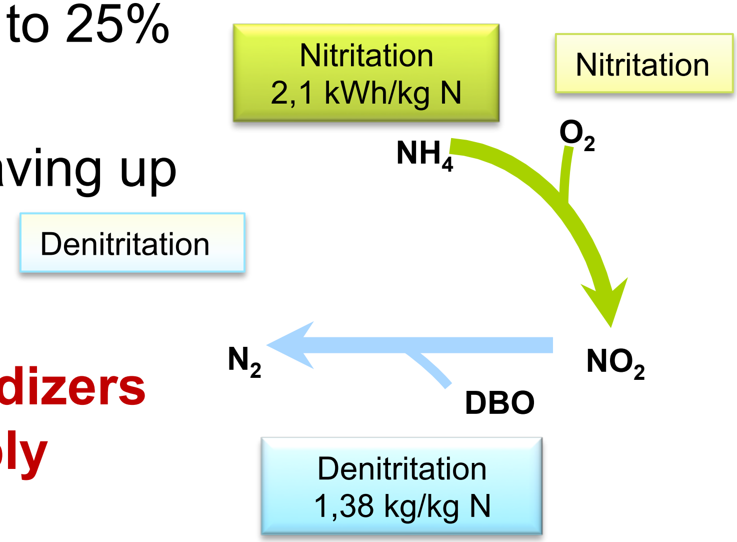
Conventional nitrogen treatment:

- Oxidation of ammonia to nitrate
- Denitrification of nitrate to nitrogen gas, with carbon supply



Nitrogen Shunt:

- Industrialized in early 2000
- Oxidation of ammonia to nitrite, saving up to 25% in oxygen requirement,
- Denitrification of nitrite to nitrogen gas, saving up to 40% in carbon supply



Process designed to out select nitrite oxidizers (NOB) with temperature and oxygen supply limitation controls

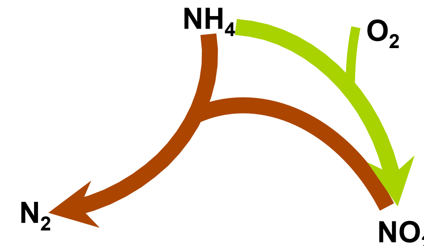
Deammonification theoretical energy requirements

Deammonification:

- 50-60% of ammonia oxidized to nitrite
- Nitrogen gas formation by reaction of residual ammonia and nitrite throughout anammox reaction

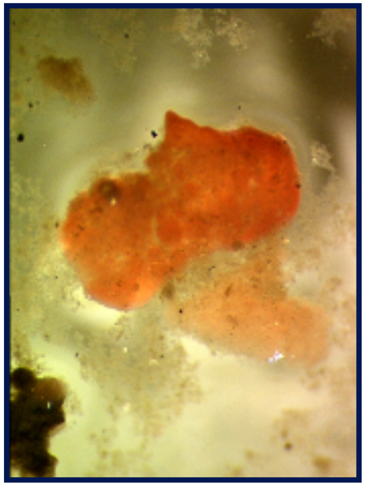
Deammonification
1.3 kWh/ kg-N

$$NH_3 + 1.32\ NO_2 + H^+ \rightarrow 1.02\ N_2 + 0.26\ NO_3 + 2H_2O$$



- Process designed to out compete nitrite oxidizers (NOB) and to develop slow growing bacteria for deammonification (AnAOB)
- Processes such as
  - CANON (Sharon-Anammox)
  - DEMON
  - OLAND (LabMet – University of Gent)

  developed in early 2000s with specific sludge inoculation for start-up (from 20 to 50% of the sludge)



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Deammonification real energy requirements

Energy Requirements Depend on Centrate Characteristics:

- Ammonia-N concentration can varies from 700 mg/l up to 1,200 mg/l
- Alkalinity
- Micronutrients
- Biodegradable organic matter → N to COD ratio

Treatment Achievements Requirement:

- Centrate Availability (When centrate production is limited, it requires storage and to maintain centrate temperature)
- Total Inorganic Nitrogen Removal

Case Study # 1

Henrico, VA

Centrate Characteristics:

Parameter	Units	Average
COD	g/m^3	967
TKN	$g\text{-}N/m^3$	1026
TP	$g\text{-}P/m^3$	133
TSS	g/m^3	530
VSS	g/m^3	374
Alkalinity	$g\text{-}CaCO_3/m^3$	3302
pH	s.u.	7.7
Temperature	°C	33

Influent Characteristics:

Parameter	Units	Ave. (Min.; Max)
sCOD	g/m^3	367 (75; 3292)
TKN	$g\text{-}N/m^3$	346 (125; 820)
TP	$g\text{-}P/m^3$	36 (13; 220)
TSS	g/m^3	257 (95; 5550)
VSS	g/m^3	181 (85; 3750)
Alkalinity	$g\text{-}CaCO_3/m^3$	1613 (690; 3960)
MLSS	g/m^3	4470 (1150; 112000)
MLVSS	g/m^3	3038 (930; 7800)

In-situ Bacteriologic Activities		
AerAOB	AnAOB	OHO
mg NH3-N/g VSS/ hour	mg N/g VSS	mg NOx-N/g VSS
9.4	10.2	1.6
Calculated from onsite data analysis (1 sub-cycle)		

Reactions Time per Cycle	
Aerobic Duration	Anoxic Duration
Minutes	Minutes
41	49

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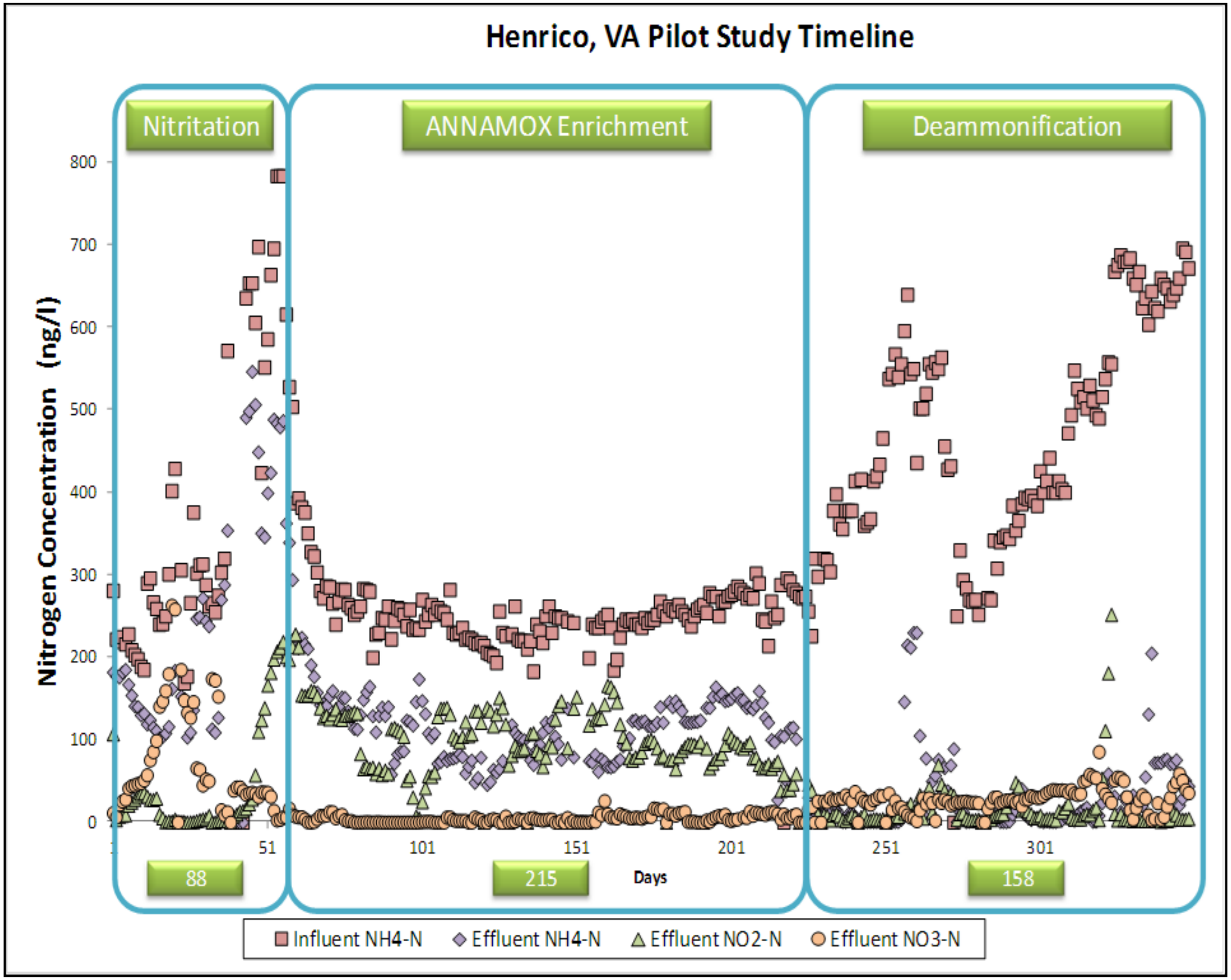
Case Study # 1 Henrico, VA



Process Performances:

- No anammox seeding
- 0.52 kg NH3-N/m³/day
- Ammonia-N Removal 96 %
- TIN Removal 86 %
- C/N ratio averaged at0.3 during the deammonification period

Because of centrate low C/N ratio the nitrate produced from the anammox reaction started to accumulate in SBR (orange dot).

AerAOB/aeration → 20.2 mg/l

AnAOB/anoxic → 7.1 mg N/l

OHO/anoxic → 2.7 mg Nox/l

Case Study # 2

Hyperion Los Angeles, CA

Centrate Characteristics:

Parameter	Units	Average
tCOD	g/m^3	1359
TKN	$g\text{-}N/m^3$	675
TP	$g\text{-}P/m^3$	46
TSS	g/m^3	457
VSS	g/m^3	386
Alkalinity	$g\text{-}CaCO_3/m^3$	2838
pH	s.u.	7.7
Temperature	°C	29.4

Influent Characteristics:

Parameter	Units	Ave. (Min.; Max)
sCOD	g/m^3	1359 (784; 3635)
TKN	$g\text{-}N/m^3$	675 (211; 1170)
TP	$g\text{-}P/m^3$	46 (17; 183)
TSS	g/m^3	457 (67; 2450)
VSS	g/m^3	386 (115; 1850)
Alkalinity	$g\text{-}CaCO_3/m^3$	2838 (800; 4200)
MLSS	g/m^3	3761 (1420; 7300)
MLVSS	g/m^3	3359 (1350; 5800)

In-situ Bacteriologic Activities		
AerAOB	AnAOB	OHO
mg NH3-N/g VSS	mg N/g VSS	mg NOx-N/g VSS
15.8	3.37	2.54
Calculated from onsite data analysis (1 sub-cycle)		

Reactions Time per Cycle	
Aerobic Duration	Anoxic Duration
Minutes	Minutes
31	59

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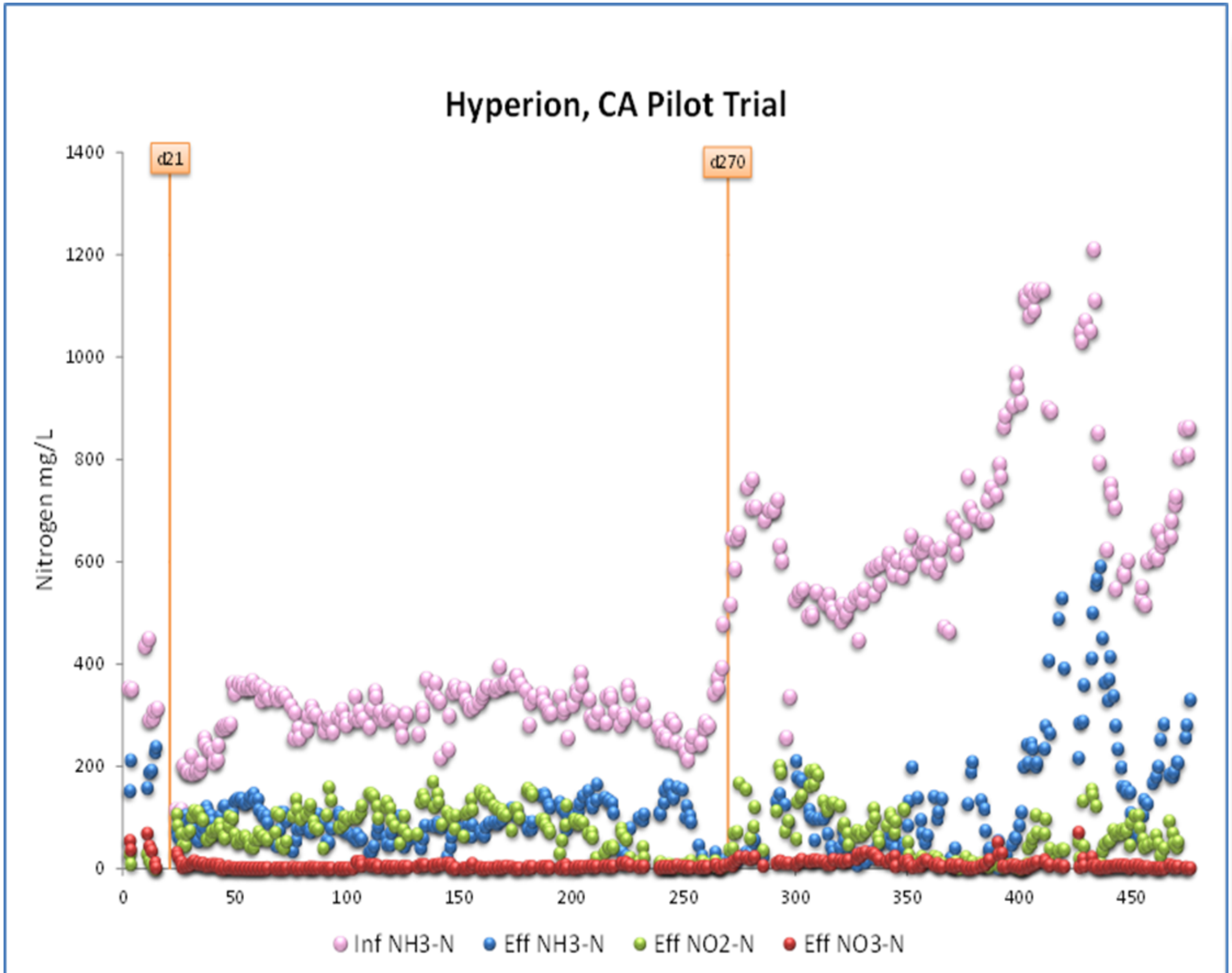
Case Study # 2

Hyperion Los Angeles, CA



Process Performances:

- No anammox seeding
- 0.78 kg NH3-N/m³/day
- Ammonia-N Removal 96 %
- TIN Removal 85 %
- C/N ratio averaged at 2.5 during the deammonification period

Because of centrate high C/N ratio the nitrate produced from the anammox reaction never accumulated in SBR (red dots).

AerAOB/aeration → 15.8 mg/l

AnAOB/anoxic → 12.1 mg N/l

OHO/anoxic → 3.3 mg Nox/l

Case Study # 3

Tri-City, OR

Centrate Characteristics:

Parameter	Units	Average
COD	g/m^3	3960
TKN	$g\text{-}N/m^3$	1360
TP	$g\text{-}P/m^3$	804
TSS	g/m^3	2080
VSS	g/m^3	1640
Alkalinity	$g\text{-}CaCO_3/m^3$	4040
pH	s.u.	7.9
Temperature	°C	16.5

Influent Characteristics:

Parameter	Units	Ave. (Min.; Max)
sCOD	g/m^3	167 (36; 326)
TKN	$g\text{-}N/m^3$	332 (64; 978)
TSS	g/m^3	103 (18; 795)
VSS	g/m^3	84 (12; 590)
Alkalinity	$g\text{-}CaCO_3/m^3$	2150 (1140; 3200)
MLSS	g/m^3	4509 (1500; 6400)
MLVSS	g/m^3	3393 (1000; 3300)

In-situ Bacteriologic Activities		
AerAOB	AnAOB	OHO
mg NH3-N/g VSS	mg N/g VSS	mg NOx-N/g VSS
7.1	5.9	0.8
Calculated from onsite data analysis (1 sub-cycle)		

Reactions Time per Cycle	
Aerobic Duration	Anoxic Duration
Minutes	Minutes
39	51

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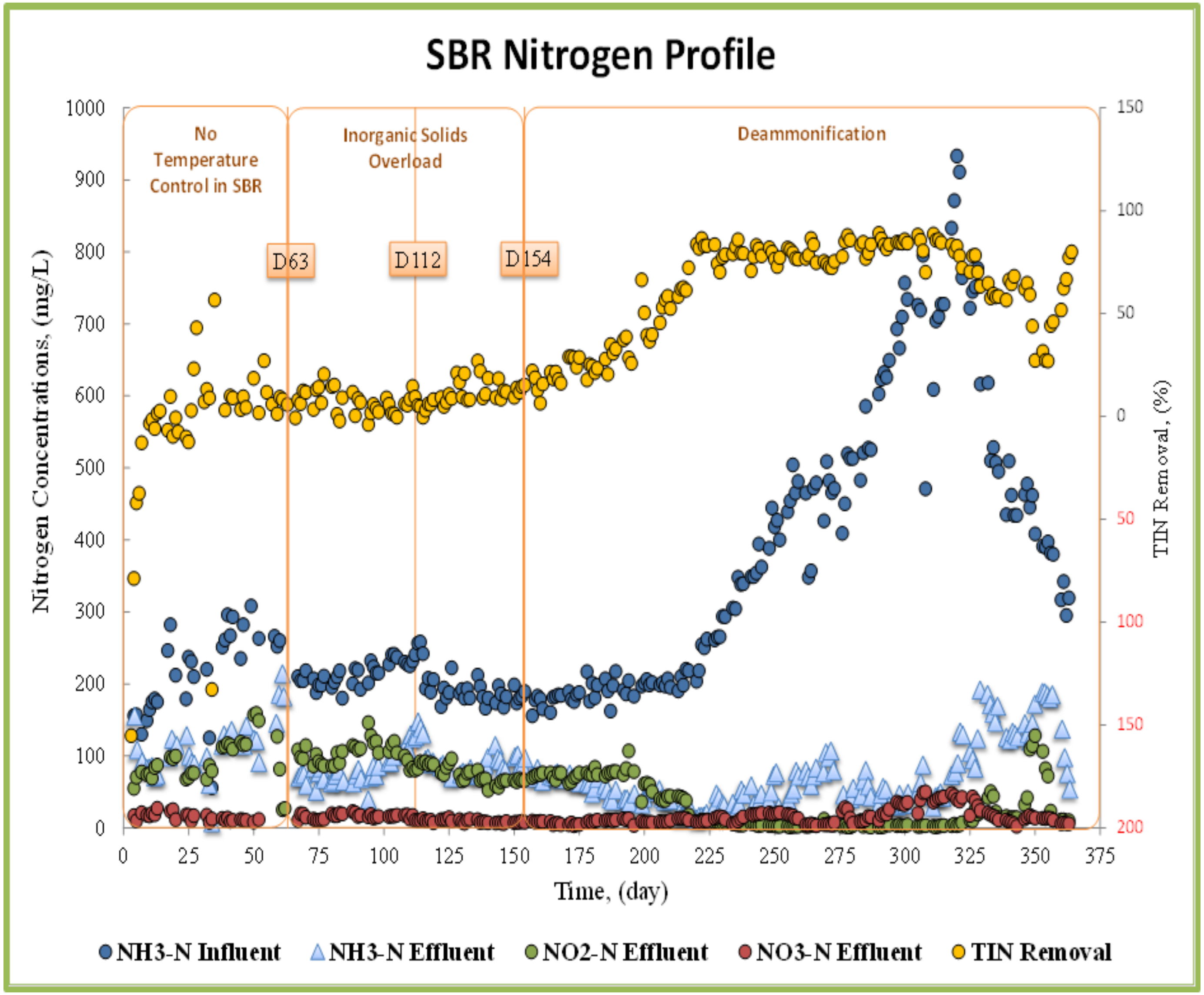
Case Study # 3 Tri-City, OR



Process Performances:

- Anammox seeding
- 1.0 kg NH3-N/m³/day
- Ammonia-N Removal 96 %
- TIN Removal 85 %
- C/N ratio averaged at 1.0 during the deammonification period

Because of centrate C/N ratio the nitrate produced from the anammox reaction slightly accumulated in SBR (red dots).

AerAOB/aeration → 15.2 mg/l

AnAOB/anoxic → 13.2 mg N/l

OHO/anoxic → 3.5 mg Nox/l

Conclusions

- Energy requirements for side streams deammonification process depends on amount of biodegradable organic matter in the centrate

- Respirometer test can assess the biodegradability of organic matter from centrate in relation to the side stream HRT and SRT design parameters

- Side stream deammonification should be optimized based on biodegradable organic matter to limit bacteriologic competition between OHO and AnAOB while permitting TIN removal > 80%