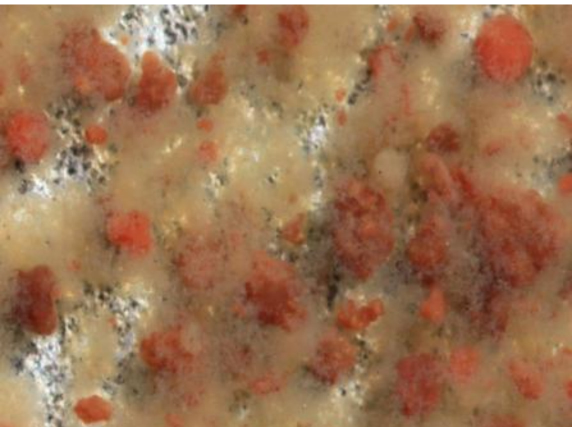
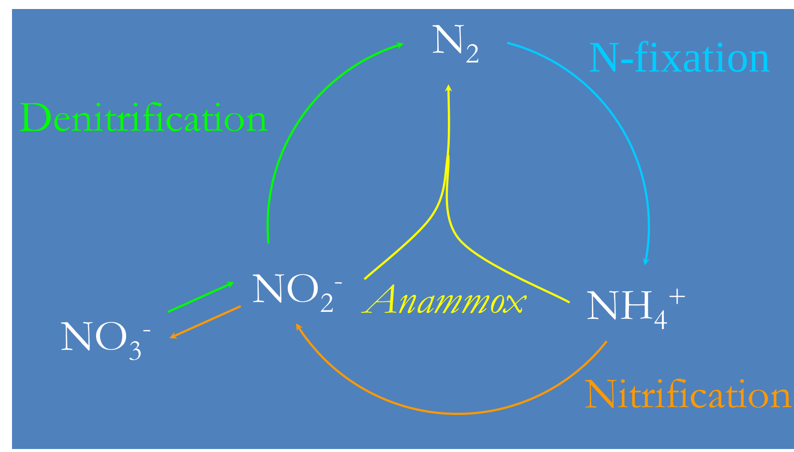
Update on Technology Developments and Research Needs in Point Source Nutrient Removal



Charles B. Bott, PhD, PE, BCEE

Hampton Roads Sanitation District



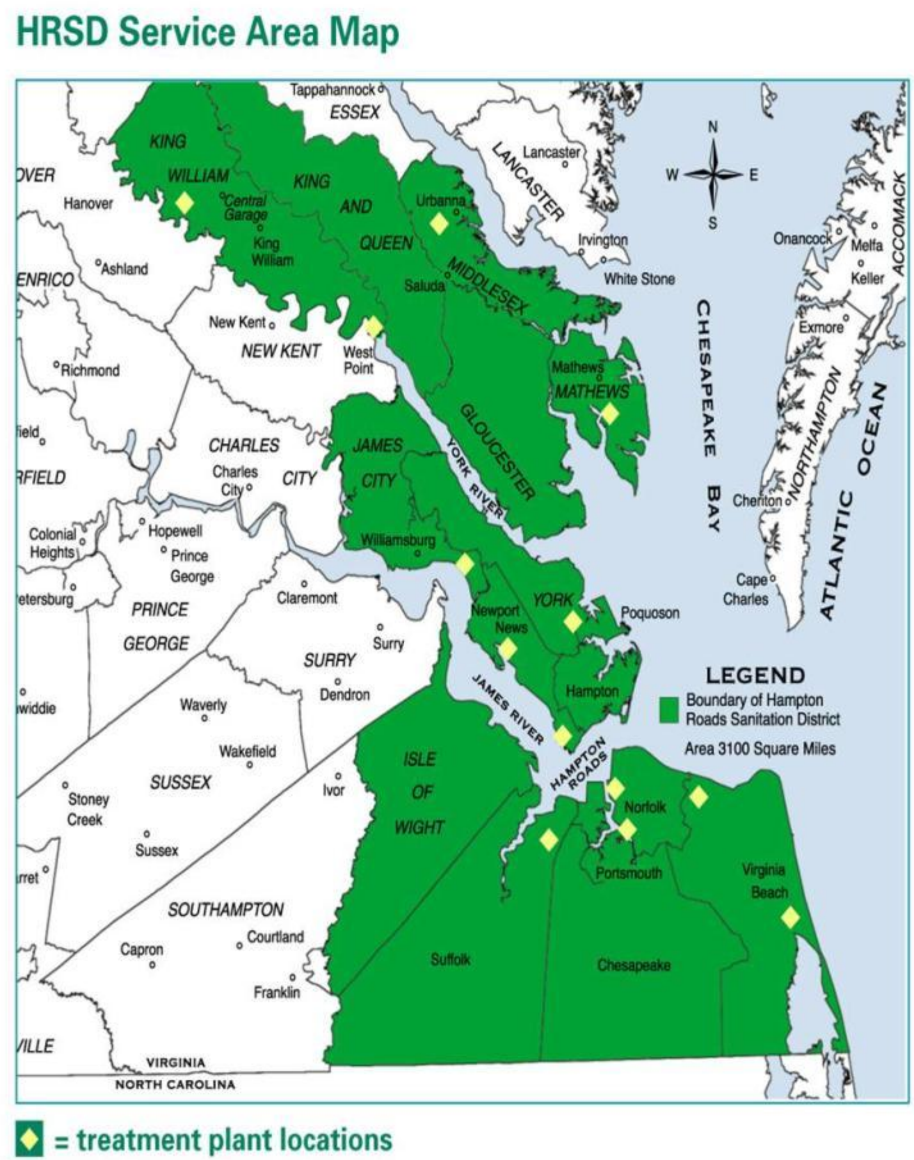
HRSD

Outline

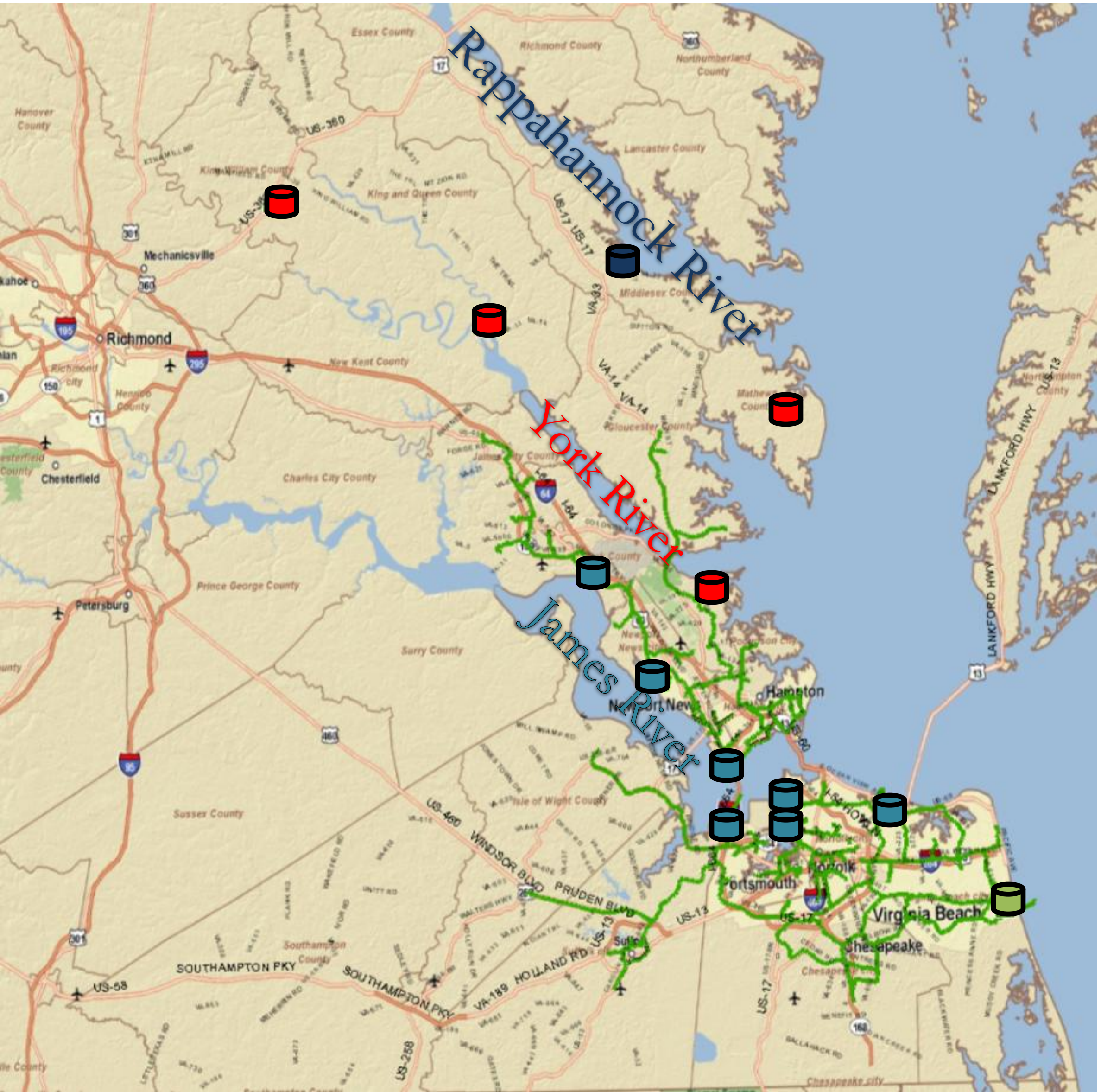
- HRSD and nutrient removal requirements
- BNR Research at HRSD
- Wastewater Treatment and BNR 101
  - N removal process 1.0
- Dewater liquor treatment (sidestream) - plants with anaerobic digestion
  - 1.0 with AOB and NOB bioaugmentation (brief)
  - 2.0 nitrite shunt (brief)
  - 3.0 deammonification (partial nitritation + anammox)
    - HRSD York River Plant DEMON
    - HRSD James River Plant ANITA Mox
  - Struvite recovery
    - HRSD Nansemond Plant
- Mainstream 2.0 and 3.0 Technology Development
- **Discussion of needs – research & regulatory**

Hampton Roads Sanitation District

- Created in 1940
- Serves 1.6 million people
- Includes 17 jurisdictions – 3,100 square miles
- 9 major plants, 4 small plants
- Capacity of 249 MGD



HRSD's Bubble Permit - 2011



- James River
  - 6,000,000 lbs/yr TN
  - 573,247 lbs/yr TP
- York River
  - 288,315 lbs/yr TN
  - 33,660 lbs/yr TP
- Rappahannock River (one plant)
  - 1,218 lbs TN
  - 91 lbs/yr TP

Chesapeake Bay TMDL & VA WIP

- Nitrogen – James River
  - 2011 – 6.0 million pounds/year
    - Major upgrades ongoing at Nansemond, James River, Williamsburg, Army Base
  - 2017 – 4.4 million pounds/year
    - VIP - biological process upgrade for improved denitrification
    - Small upgrade at Williamsburg possible
  - 2021 – 3.4 million pounds/year
    - Upgrade Chesapeake-Elizabeth (full plant)
- Nitrogen – York River
  - Rapid upgrade to add denite filters for 2011 compliance
  - Additional upgrade needed for cost-effective BNR and reliability

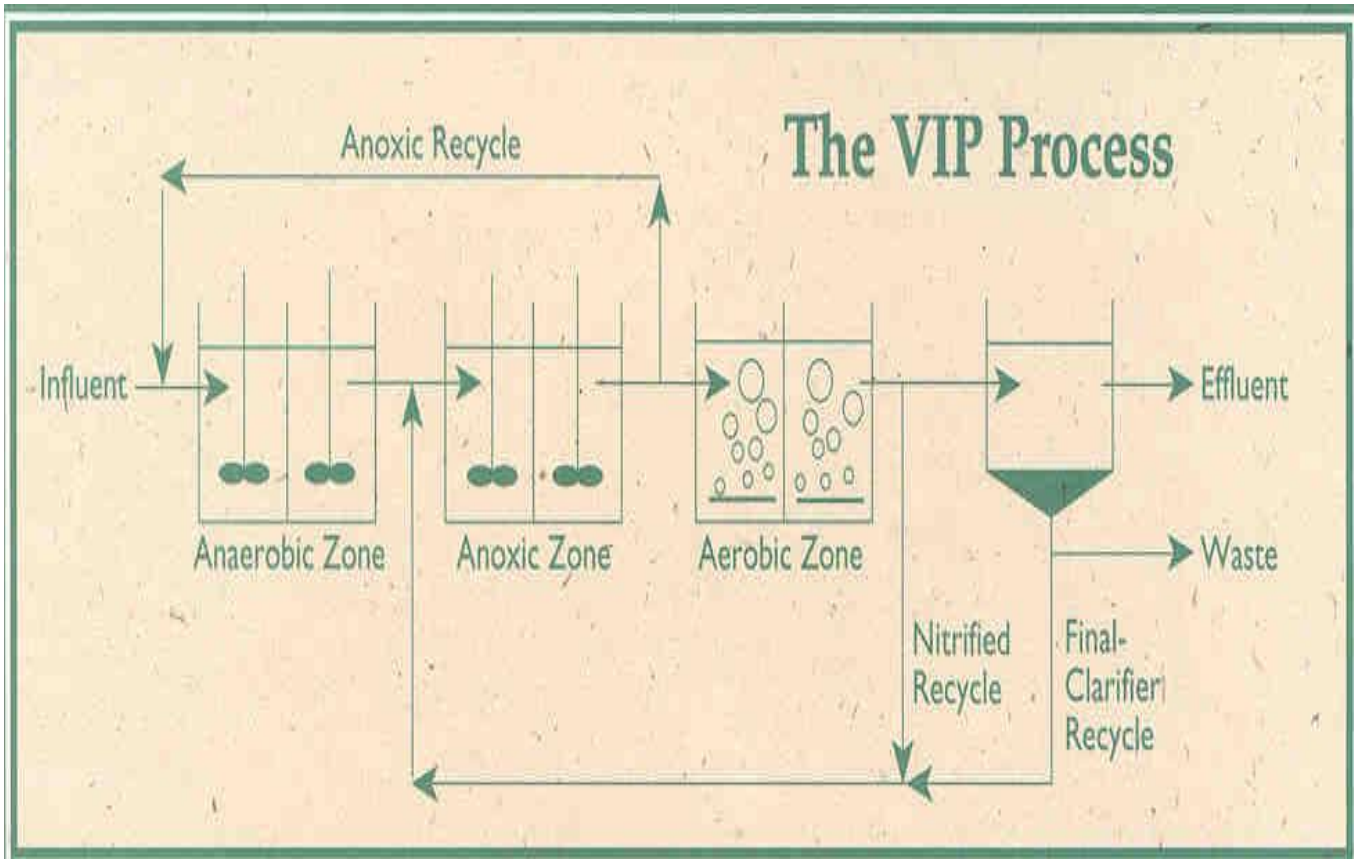
HRSD R&D Program Focus

- Resource utilization:
  - Energy
  - Chemicals
  - Labor (operations, maintenance, instrumentation…)
  - Concrete
- Resource recovery
  - Water
  - P
  - N (maybe)
  - CH_4 - biogas
  - Heat
  - Hydraulic energy
  - Chemicals of interest (maybe)
  - Biosolids (N, P, organics)
  - Etc, etc, etc

Current HRSD R&D Efforts in BNR:

- Supplemental carbon for denitrification (chemicals)
  - AOB conversion of methane to methanol
  - Reduced S compounds
  - Ethanol used for fuel blending
  - Industrial waste materials
- SND/Nitrite Shunt/Mainstream Nitritation-Denitritation (chemicals, energy, concrete)
- Mainstream Deammonification (chemicals, energy, concrete)
- Centrate treatment – deammonification (chemicals, energy)
- Ammonia-based DO control systems (energy, chemicals)
- Ultra-high efficiency fine pore diffusers and fouling (energy)
- Organic nitrogen sources and fate
- Cost-effective Chemically Enhanced Primary Treatment (chemicals)
- Algae-based nutrient removal (chemicals, energy)
- Nitrite accum. and excessive chlorine demand (chemicals)
- IFAS process development and modeling (concrete, energy)
- Nitrification inhibition (concrete)
- BNR process reliability and stochastic methods (concrete)
- Struvite avoidance and recovery (chemicals, energy)
- Primary sludge, mixed liquor, and FOG fermentation (chemicals, labor)
- Improvement of BNR process models (chemicals, energy, concrete)
- Urine separation (source separation)

The VIP® Process



- **It was developed and patented by HRSD and CH2M Hill Engineers**
- **Biologically removes Phosphorus and Nitrogen**
- **Its free for any one to use…**

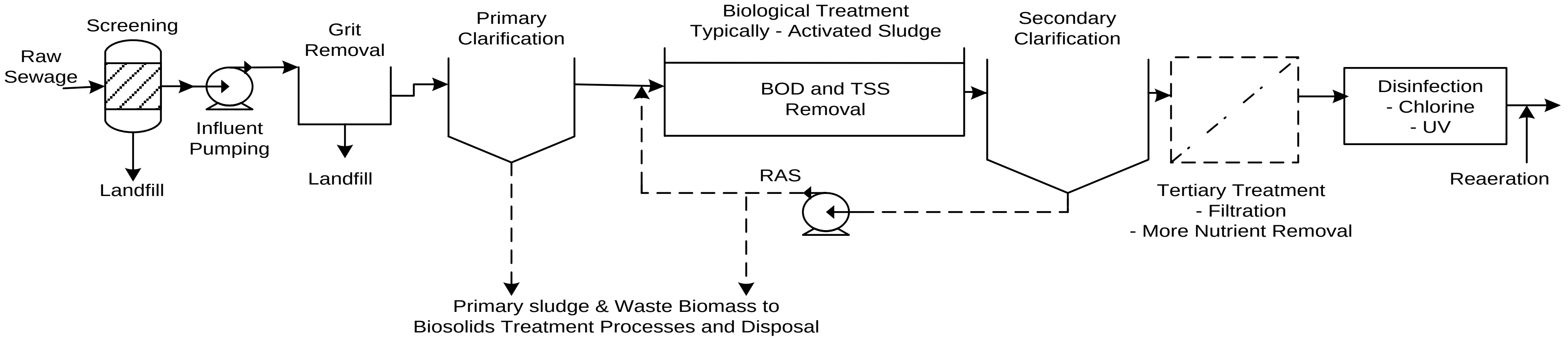
Wastewater Treatment 101 – Liquid Processes

Raw Sewage

Raw Sewage Characteristics

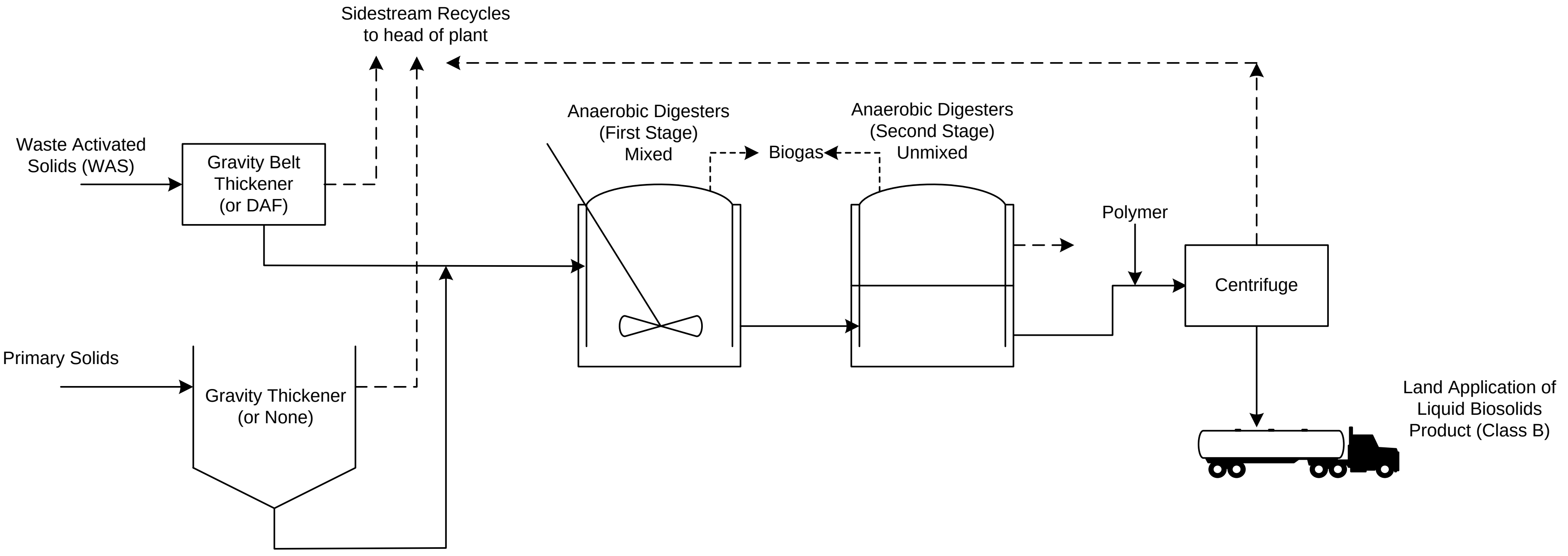
Parameter	Abbreviation	Units	Value
Flow rate		gpd/capita	50-100
Biochemical Oxygen Demand	BOD	mg/L	120-350
Chemical Oxygen Demand	COD	mg/L	250-800
Total Suspended Solids	TSS	mg/L	120-350
Total Kjeldahl Nitrogen	TKN	mg/L	30-50
Total Ammonia Nitrogen	NH4-N	mg/L	25-40
Nitrate –N + nitrite-N	NOx-N	mg/L	0
Total Phosphorus	TP	mg/L	4-10
ortho-Phosphate as P	OP	mg/L	3-8
Fecal Coliform	FC	No./100 mL	10^5-10^8

Wastewater Treatment 101 – Liquid Processes

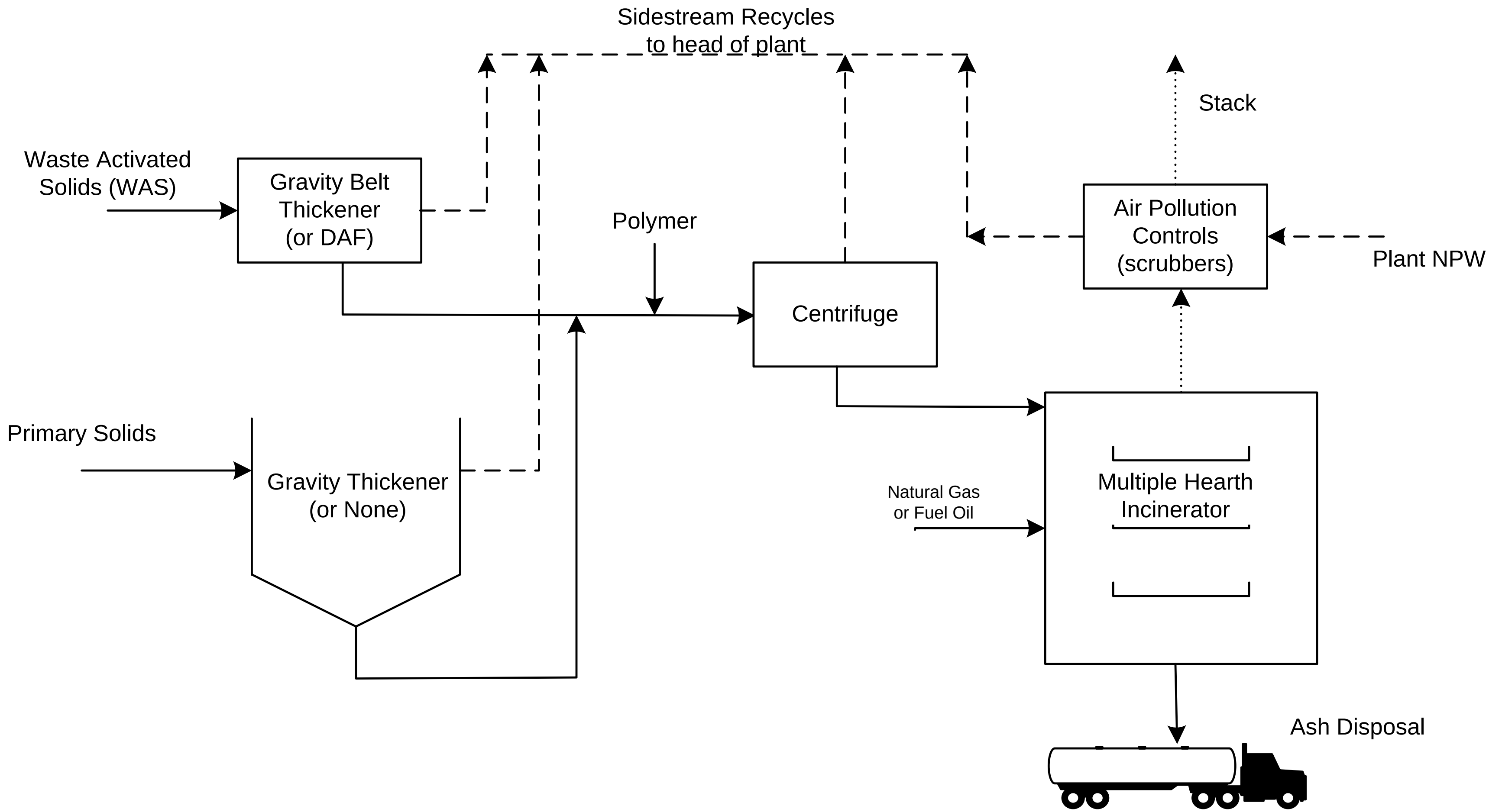


Description of York River Treatment Plant (15 MGD)

Digestion Plant Example



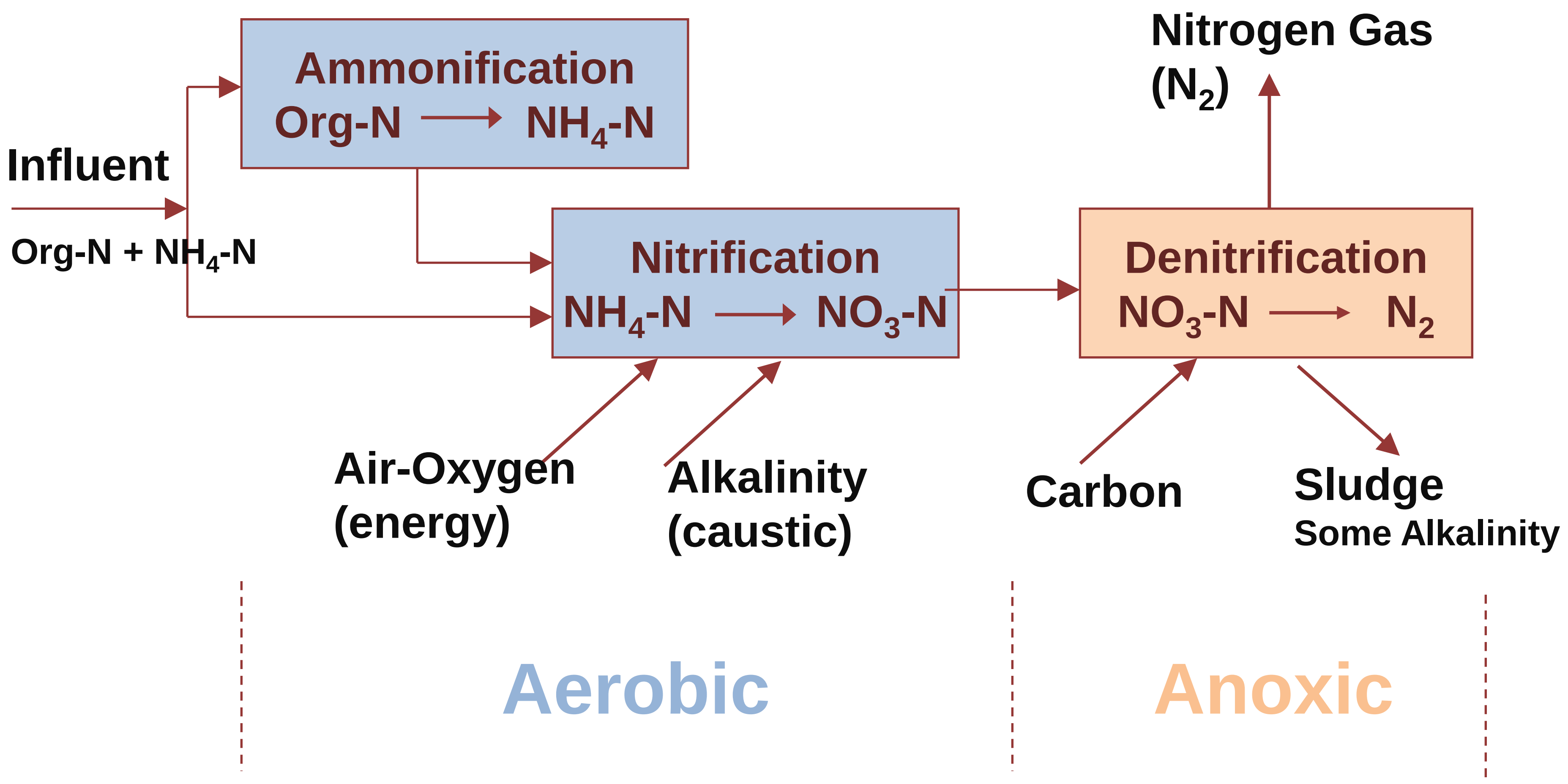
Incineration Plant Example



Definitions

- AEROBIC / OXIC
  - Presence of dissolved oxygen (DO)
- ANOXIC
  - Absence of dissolved oxygen (DO)
  - Presence of nitrate or nitrite (NO_3^- and NO_2^-)
- ANAEROBIC
  - Absence of dissolved oxygen (DO)
  - Absence of nitrate or nitrite (NO_3^- and NO_2^-)

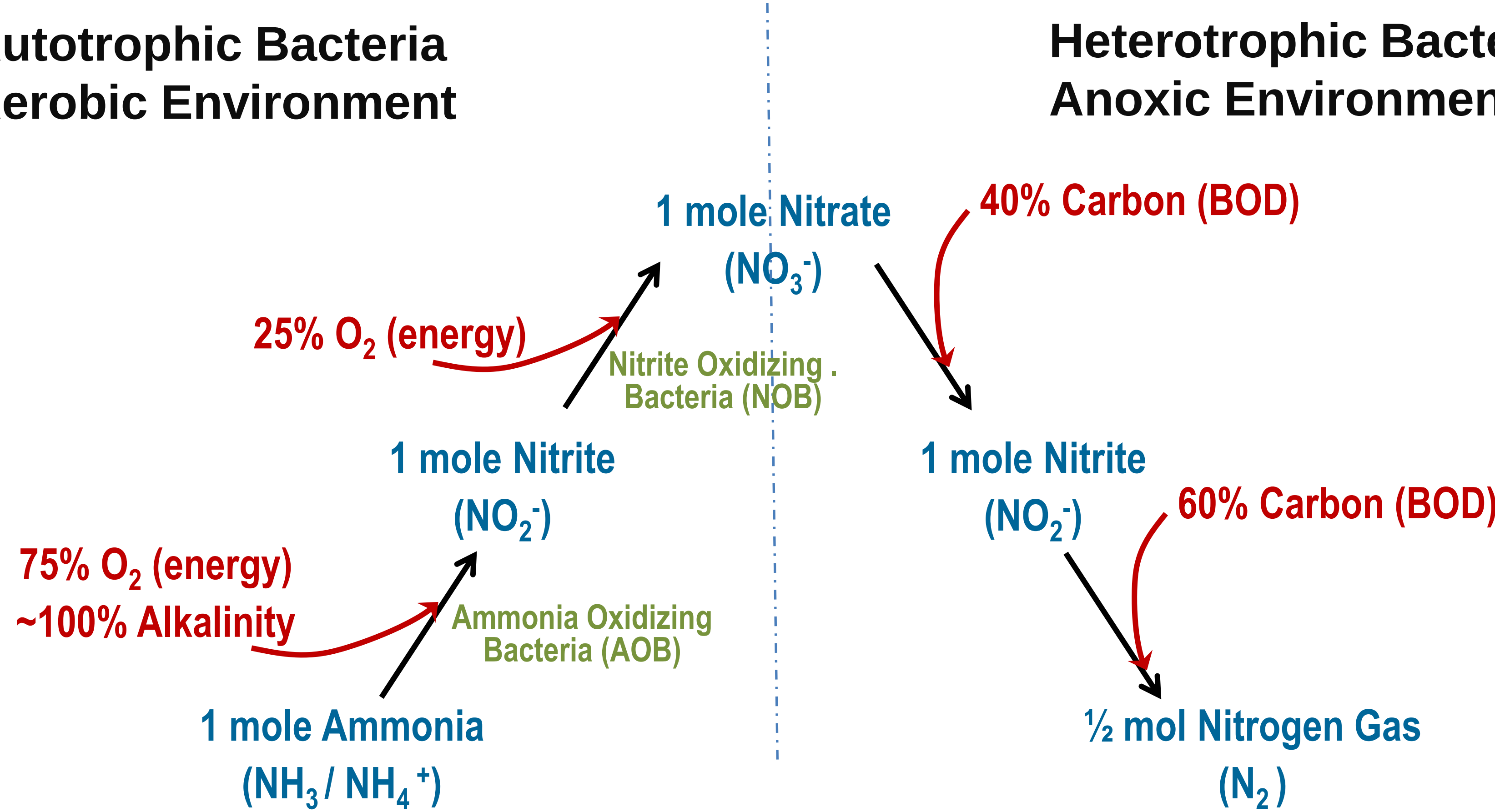
BNR-N consists of three processes



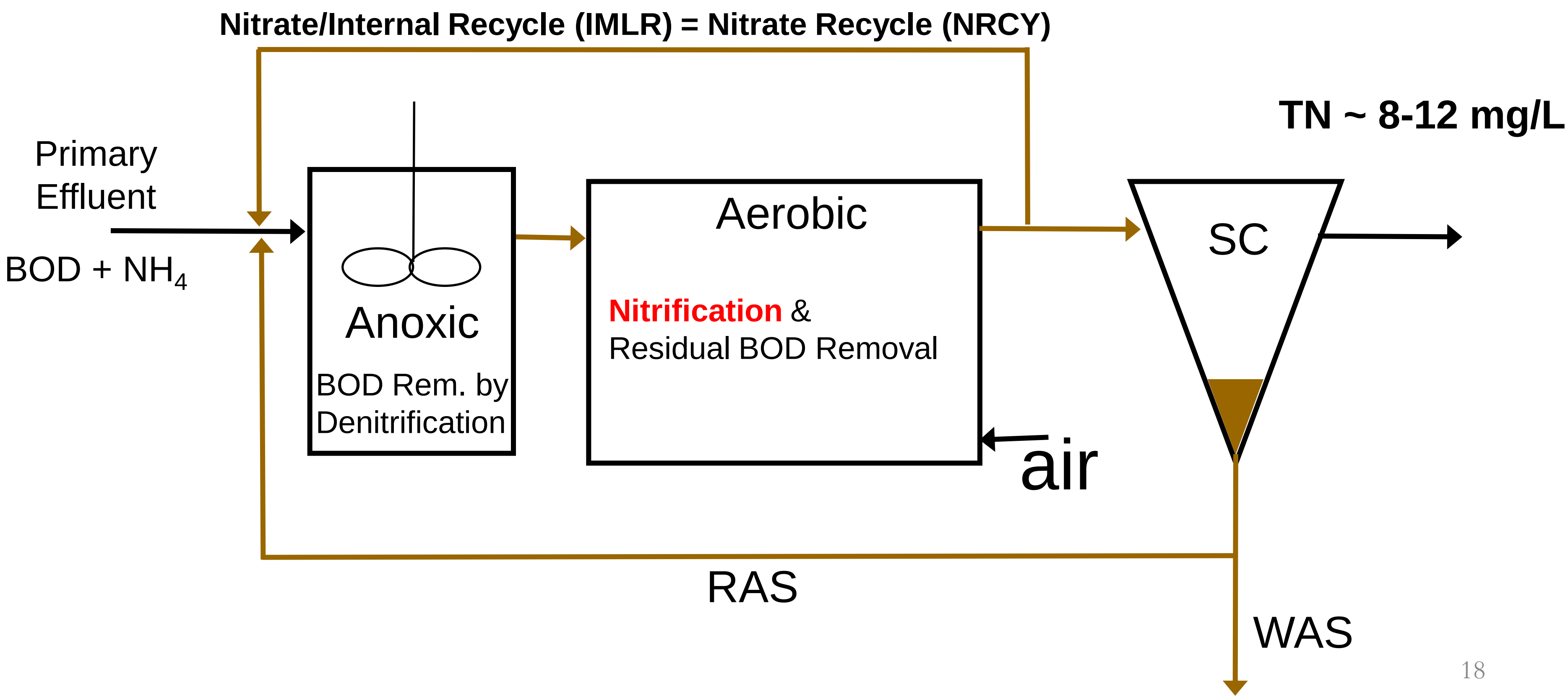
Conventional Nitrification-Denitrification **(1.0)**

Autotrophic Bacteria
Aerobic Environment

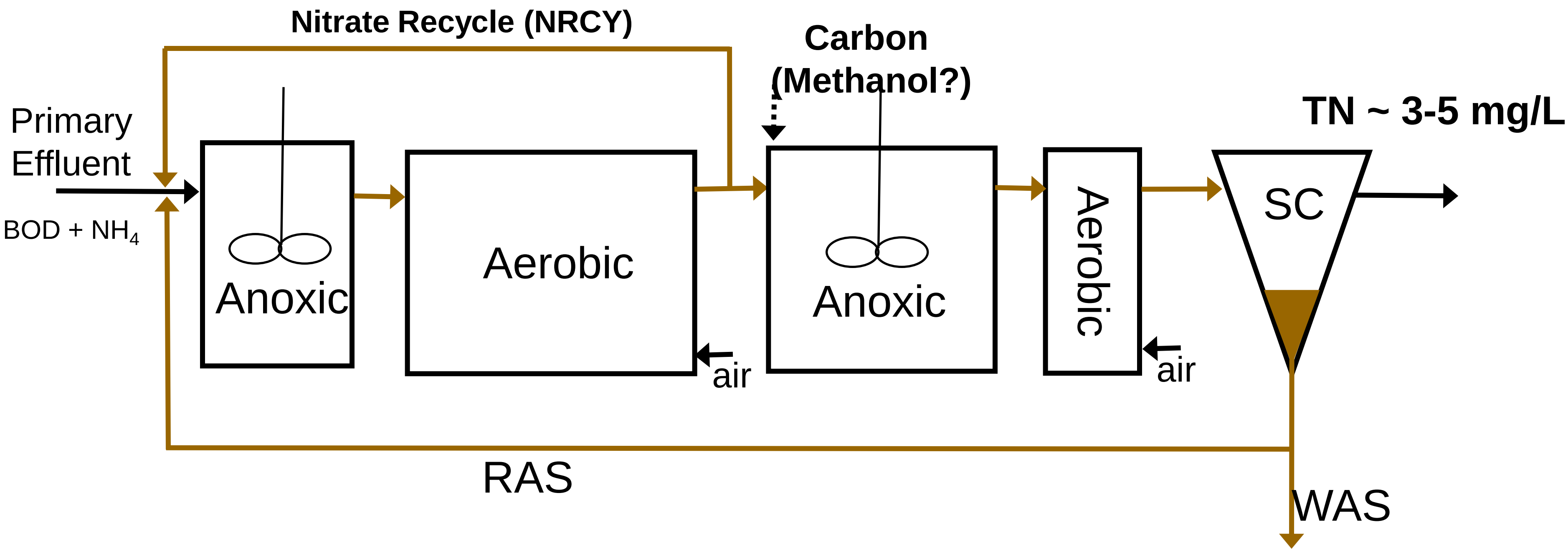
Heterotrophic Bacteria
Anoxic Environment



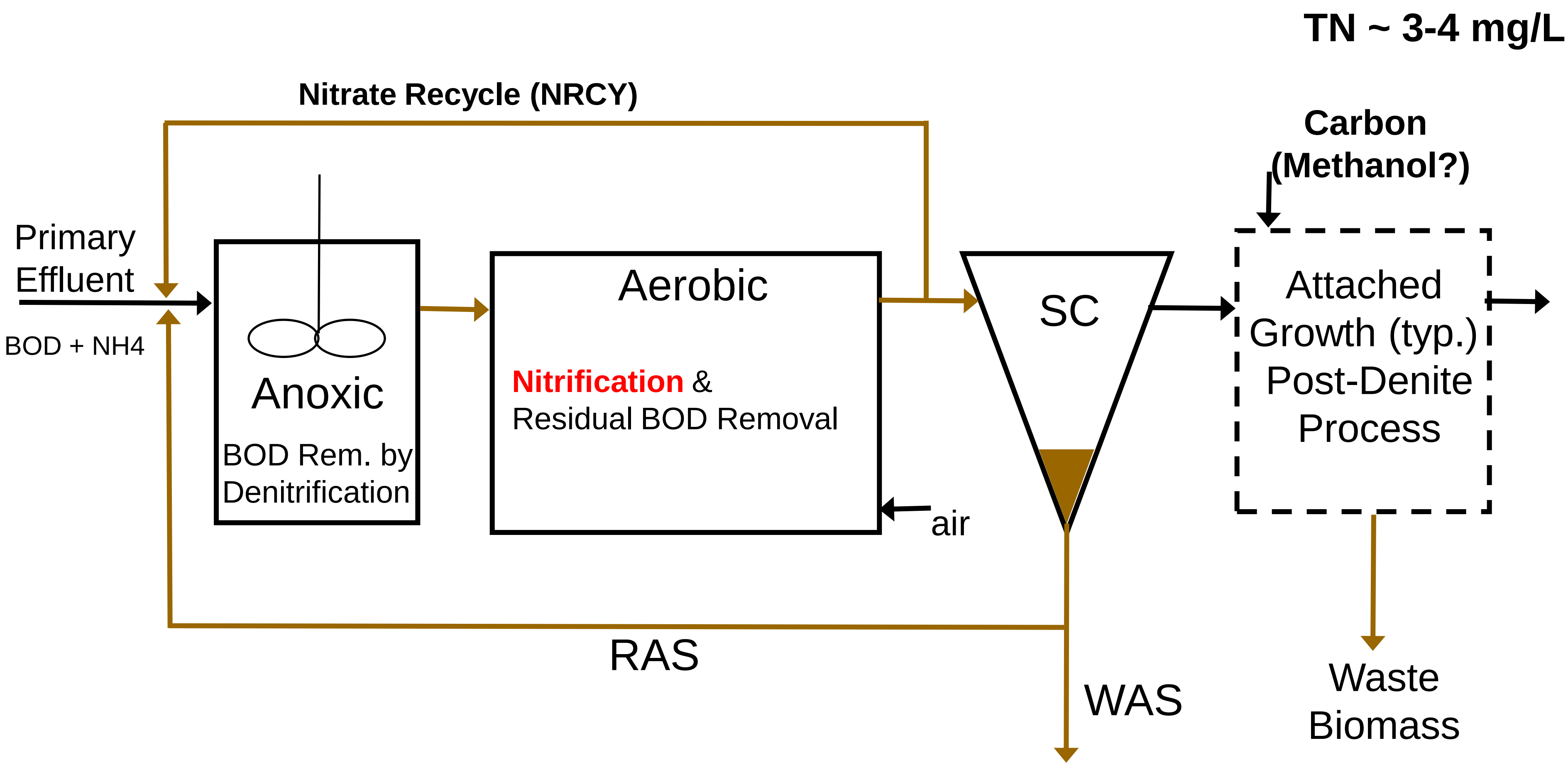
MLE Process (N Removal)



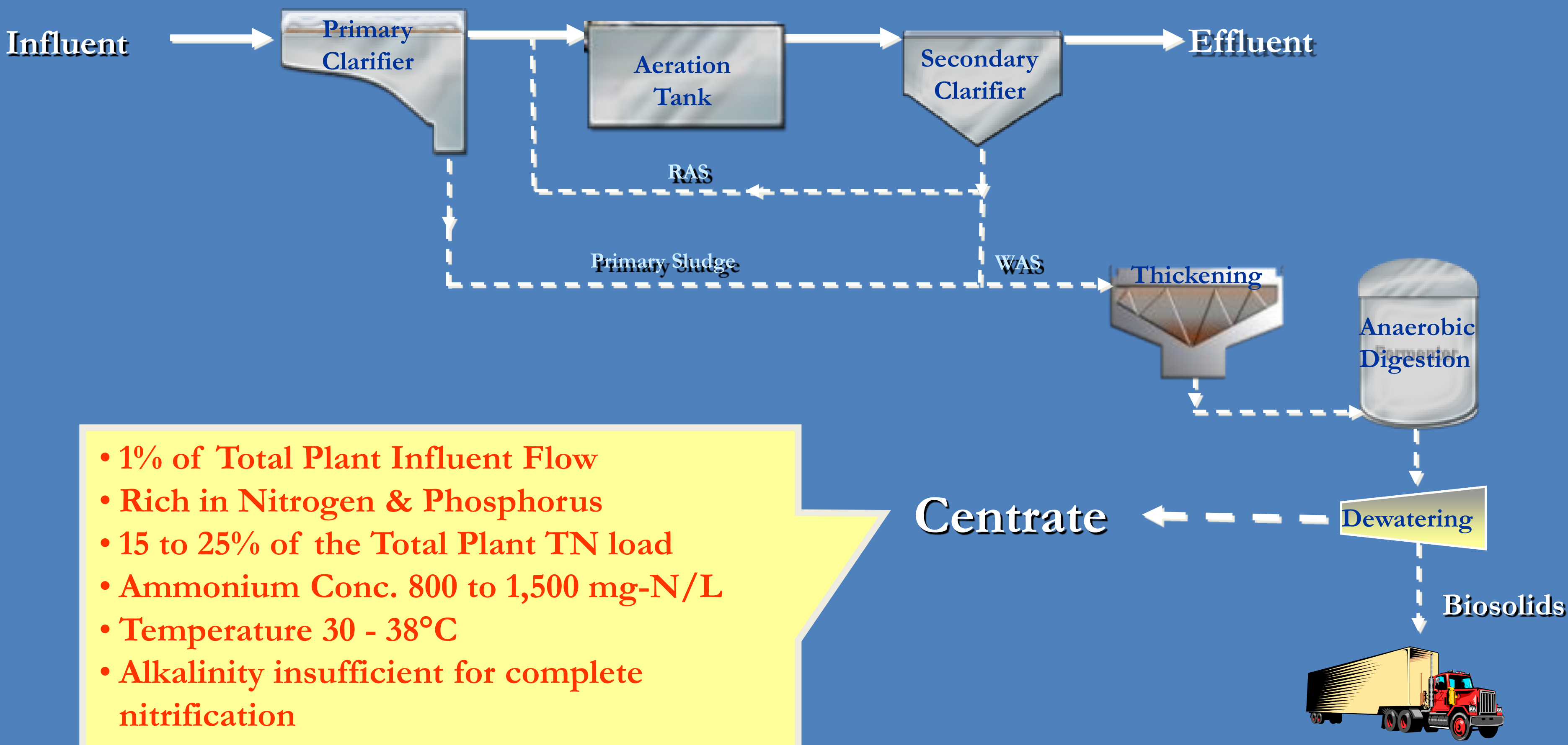
4-Stage Bardenpho (Better N Removal)



MLE Process + Post-Denite (Better N Removal)



Recycle Streams with High Ammonia - Sidestream



- 1% of Total Plant Influent Flow
- Rich in Nitrogen & Phosphorus
- 15 to 25% of the Total Plant TN load
- Ammonium Conc. 800 to 1,500 mg-N/L
- Temperature 30 - 38°C
- Alkalinity insufficient for complete nitrification
- Insufficient carbon for denitrification

- For a Bio-P plant with no iron addition:
    - Centrate TP = 200-800 mg/L

Sidestream Treatment Options

Biological - N

1.0 Nitrification / Denitrification & Bioaugmentation
- With RAS & SRT Control
- With RAS
- Without RAS

2.0 Nitritation / Denitritation
- Chemostat
- SBR
- Post Aerobic Digestion

3.0 Deammonification
- Suspended Growth SBR
- Attached Growth MBBR
- Upflow Granular Process

Physical-Chemical – N&P

Ammonia Stripping
- Steam
- Hot Air
- Vacuum Distillation

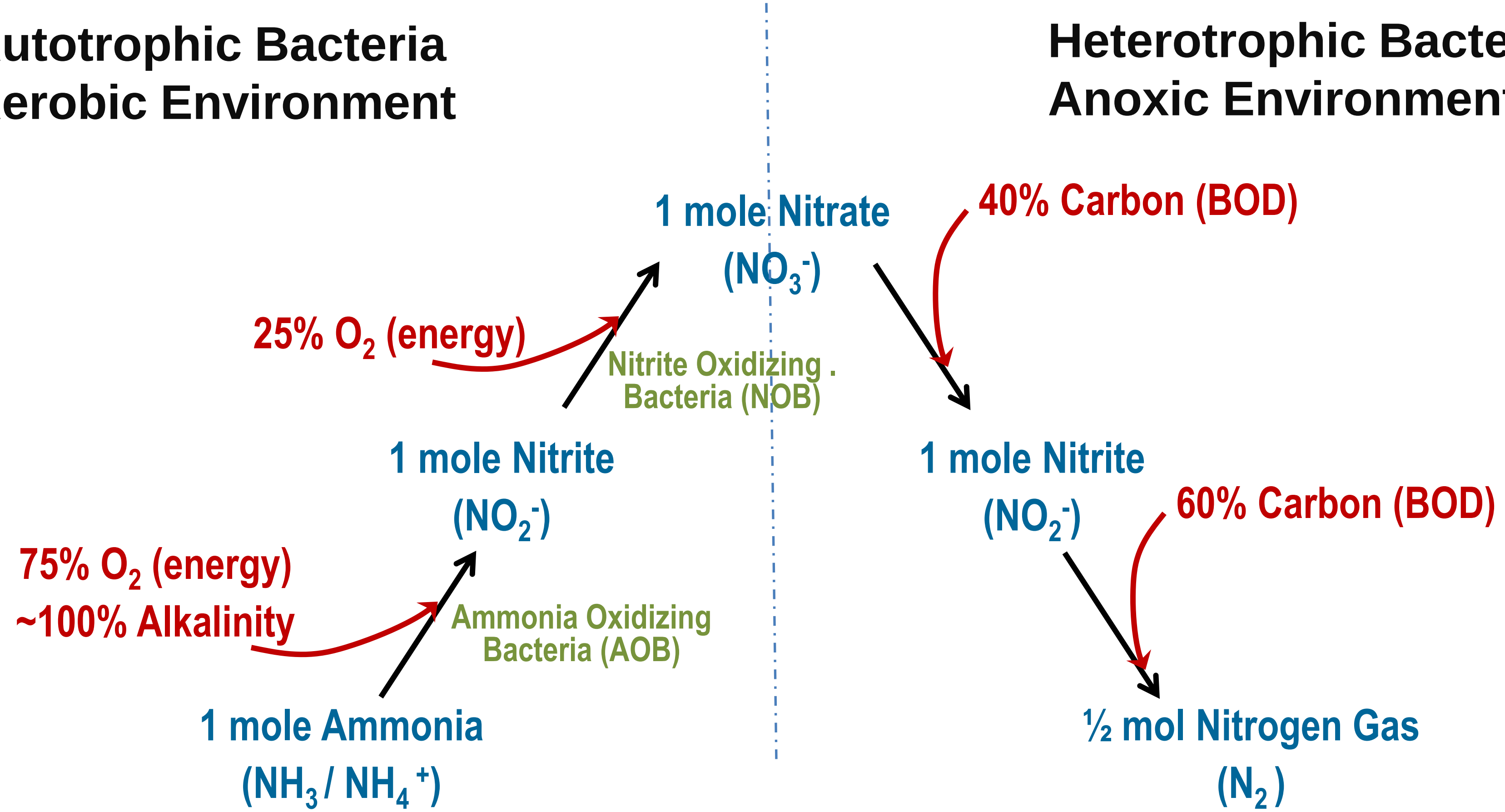
Ion-Exchange
- ARP

Struvite Precipitation
- Ostara Process
- PhosPaq Process

Conventional Nitrification-Denitrification

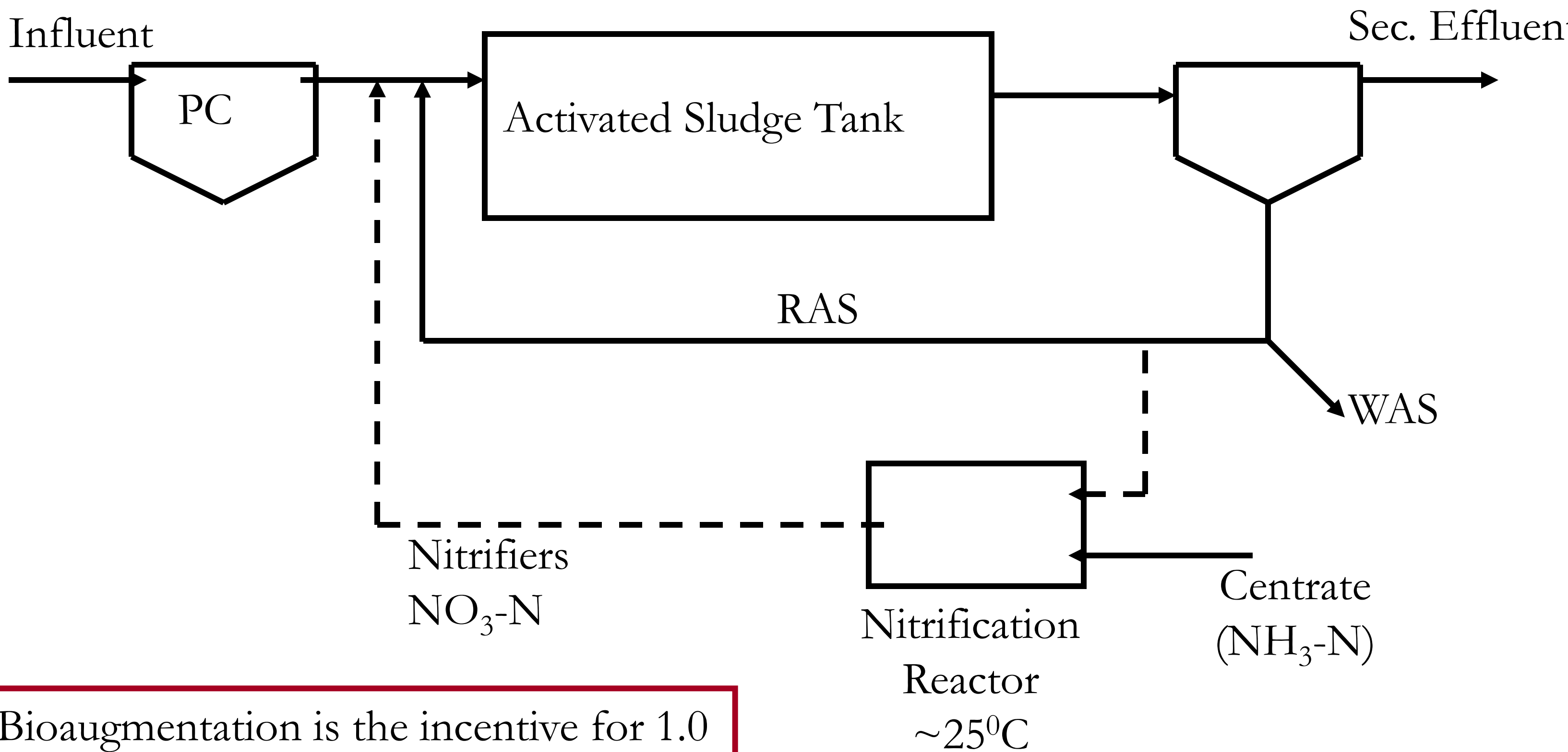
Autotrophic Bacteria
Aerobic Environment

Heterotrophic Bacteria
Anoxic Environment



Sidestream Treatment with Nitrifier Bioaugmentation

BABE, AT-3, BAR, CaRRB, Maureen, etc.



Bioaugmentation is the incentive for 1.0

Sidestream Treatment Options

Biological - N

1.0

Nitrification / Denitrification & Bioaugmentation
- With RAS & SRT Control
- With RAS
- Without RAS

2.0

Nitritation / Denitritation
- Chemostat
- SBR
- Post Aerobic Digestion

3.0

Deammonification
- Suspended Growth SBR
- Attached Growth MBBR
- Upflow Granular Process

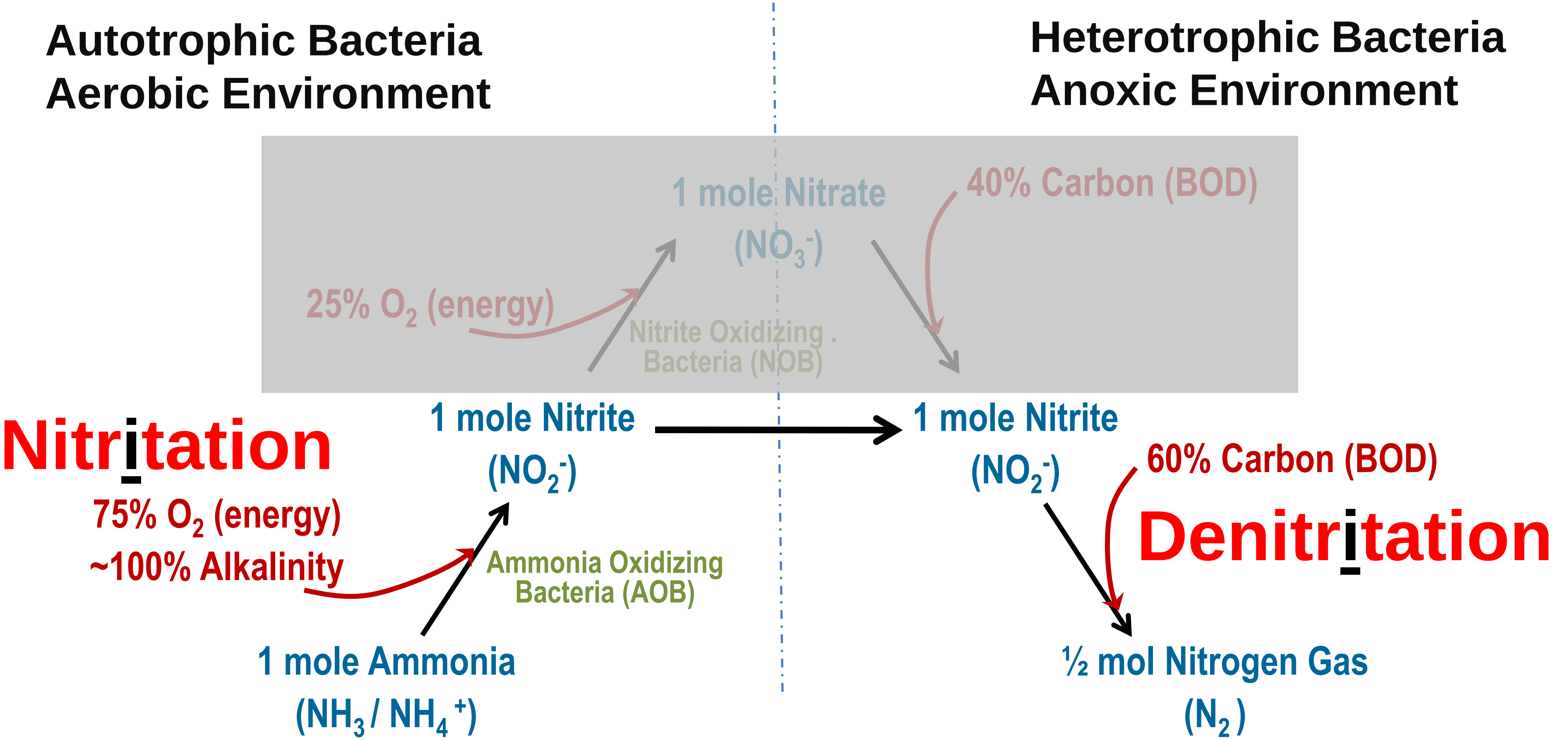
Physical-Chemical – N&P

Ammonia Stripping
- Steam
- Hot Air
- Vacuum Distillation

Ion-Exchange
- ARP

Struvite Precipitation
- Ostara Process
- PhosPaq Process

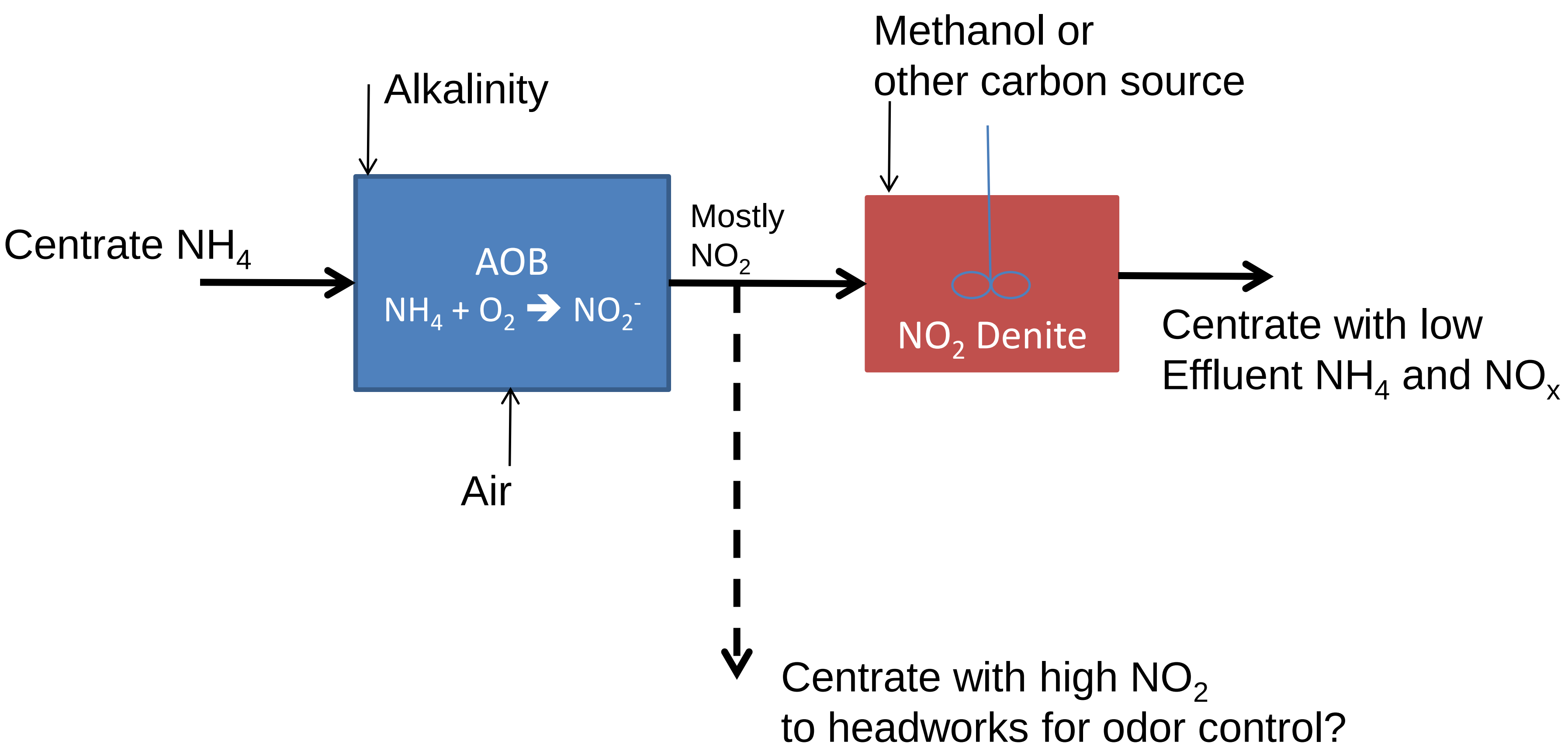
Nitritation-Denitritation = "Nitrite Shunt" (2.0)



Advantages:

- 25% reduction in oxygen demand (energy)
- 40% reduction in carbon (e^- donor) demand
- 40% reduction in biomass production

Nitritation - Denitritation



Sidestream Nitritation – NOB Repression

- Control
  - Elevated temperature (30-35 deg C)
  - Low SRT (1-2 days)
  - Low DO (~0.5 mg/L)
- NOB Repression Mechanisms (all the possibilities)
  - AOB max growth rate > NOB max growth rate at high temp
  - Free NH_3 inhibition of NOB > AOB
  - AOB DO affinity > NOB DO affinity *(perhaps only at high temp)*
  - Nitrous acid inhibition of NOB > AOB

SHARON Experience

- 6 operational >10 years experience
- 5 planned
- NYC DEP Wards Island
  - First in USA & largest in world

≈ 30 - 40% TKN-load

WWTP	Capacity (pe)	SHARON kgN/day	Operational
Utrecht	400.000	900	1997
Rotterdam-Dokhaven	470.000	850	1999
Zwolle	200.000	410	2003
Beverwijk	320.000	1,200	2003
Groningen-Garmerwolde	300.000	2,400	2005
The Hague - Houtrust	430.000	1,300	2005
New York-Wards Island	*~2,000,000*	*5,770*	*2009*
Whitlingham, UK	*275.000*	*1,500*	*2009*
MVPC Shell Green, UK	*-*	*1,600*	*2009*
Geneva – Aïre 2	*600.000*	*1,900*	*2010*
Paris Seine Grésillons		*3,500*	*2010*

Sidestream Treatment Options

Biological - N

1.0

Nitrification / Denitrification & Bioaugmentation
- With RAS & SRT Control
- With RAS
- Without RAS

2.0

Nitritation / Denitritation
- Chemostat
- SBR
- Post Aerobic Digestion

3.0

Deammonification
- Suspended Growth SBR
- Attached Growth MBBR
- Upflow Granular Process

Physical-Chemical – N&P

Ammonia Stripping
- Steam
- Hot Air
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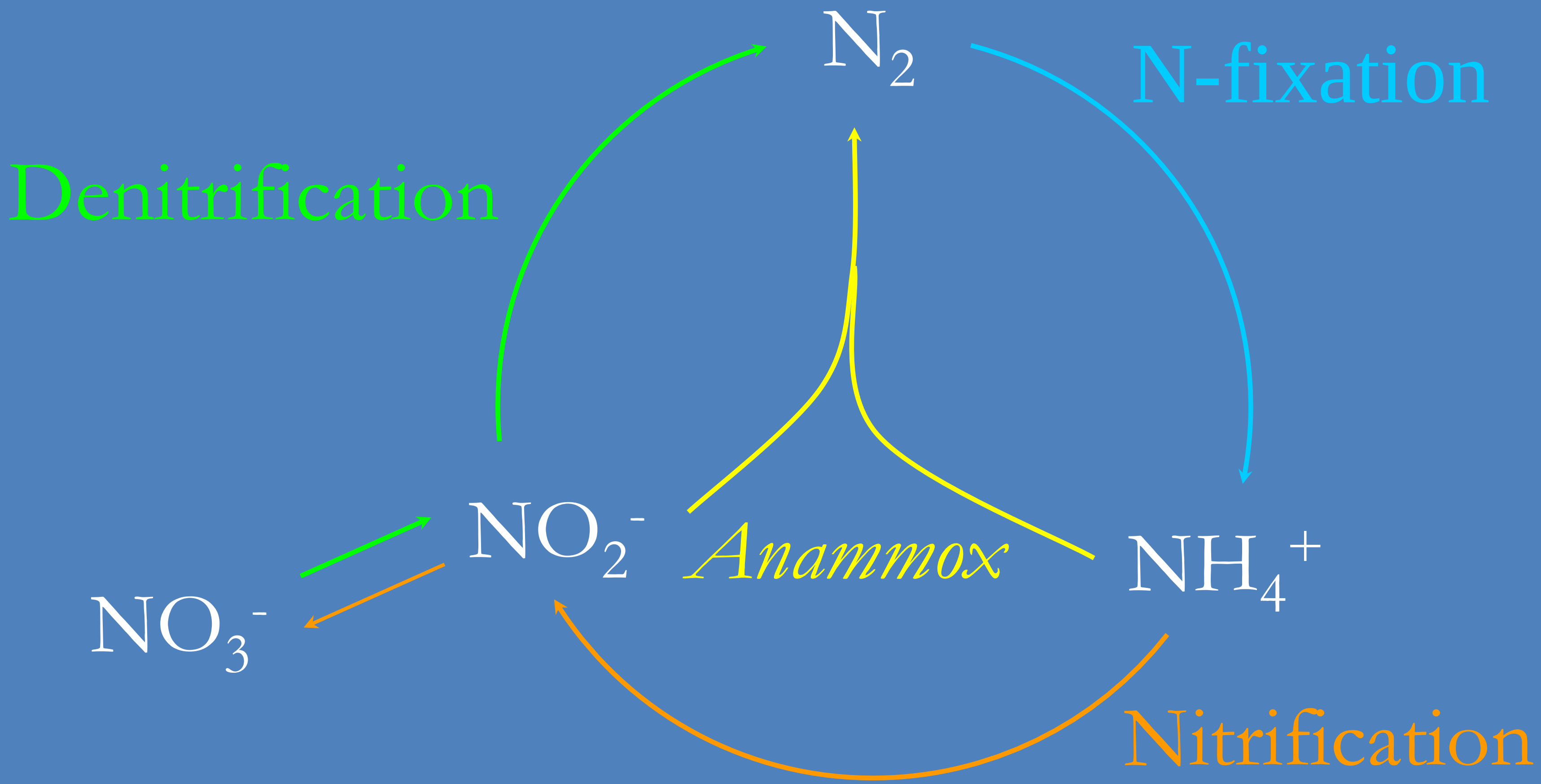
Ion-Exchange
- ARP

Struvite Precipitation
- Ostara Process
- PhosPaq Process

The N-Cycle



E. Broda (1977): „missing lithotroph“ … „might have existed or still exists“

free enthalpy -360 kJ/mol

Partial Nitritation-Anammox = "Deammonification" (3.0)

ANAMMOX
"Anaerobic" Ammonia Oxidation - (New Planctomycete - Strous et al, 1999)

$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13\ H^+ \rightarrow$$
$$0.26\ NO_3^- + 1.02 N_2 + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O$$

Autotrophic Bacteria
Aerobic Environment

0.5 mole Nitrite (NO_2^-)

37% O_2 (energy)
~50% Alkalinity

Ammonia Oxidizing Bacteria (AOB)

1 mole Ammonia (NH_3 / NH_4^+)

Autotrophic Anoxic Environment

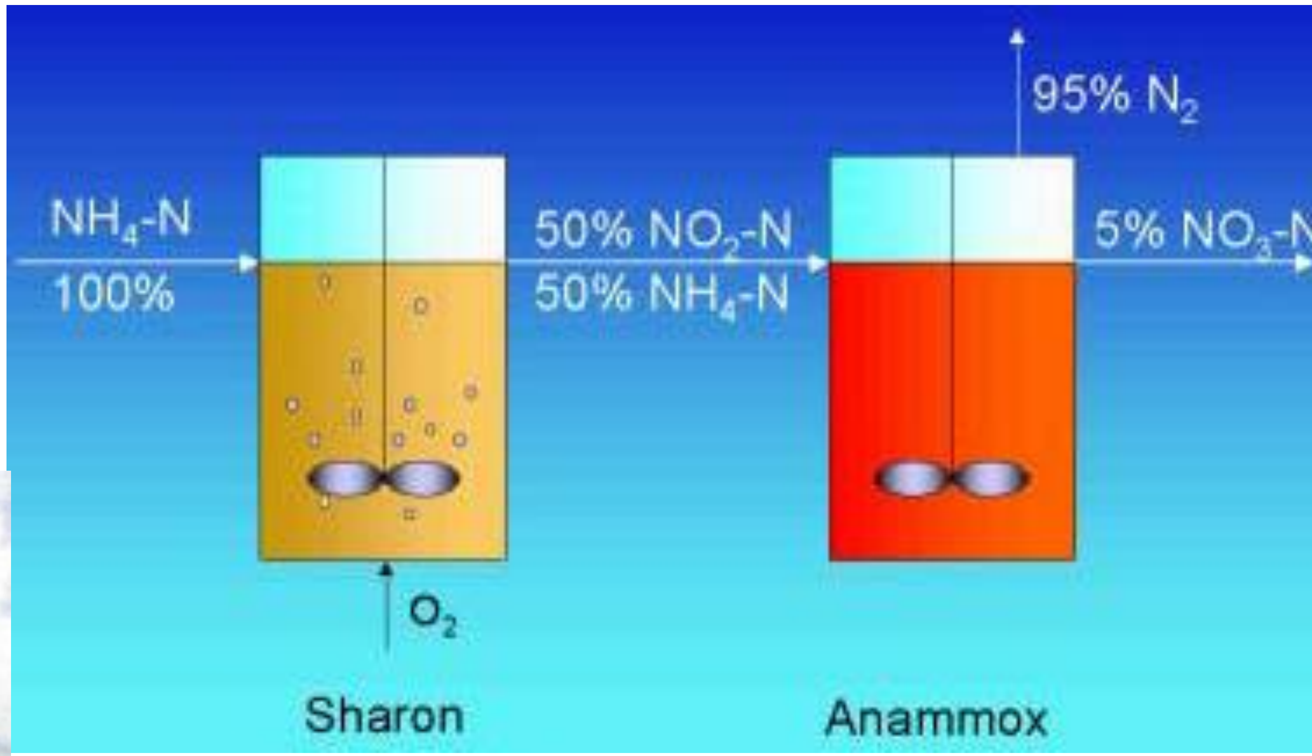
½ mol Nitrogen Gas (N_2) +
a little bit of nitrate (NO_3^-)

Advantages:

- 63% reduction in oxygen demand (energy)
- Nearly 100% reduction in carbon demand
- 80% reduction in biomass production
- No additional alkalinity required

Partial Nitritation – Anammox

- Two Step Anammox Process (Paques)
  - Dokhaven, Rotterdam (NL) + ~5 others



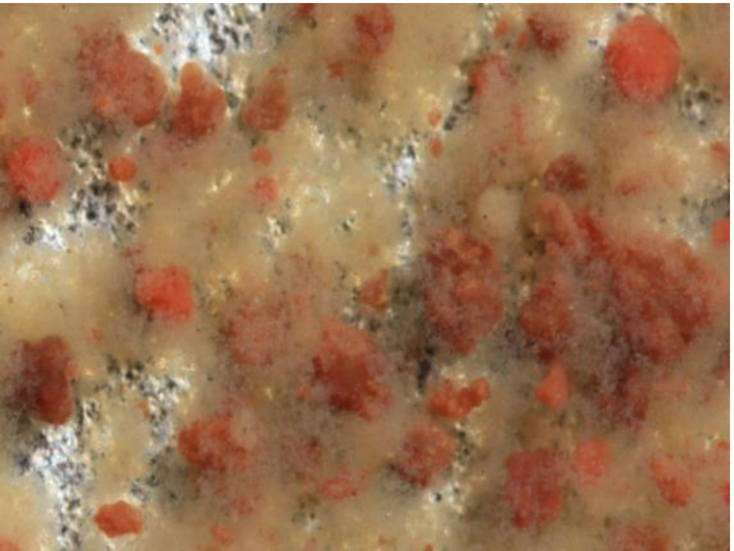
One-Step Sidestream Deammonification

- **SBR + Hydrocyclone Granular Sludge (DEMON)**
  - Strass, Austria + ~20 others
  - Cyklar-Stulz – World Water Works, Inc.

- **Upflow Granular Sludge (CANON/ANAMMOX)**
  - Olburgen, Netherlands + ~7 others
  - Paques (NL)

Partial Nitritation and Anammox
- combined in a single reactor

- **Biofilm process (MBBR-style)**
  - ANITA Mox -- Malmo & Växjö, Sweden
    - AnoxKaldnes – Kruger - Veolia
  - Deammon -- Hattingen, Germany & Stockholm
    - Purac



Sidestream Deammonification: What's the benefit?

- Remove ~20% of the N load to the plant by treating the centrate separately
- Do it with:
  - No chemicals (caustic & methanol)
  - < 40% of the energy cost
  - (as compared to traditional nitrification-denitrification)
- Risks:
  - Requires robust process control, particularly during startup
  - *Process has been adequately demonstrated in Europe*
  - *Seeding required for fast startup*

Sidestream Deammonification Status in North America

- DEMON – HRSD York River; Started October 2012; **operating**
- ANITA Mox – HRSD James River; **in construction; startup October 2013**

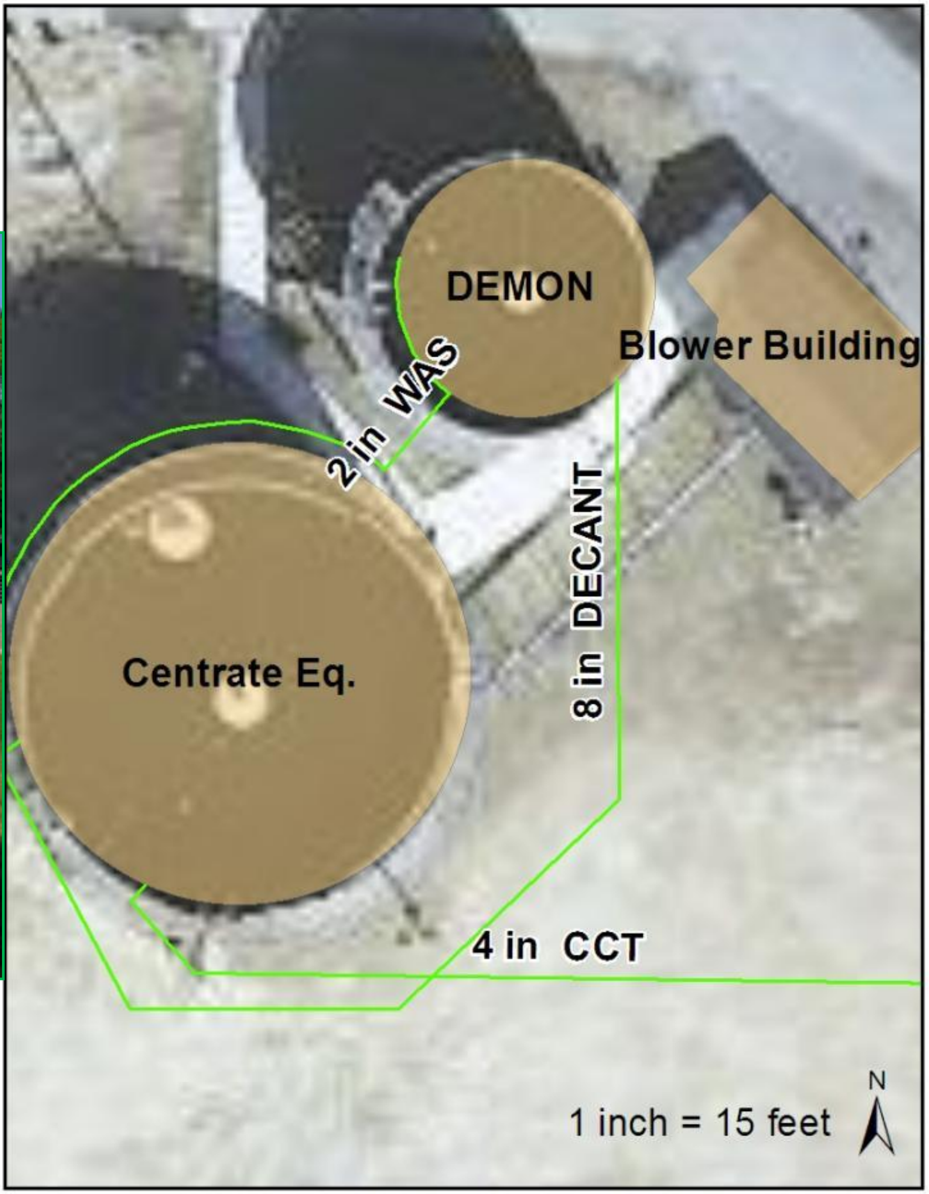
- DEMON – Industrial Project Orlando, FL; **in construction, startup Oct 2013**
- DEMON – Alexandria, VA; **in construction, startup Nov 2013**
- ANITA Mox – South Durham, NC; **in construction**
- DEMON – Philadelphia, PA; 90% design
- DEMON- Guelph, Ontario; 90% design
- DEMON – Pierce County, WA; **pilot complete; 60% design**
- DEMON – DCWater Blue Plains; **60% design**

- ANITA Mox (MBBR style) – LA County San District; **pilot ongoing 2013**
- DEMON – Chicago MWRDGC; **pilot completion Feb 2013**
- ANITA Mox (MBBR style) - Denver MWRD; **pilot completion Feb 2013**
- MBBR-style process – New York DEP; **pilot ongoing**

- DEMON - Alexandria, VA + DCWater **pilot** (no cyclone)
- DEMON – New York DEP + DCWater **pilot** (no cyclone)

DEMON at York River

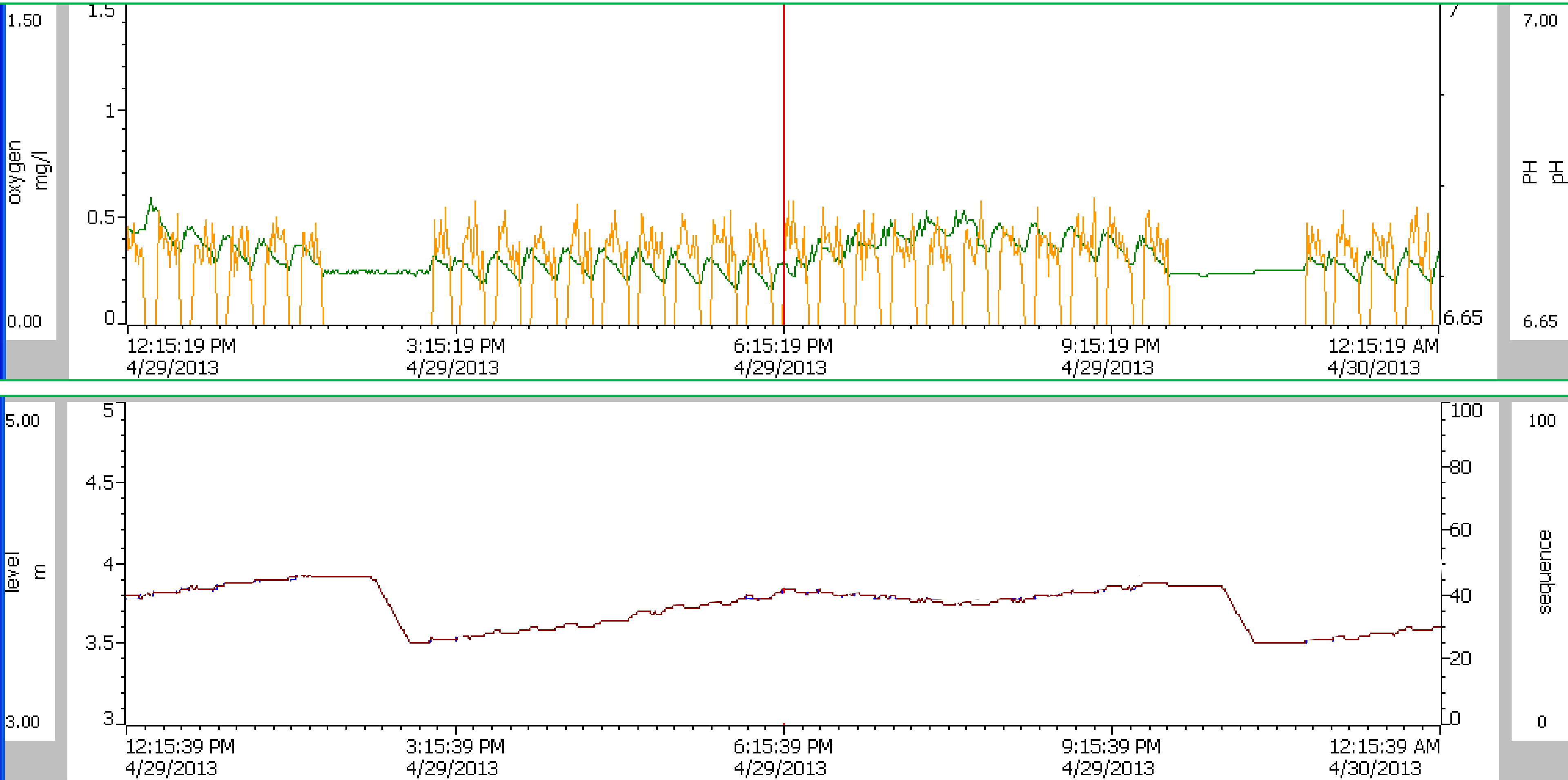
Implementation of DEMON at York River




LIFERING

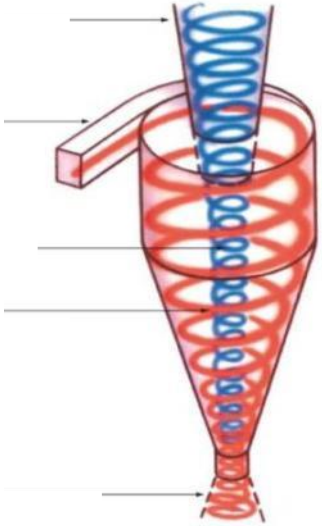

DEMON® Control Strategy

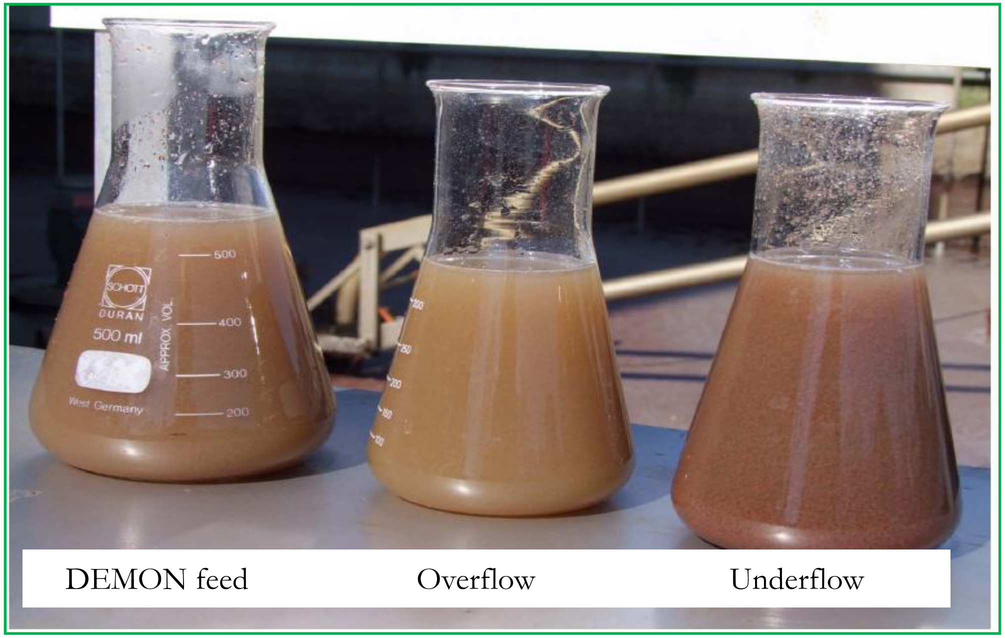
- Intermittently fed and intermittently aerated SBR
- Aeration On/OFF based on pH and timer control (also loading)
- DO controlled to 0.2-0.5 mg/L when blower is operating



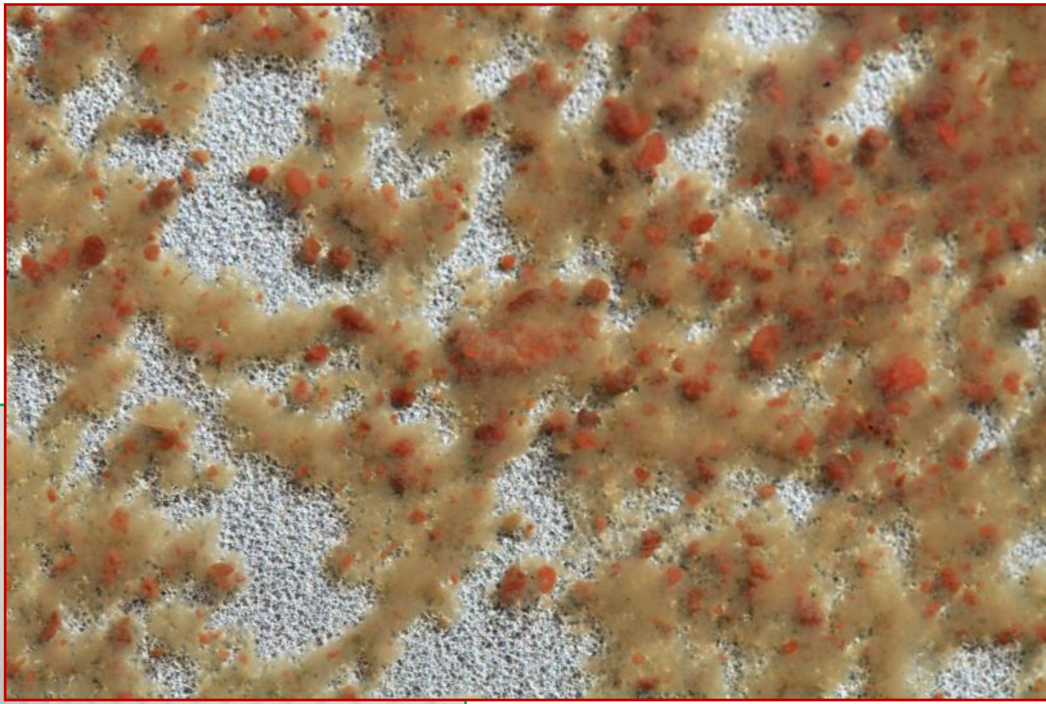
Biomass Seperation

- Retain anammox bacteria in small dense granules
- SRT of anammox granules >> SRT of AOB, NOB, heterotrophs, debris
- Create “washout” conditions for NOBs
- Control activity of AOB population





DEMON Seed Sludge



DEMON Benefits for HRSD

- Capital Cost Savings:
  - Use existing tanks, piping and equipment
- Operation and Maintenance Cost Savings:
  - Alkalinity cost offset by DEMON process:
    - $98,000/year
  - External Carbon (methanol)
    - $88,000/year
  - Aeration Energy
    - $5,500/year

One-Step Sidestream Deammonification

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  - Strass, Austria + ~20 others
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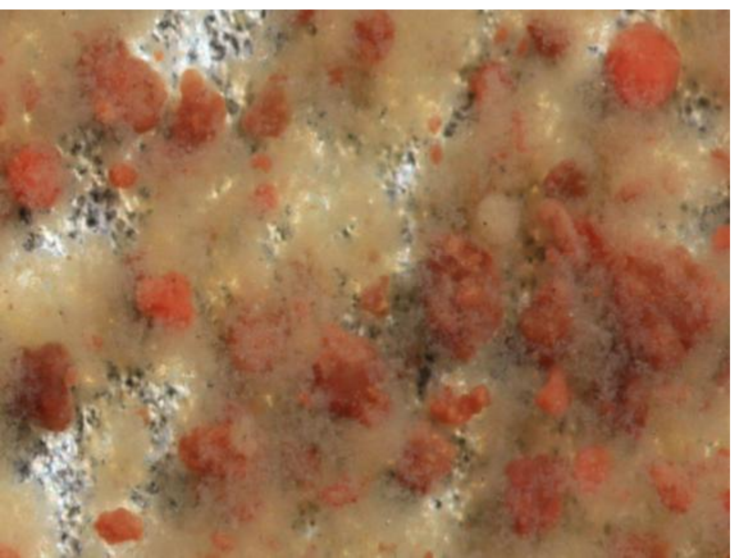
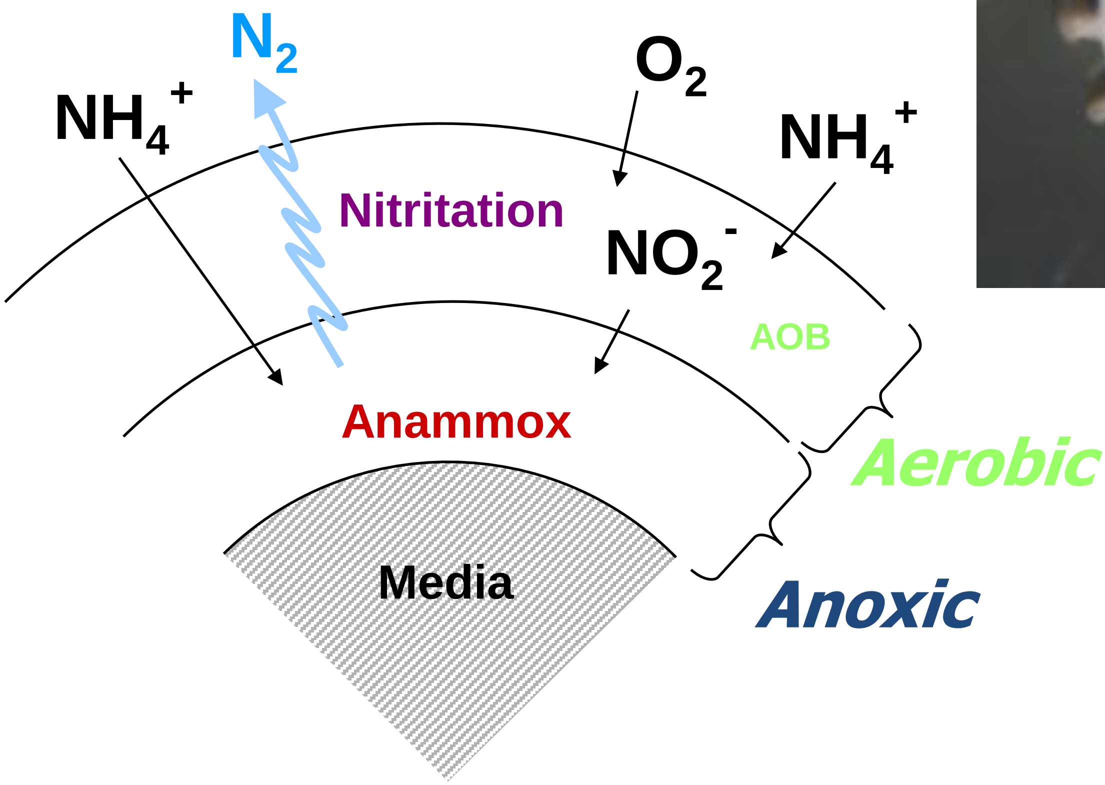
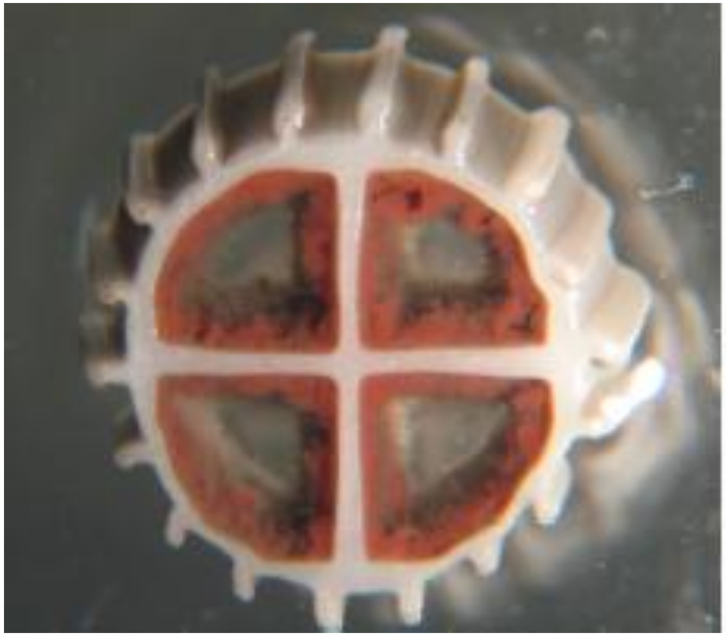


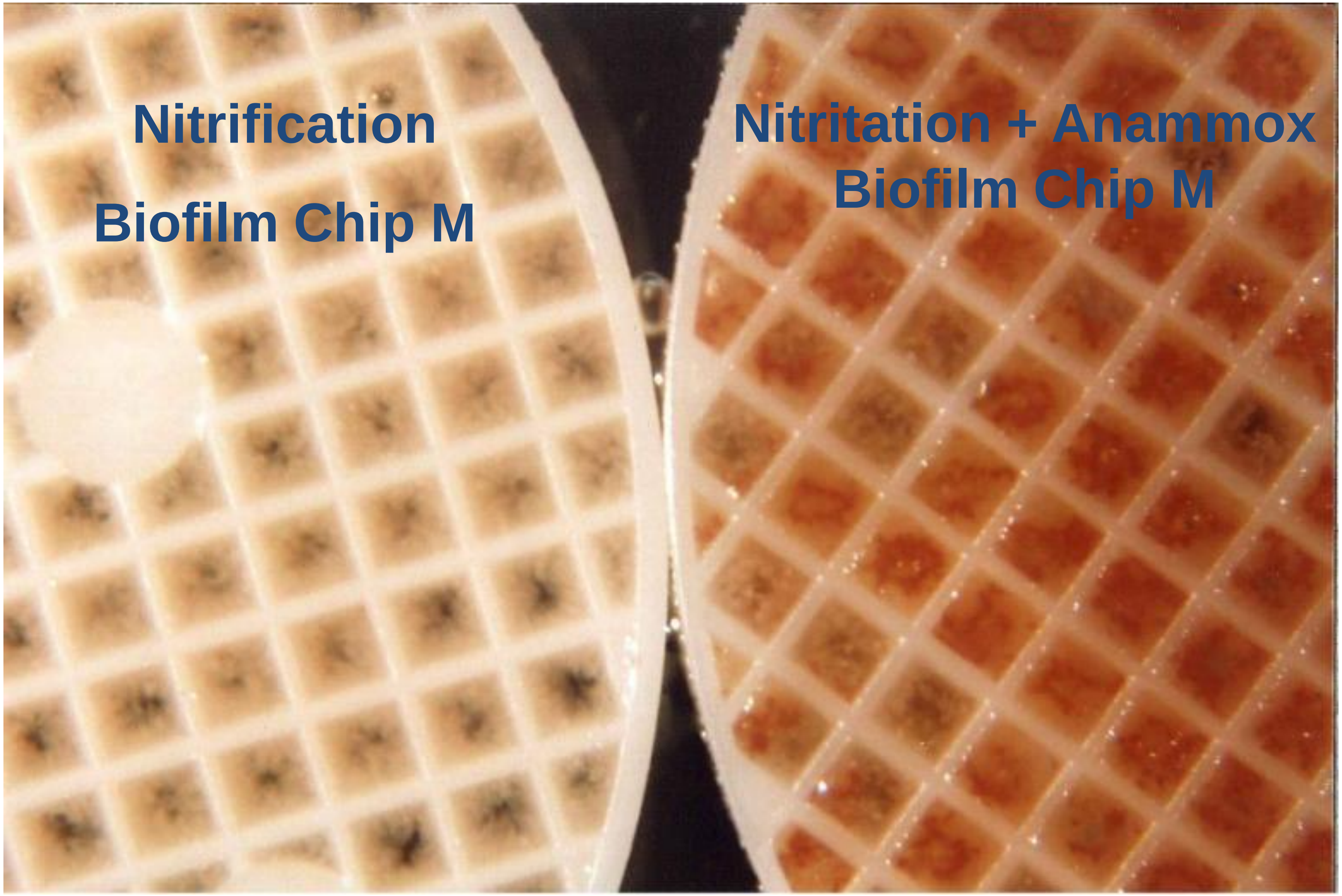
HRSD James River Treatment Plant

ANITA Mox Process



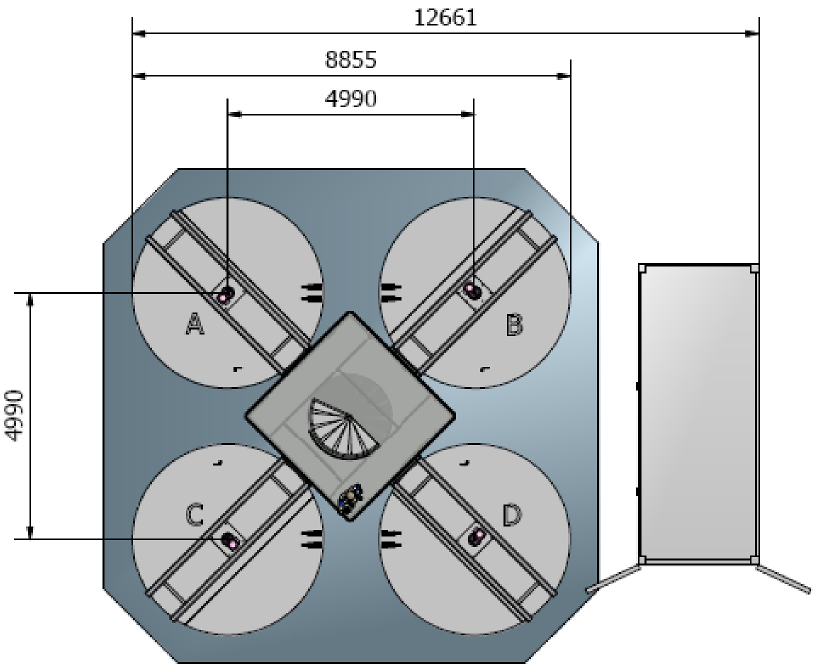


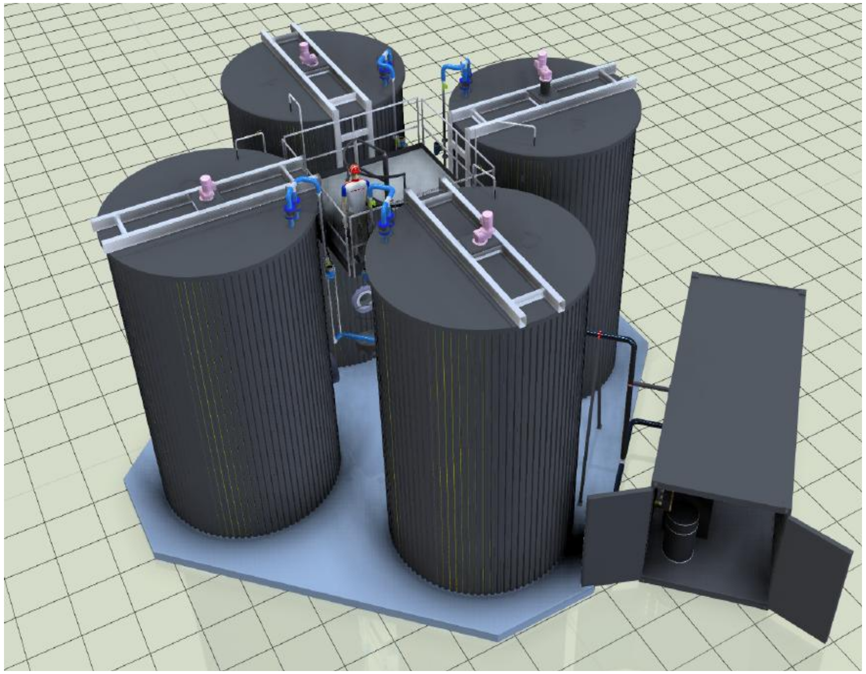
Nitrification vs ANITA Mox Biofilm



Pilot Test at Malmö Sjölunda WWTP

ANITA Mox –Malmö, Sweden





4 x 50m³ = 200m³

- ➔ Sjölunda WWTP reject water
- ➔ Capacity = 440 lbs/day NH4
- ➔ 800-1200 mgN-NH_4/L
- ➔ 1st ANITA Mox reference
- ➔ Flexibility for full-scale testing


RO SERVICE
Krüger

James River ANITA Mox Design

- Centrate flow = 0.075 MGD = 50 gpm (fully equalized)
- Centrate TKN load = 980 mg/L = 610 lbs/day
- Alk = 3500 mg/L (sufficient)
- Expected removal = 80% = 490 lbs/day N
- Tank volume = 100,000 gal
- NH4 Load Current = 0.7 kg N/day/m^3
- Tank = 25’ W x 36.5’ L x 15’ SWD
  - Media fill (K5 seed [5%] + K5 new makeup) = 32%
  - New aeration grid + one MOV
  - Mixers needed for startup and upsets
  - Tank cover replacement
  - Media retention screens
  - Process heating for startup and upsets
- DO, Temp, Conductivity, pH probes, WTW NH_4^+ &NO_3^- ISE

Sidestream Treatment Options

Biological - N

1.0

Nitrification / Denitrification & Bioaugmentation
- With RAS & SRT Control
- With RAS
- Without RAS

2.0

Nitritation / Denitritation
- Chemostat
- SBR
- Post Aerobic Digestion

3.0

Deammonification
- Suspended Growth SBR
- Attached Growth MBBR
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Physical-Chemical – N&P

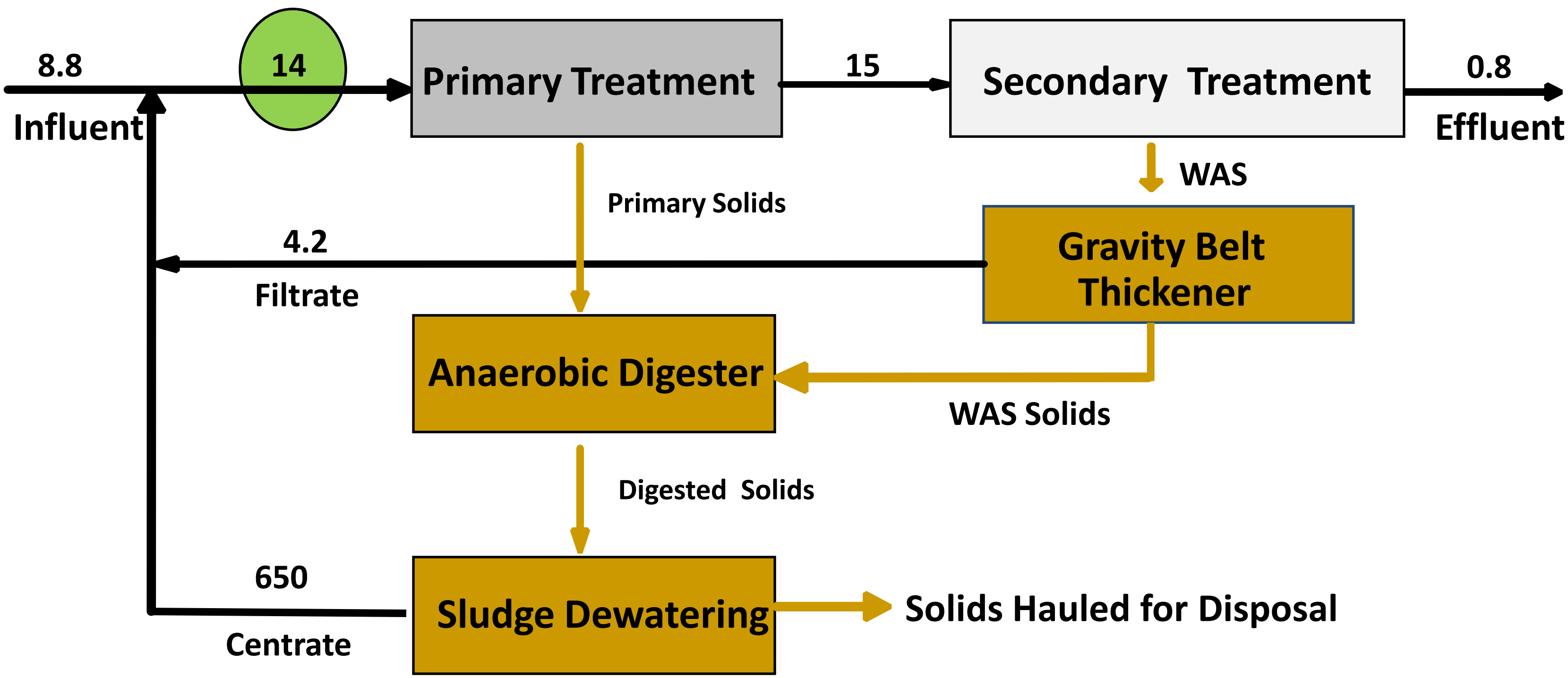
Ammonia Stripping
- Steam
- Hot Air
- Vacuum Distillation

Ion-Exchange
- ARP

Struvite Precipitation
- Ostara Process
- PhosPaq Process

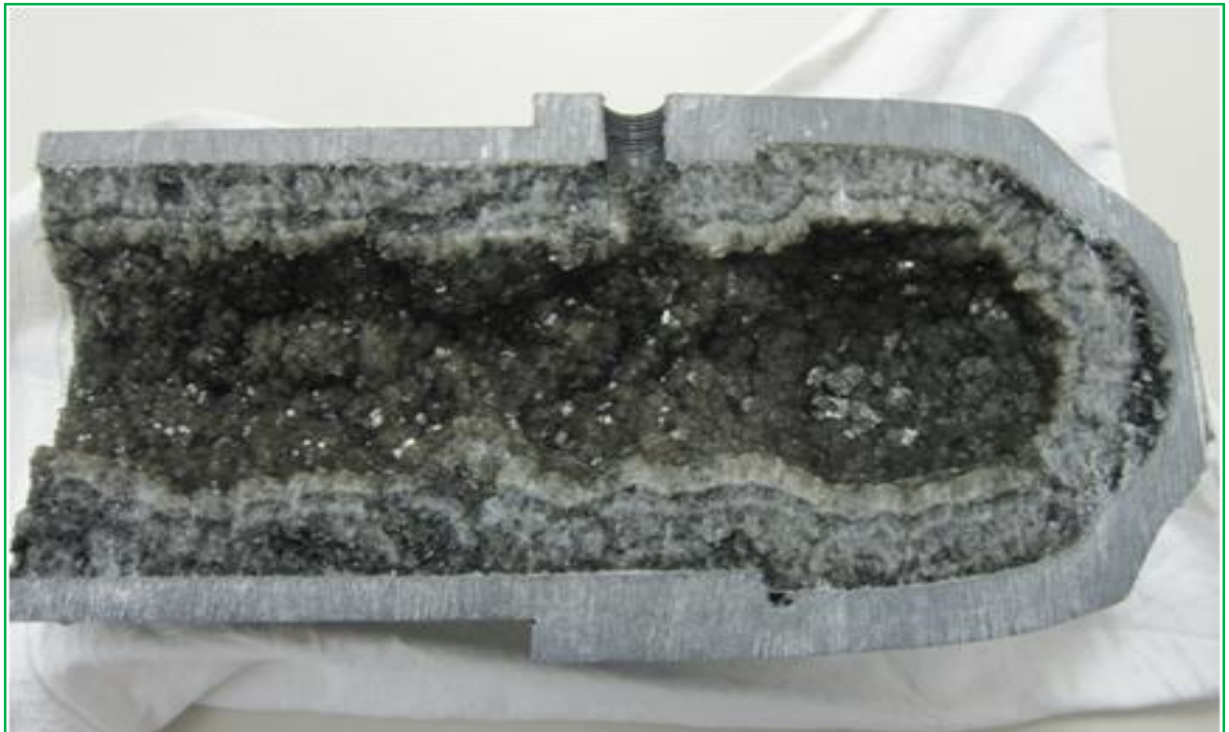
HRSD Nansemond Treatment Plant

Phosphorous Profile



Values in mg/L TP

What is Struvite?

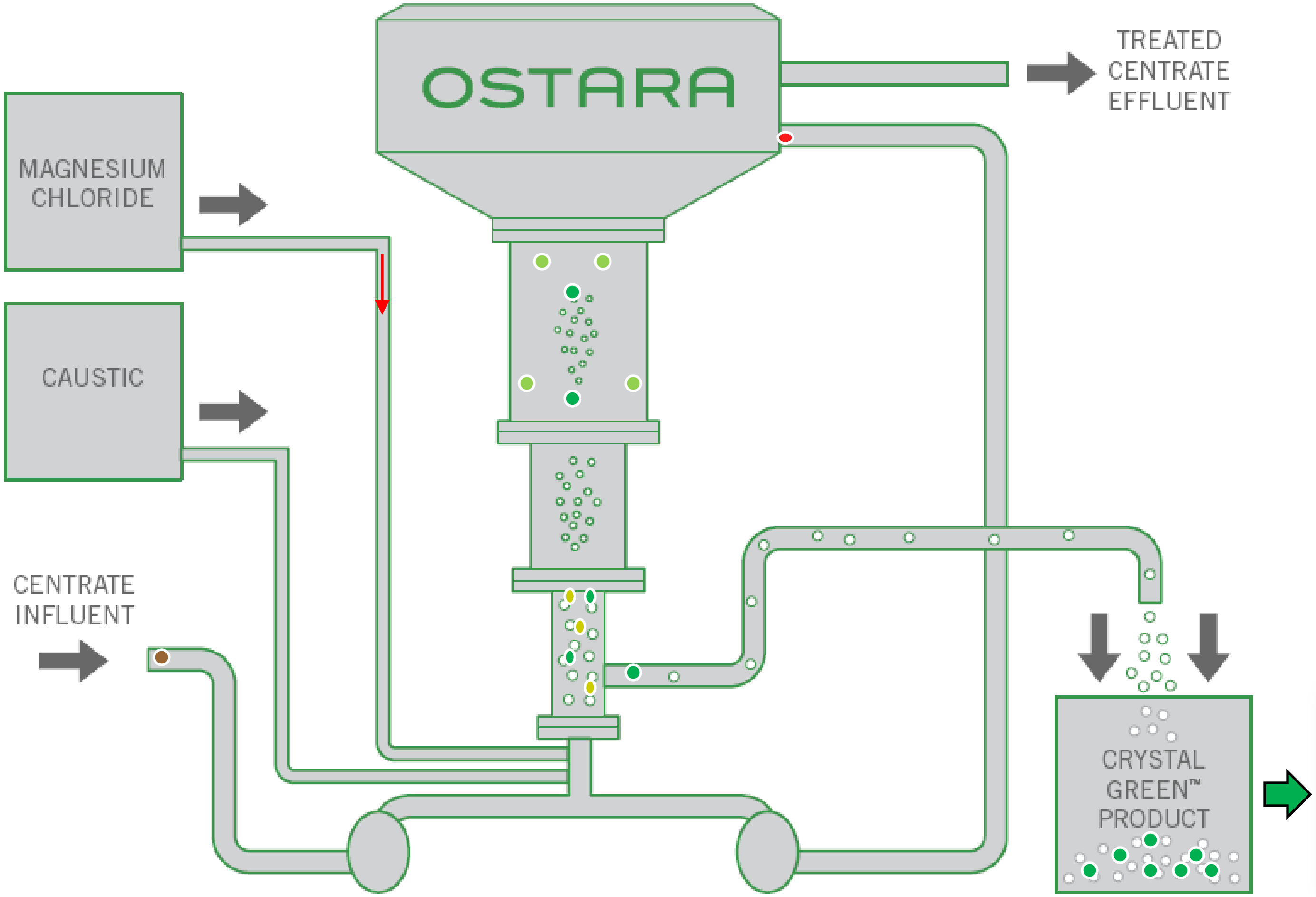


How Bad Can it Get?

Centrifuge Bowl Scoring

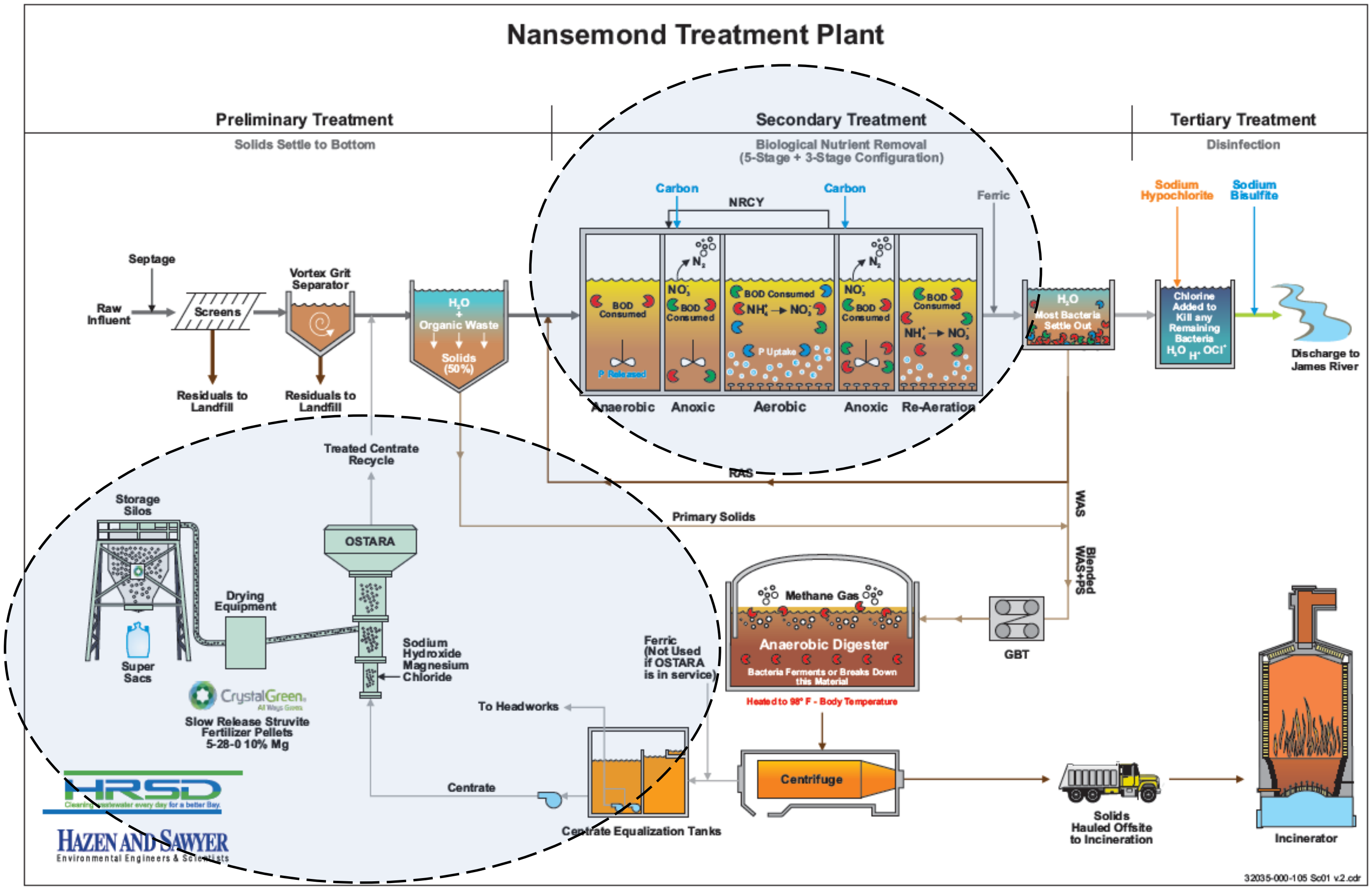
Pipe Restrictions

What is the Ostara® Process?



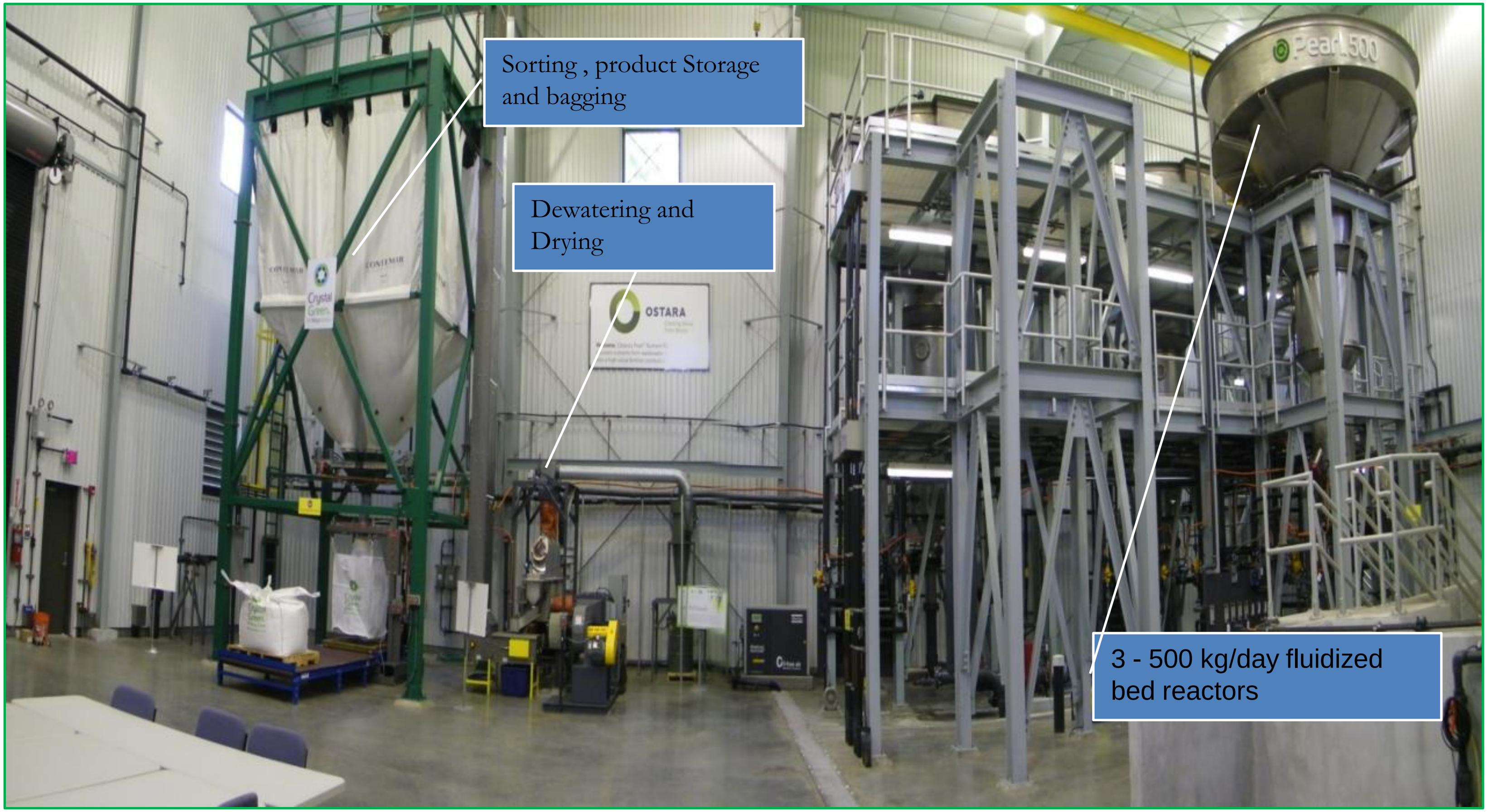
Nansemond Treatment Plant Upgrade

Process Flow Diagram



Struvite Recovery Facility

Struvite Recovery Facility



Nutrients Recovered
(Crystal Green®)

Short-Cut Nitrogen Removal Processes: Transitioning to Mainstream 2.0 & 3.0

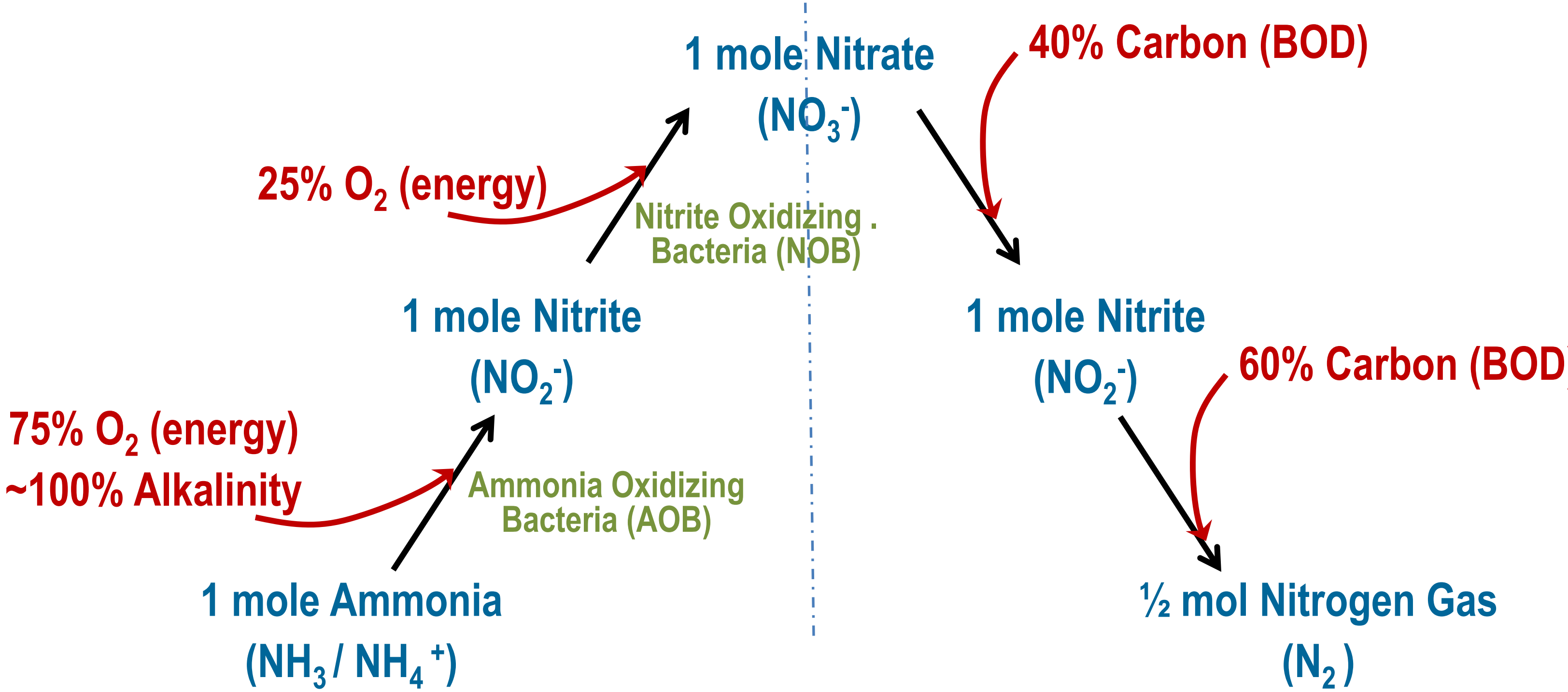
Mainstream 2.0 & 3.0 Pilot Program

– Collaboration through Water Environment Research Foundation (WERF) project grant – Soon EPA Nutrient Center grant:
  - HRSD & DCWater
  - Austrian (Strass) and Swiss wastewater utility
  - Developers of the DEMON process (Bernhard Wett, et al)
  - ODU, Virginia Tech, Columbia University (NY), University of Innsbruck (Austria), University of Central Florida
  - US engineering firms – HDR, Black & Veatch, AECOM, Brown & Caldwell
  - Several other interested US wastewater utilities

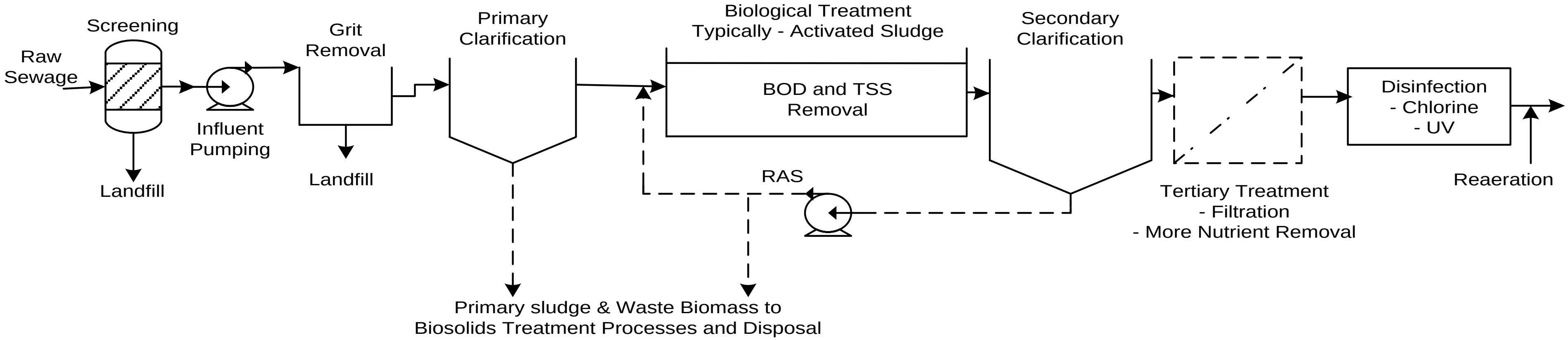
Conventional Nitrification-Denitrification **(1.0)**

Autotrophic Bacteria
Aerobic Environment

Heterotrophic Bacteria
Anoxic Environment

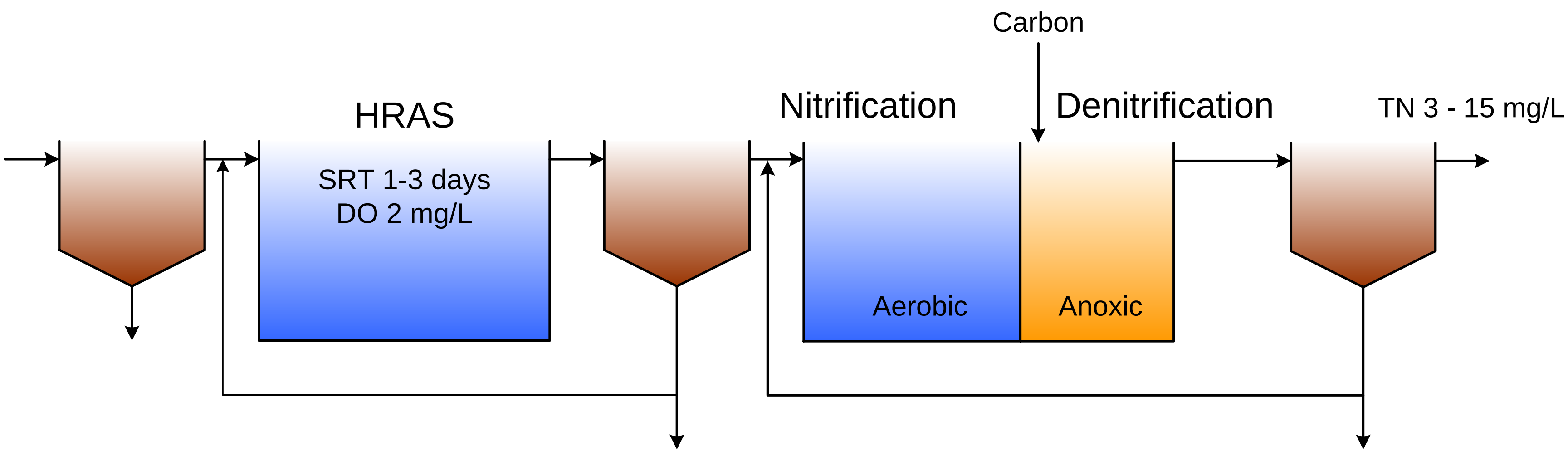


Wastewater Treatment 101 – Liquid Processes



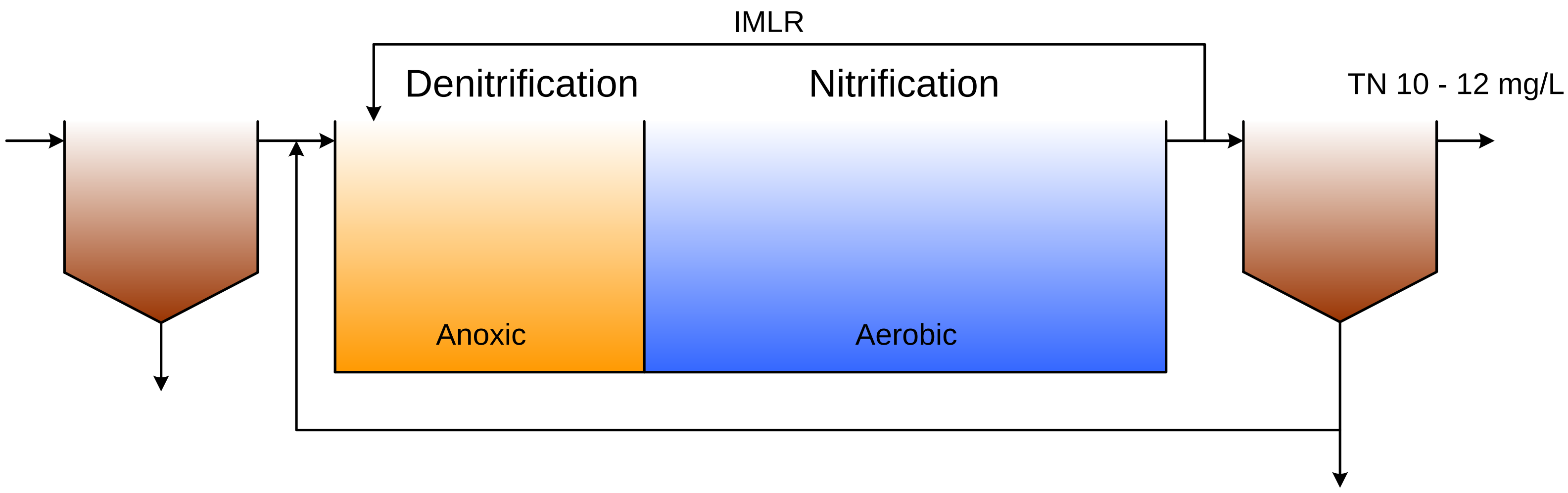
High Rate Activated Sludge

Two-Sludge BNR



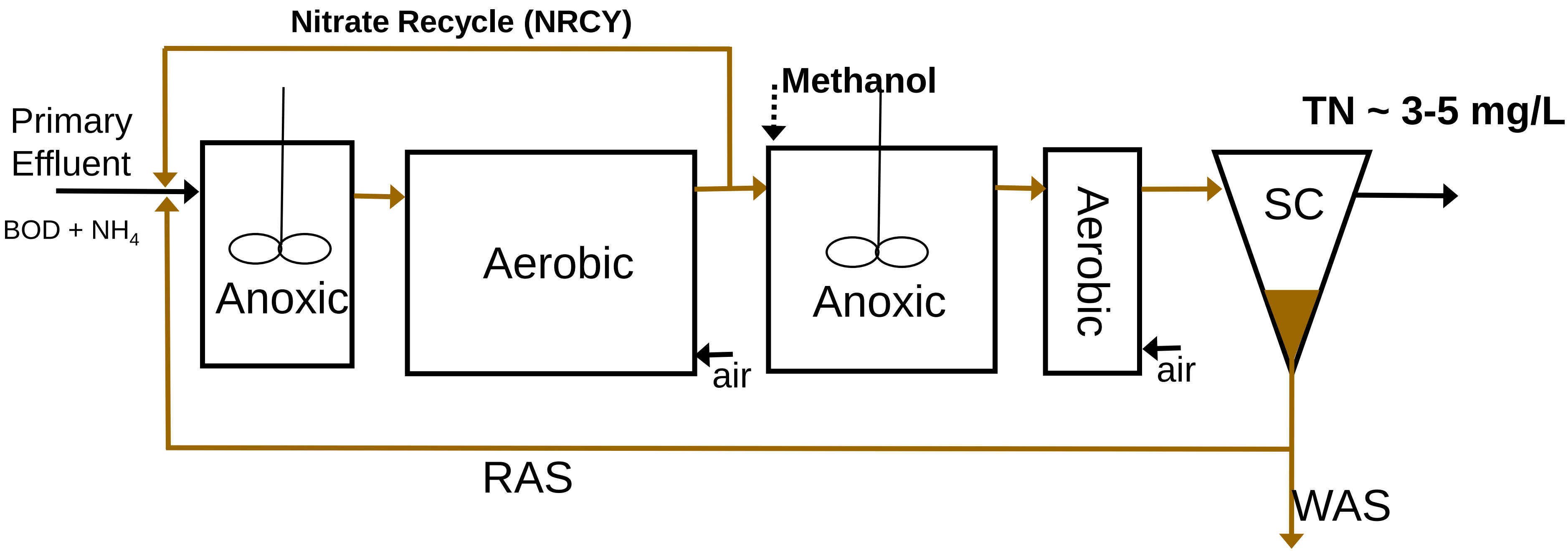
Advantages	Disadvantages
High nitrogen removal possible	WW carbon not utilized for denitrification
Low BNR volume	Nitrification can be alkalinity limited

Conventional BNR - MLE

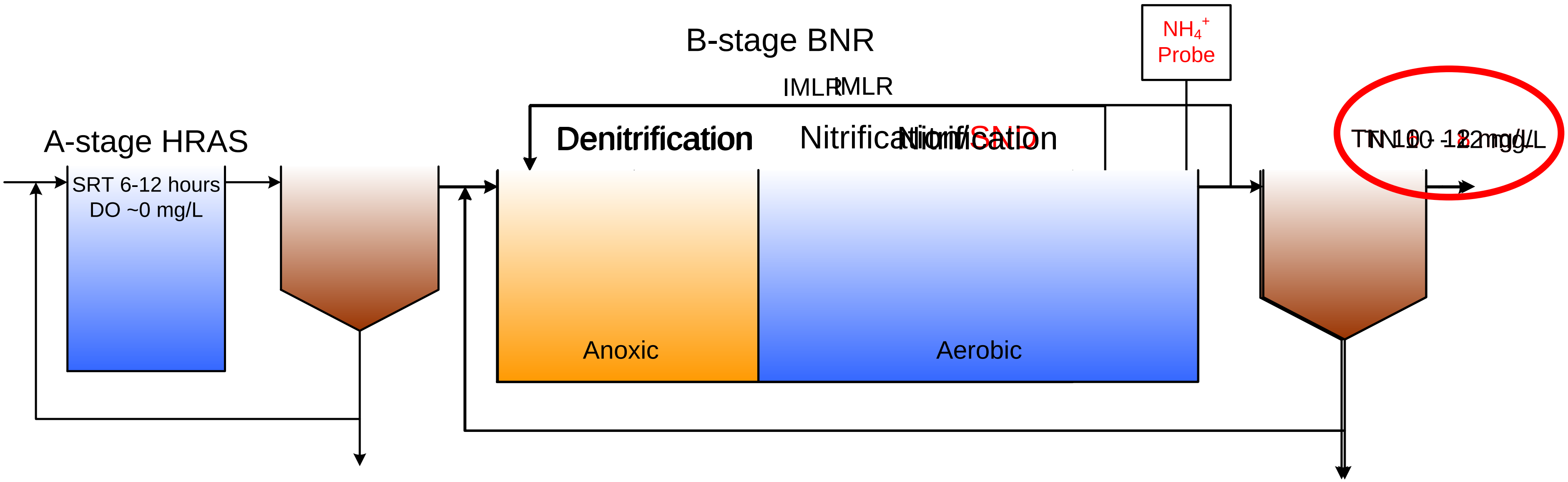


Advantages	Disadvantages
WW carbon utilized for denitrification	Large BNR volume
Alkalinity recovered	Nitrogen removal limited by IMLR

4-Stage Bardenpho
(Better N Removal)

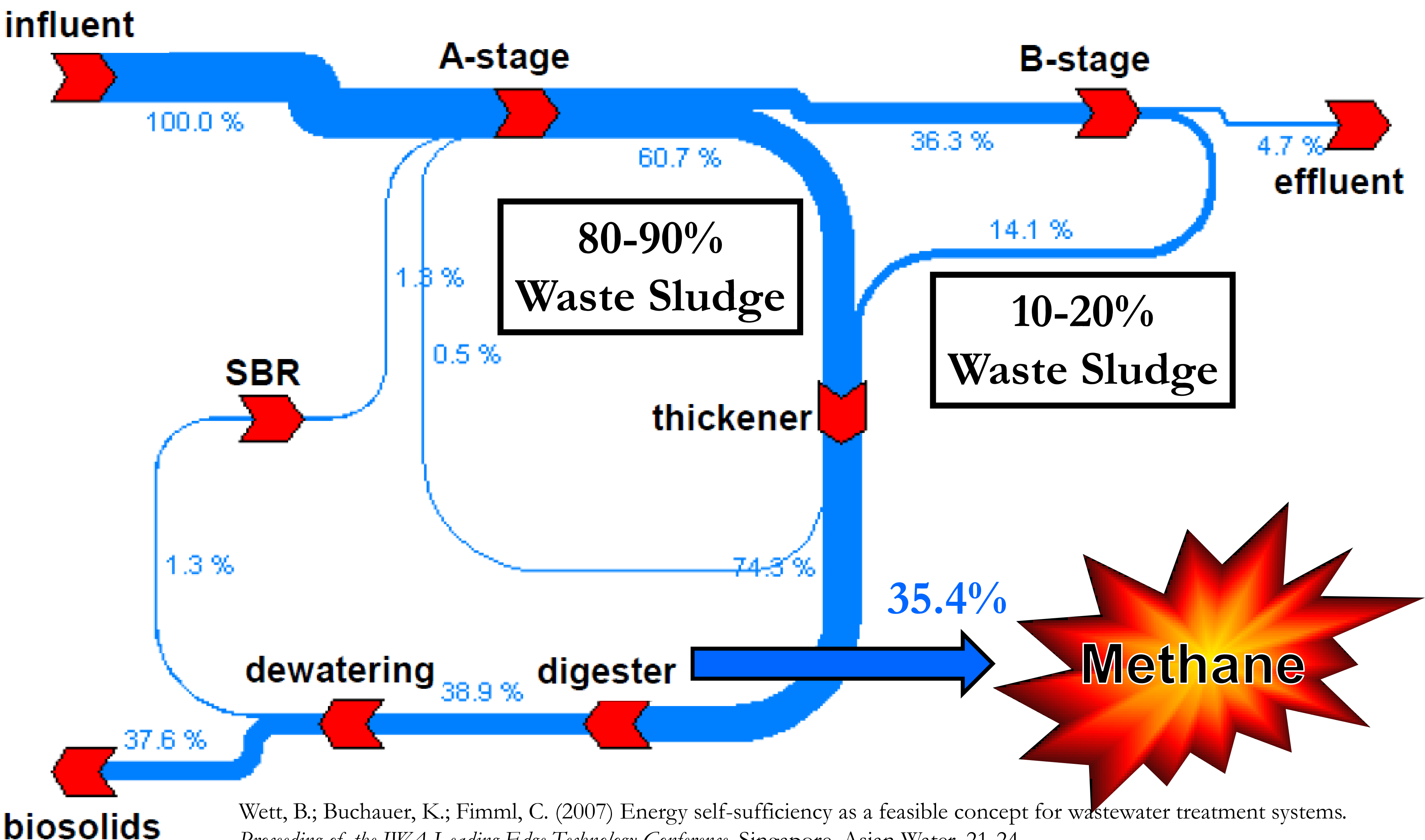


Adsorption/Bio-oxidation (A-B) Process



Advantages	Disadvantages
Low overall volume	Requires ammonia-based aeration control
Good nitrogen removal	Not operated to achieve complete nitrification
Redirect carbon to anaerobic digestion	
Low aeration energy requirement	

Simulated COD Balance of the AIZ Strass WWTP

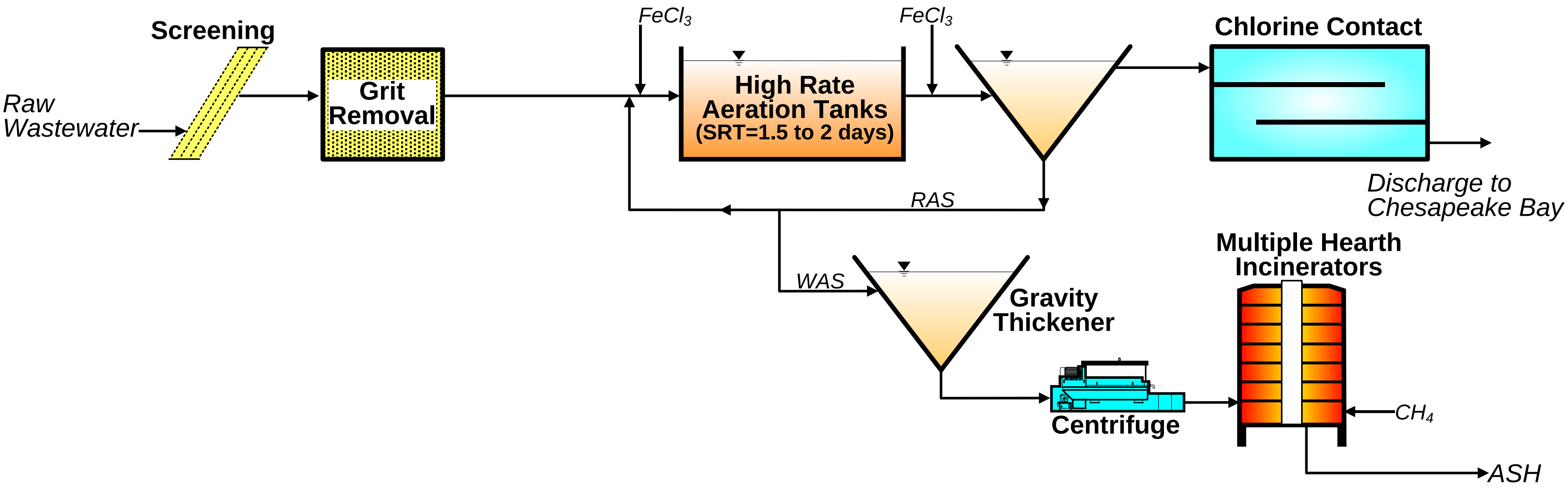


Wett, B.; Buchauer, K.; Fimml, C. (2007) Energy self-sufficiency as a feasible concept for wastewater treatment systems. *Proceeding of the IWA Leading Edge Technology Conference*, Singapore, Asian Water, 21-24.

Some Motivation for Pilot Work…

- Nitrogen removal upgrade required by 2021 to meet TN of approximately 5 mg/L
- Capital Cost = $125-150M (conventional process)
- Operating costs will increase dramatically:
  - Incremental Energy for aeration and pumping = $1.0 M/yr
  - Incremental chemicals (caustic and carbon) = $1.0 to 2.0 M/yr
  - Labor & supplies?
- Limited land available
  - Nutrient Removal
  - Biosolids

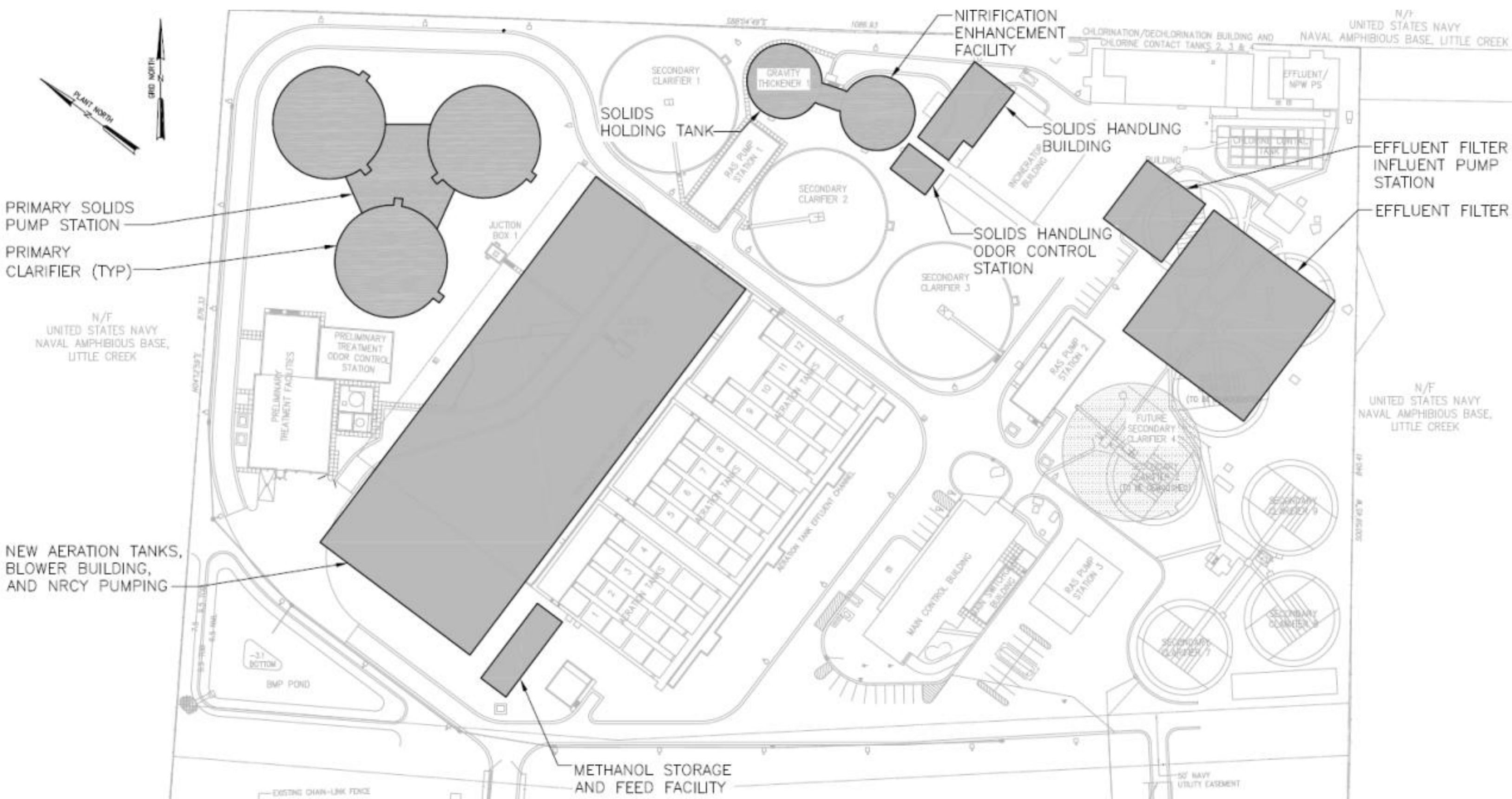
Chesapeake-Elizabeth Treatment Plant



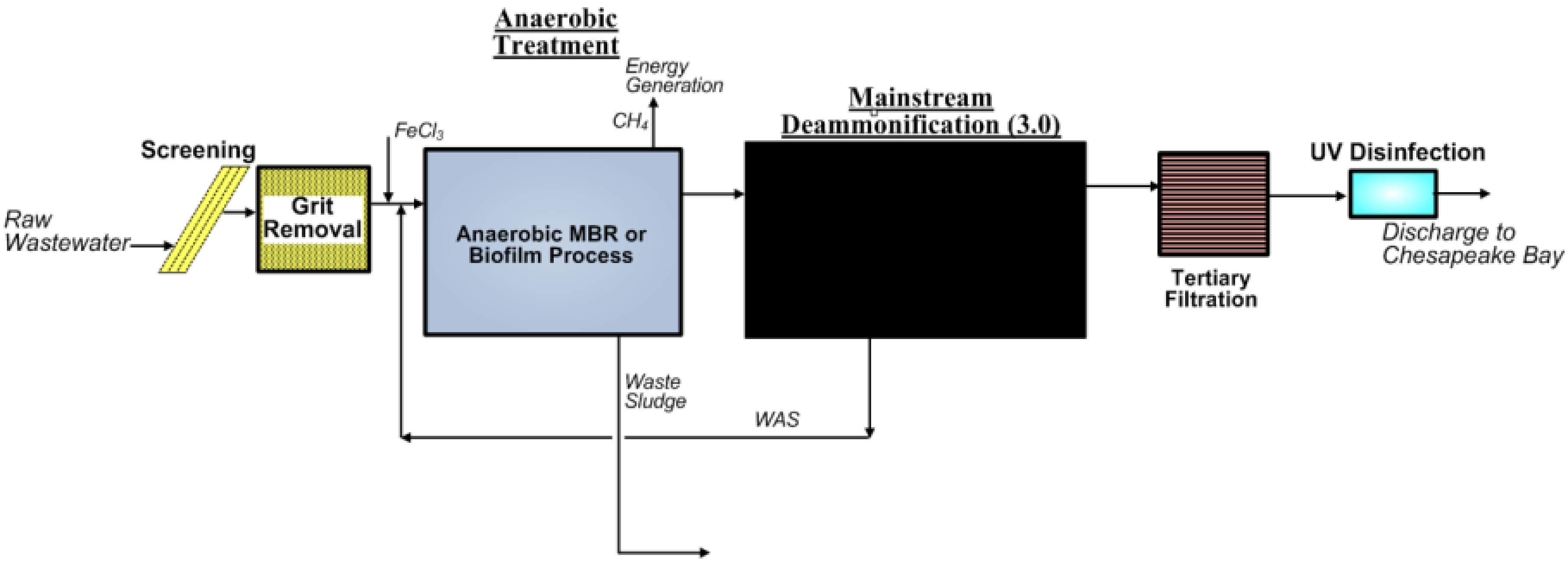
Parameter	Value
Design Flow (MGD)	24
Operating Flow (MGD)	15-20
Annual TP Limit (mg P/L)	2

Traditional BNR Alternative by 2021

- Construct primary clarifiers
- Construct:
  - 5-stage Bardenpho (+9 MG) & Filters
  - MLE or VIP + Denite Filters
- Incinerator scrubber blowdown treatment
  - Sidestream biological treatment of cyanide
- Thickening improvements
- Full Distributed Control System (DCS)



An Ideal Configuration…



Tools for SND-Style Processes **(2.0)**

- Ammonia-based Aeration Control
  - Allows stringent control over DO provided
  - Control aerobic SRT to be as long as needed

- NOB Repression
  - Must be controlled and confirmed

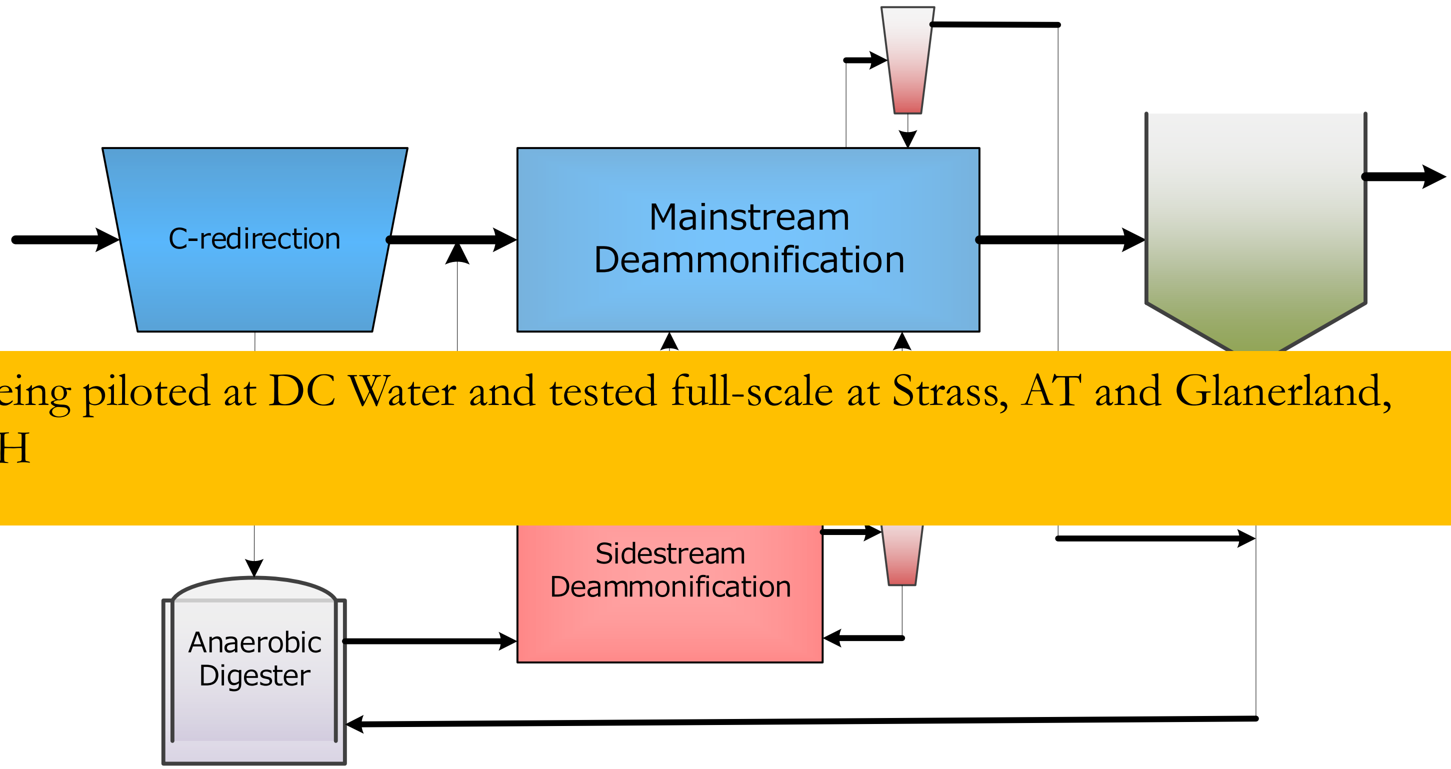
- Deliver just the right amount of COD and use it for **denitritation**

Objectives for 3.0

- Redirect unnecessary carbon/COD
  - Primary clarifier (likely insufficient for typical HRSD wastewater)
  - A-stage HRAS
  - Chemically Enhanced Primary Treatment (Fe or Al salt + polymer)
  - Anaerobic treatment (UASB, AnMBR)
  - **(Minimizes B-stage volume required)**
- Repress NOBs under difficult conditions
  - Low temp
  - Low NH4
- Retain Anammox (high SRT needed)
  - Granular sludge
  - Biofilm process (e.g. MBBR)
  - Membrane bioreactor

Plants with Anaerobic Digestion

- Incentive for C-redirection



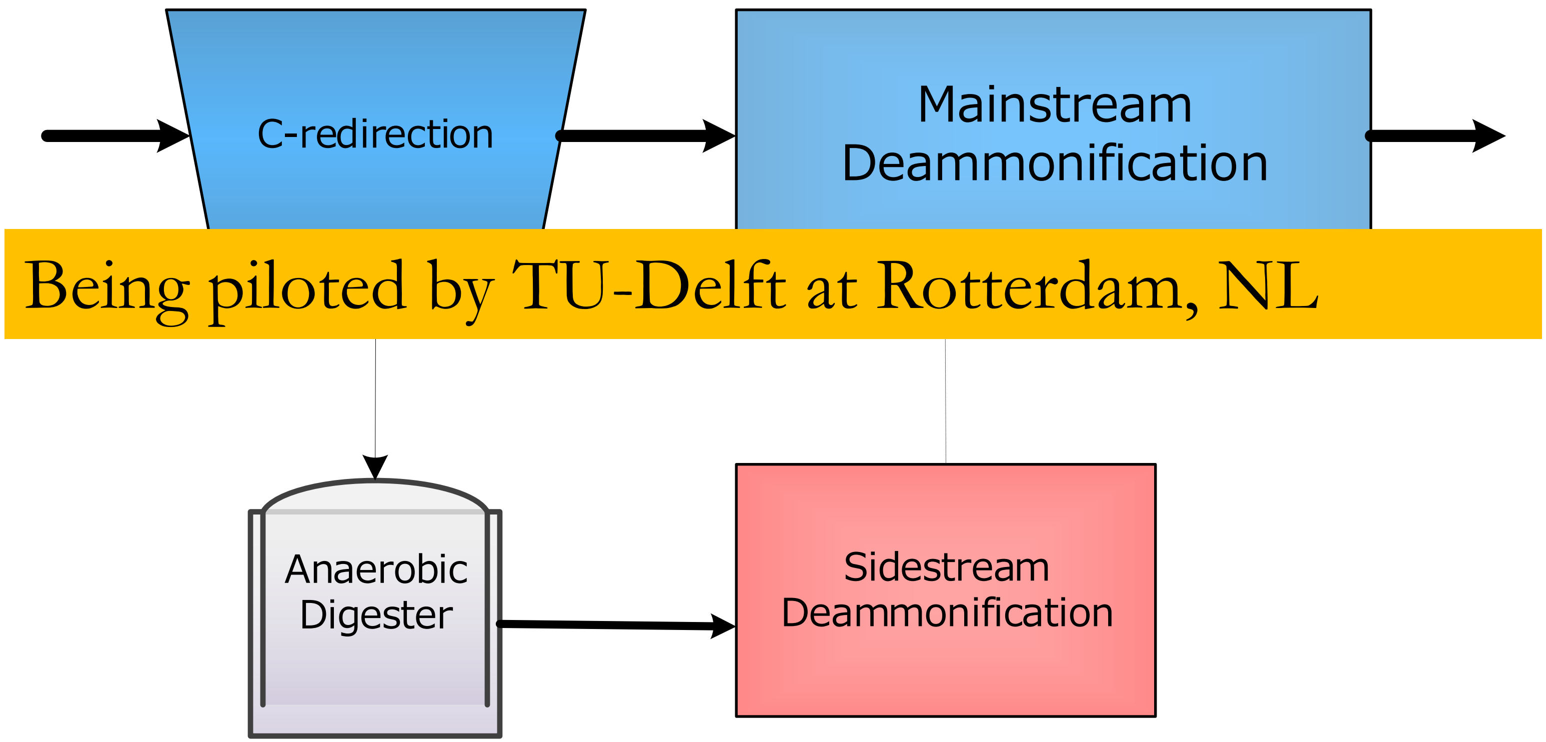
Being piloted at DC Water and tested full-scale at Strass, AT and Glanerland, CH

Key Features:

1. Bioaugment AOB in the sidestream cyclone overflow to the mainstream
2. Bioaugment anammox from sidestream to mainstream
3. Cyclone for anammox retention in mainstream
4. Repress NOB in mainstream (and sidestream)

Dutch Approach

For plants with anaerobic digestion



Key Features:

1. Large AOB-Anammox granules seeding from sidestream to mainstream
2. Large AOB-Anammox out-compete NOB in mainstream

HRSD Mainstream Approach

Anaerobic digestion is not necessary

- **Minimum aeration and volume for C-removal**
- **Reduce volumetric requirement for nitrogen removal**

- **Promote nitrite shunt pathway to achieve more nitrogen removal for a given influent C/N**
- **Produce effluent containing ammonia and nitrite for anammox polishing**

- **Remove remaining nitrogen autotrophically without additional aeration energy and supplemental carbon**
- **Meet very low effluent TIN limits**

WERF-Mainstream Deammonification Project
3 different sites and scales

DC Water

WWTP Strass

HRSD

Mechanisms for NOB Repression?

- Maintain maximum AOB rates
  - Minimize all limitations

- Competition – growth or bioaugmentation
  - Heterotrophs and anammox for nitrite
  - Heterotrophs and AOB for oxygen

- Outselection by unfavorable process conditions (DO-level, ...)

- Inhibiting or toxic impacts on NOB (e.g. NH3, NO, ...)

- Lag-phase in nitrite availability
  - intermittent aeration = transient anoxia

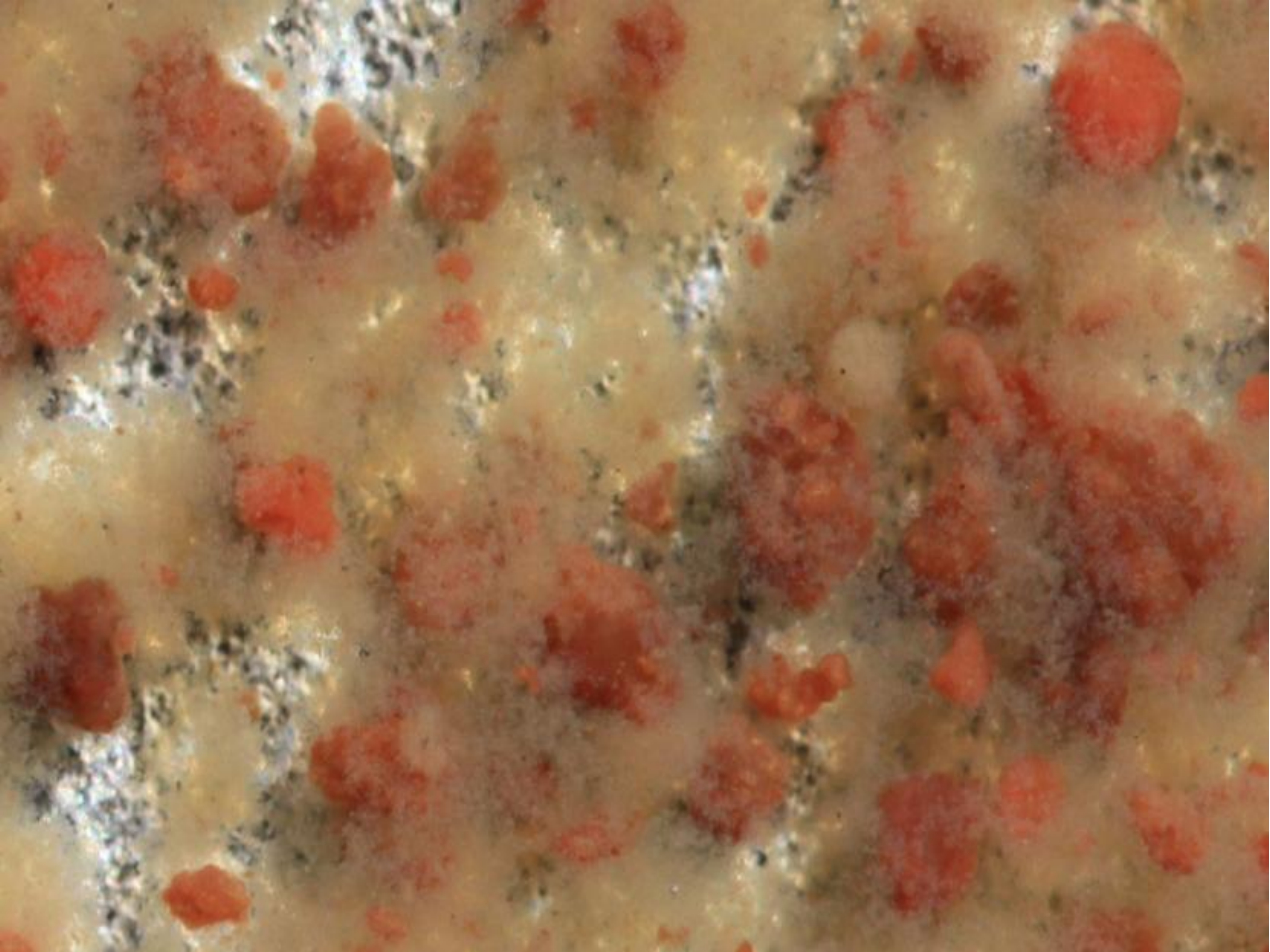
Anammox Retention Approaches

Granulation:

1) Settlers (internal or external)
2) Cyclones
3) Sieves

Biofilm:

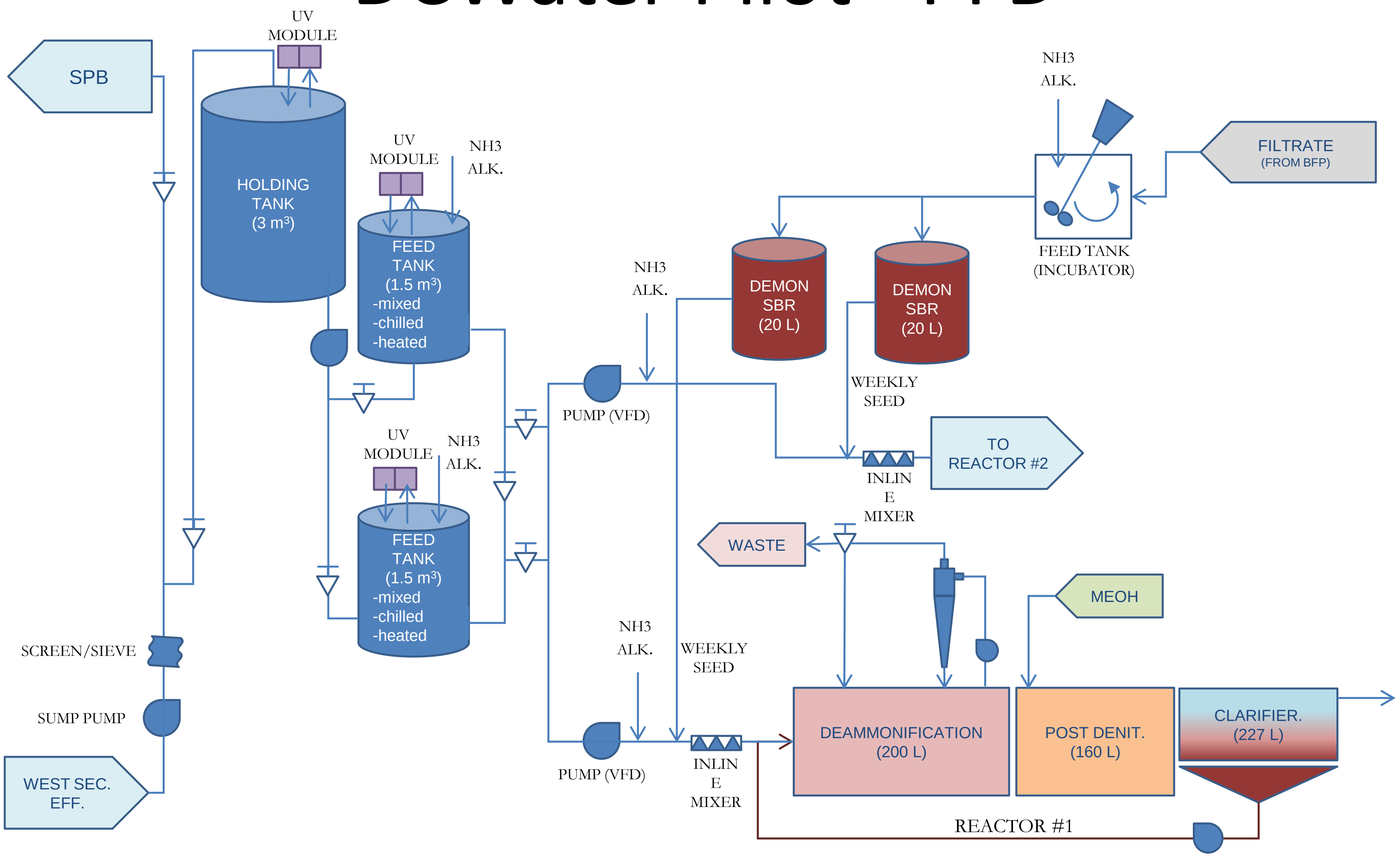
4) Plastic Media



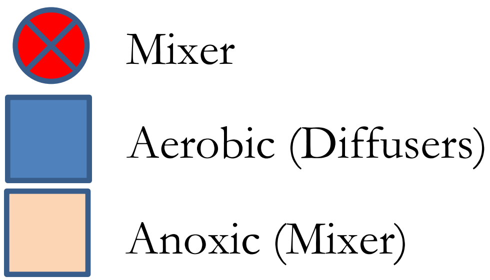
Emerging Recipe for NOB Out-Selection

- **Maintain residual ammonia**
  - *Ensures high ammonia oxidation rates*
  - *AOB compete with NOB for DO*
- **Intermittent High DO**
  - *At high DO AOB seem to grow faster than NOB*
- **Rapid transition to anoxia**
  - *DO is scavenged quickly when aeration is switched OFF*
- **Aggressive SRT control**
  - *Lower SRT results in selective washout of NOB*
  - *Ensures high operational DO for required ammonia oxidation*
- **Heterotrophic denitritation pressure on NOB in anoxia**
  - *Heterotrophic denitrifiers compete for NO_2 with NOB*
- **AOB and Anammox bioaugmentation from sidestream**
  - *AOB bioaugmentation causes population imbalance*
  - *Anammox compete with NOB for NO_2 in anoxia*

DCWater Pilot - PFD



Intermittent Aeration In Time – Cyclic Aeration



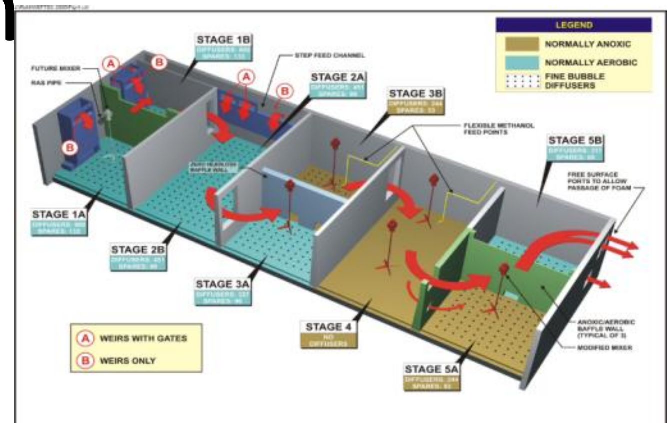
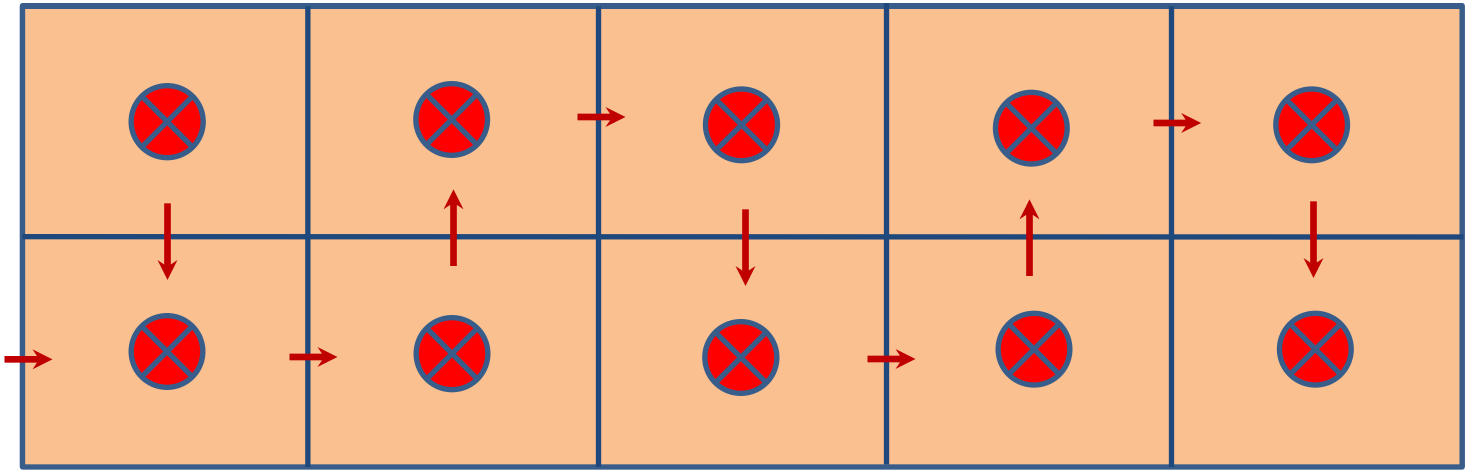


Figure 4 : Upgraded Nitrification / Denitrification Reactor

15 min "air off" **15 min "air on"**



Cyclic Aeration Operation

Intermittent Aeration In Space – Sequential Aeration

Mixer

Aerobic (Diffusers)

Anoxic (Mixer)

Swing (Mixer & Diffusers)

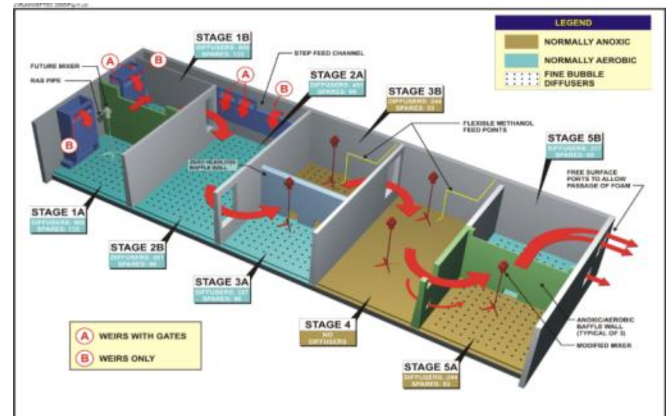
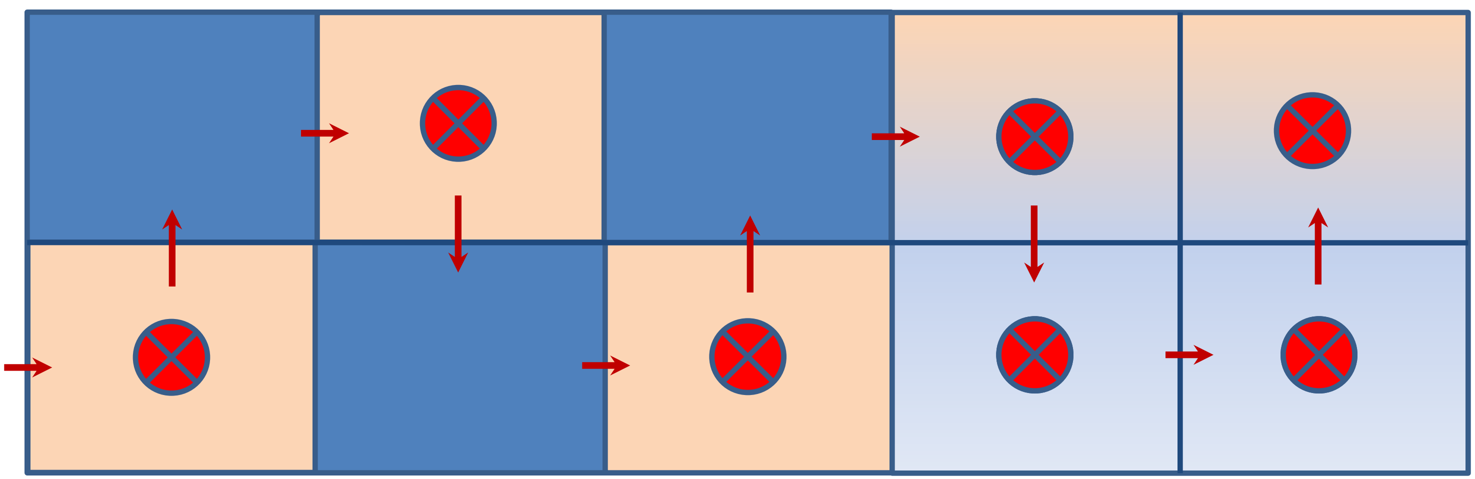
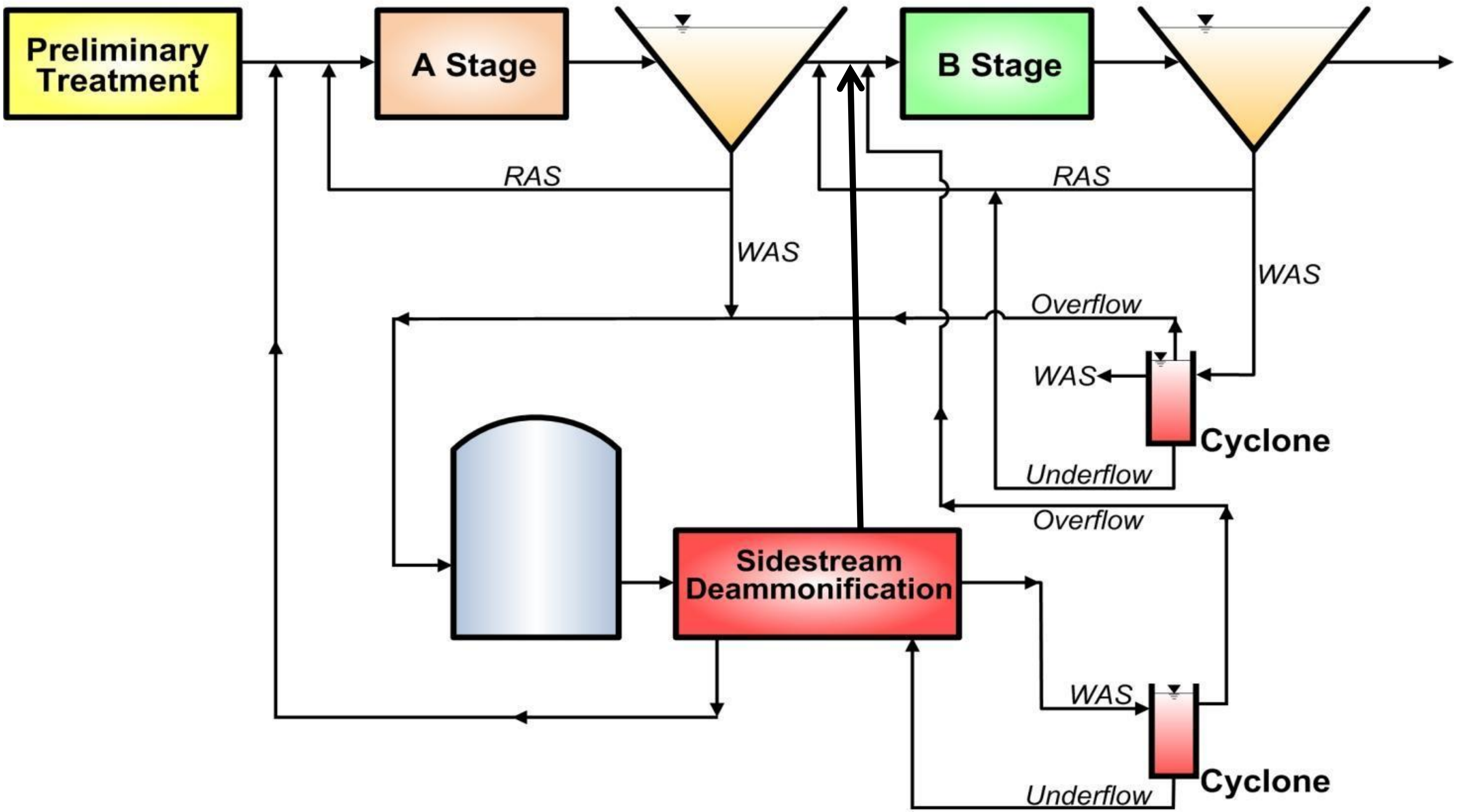


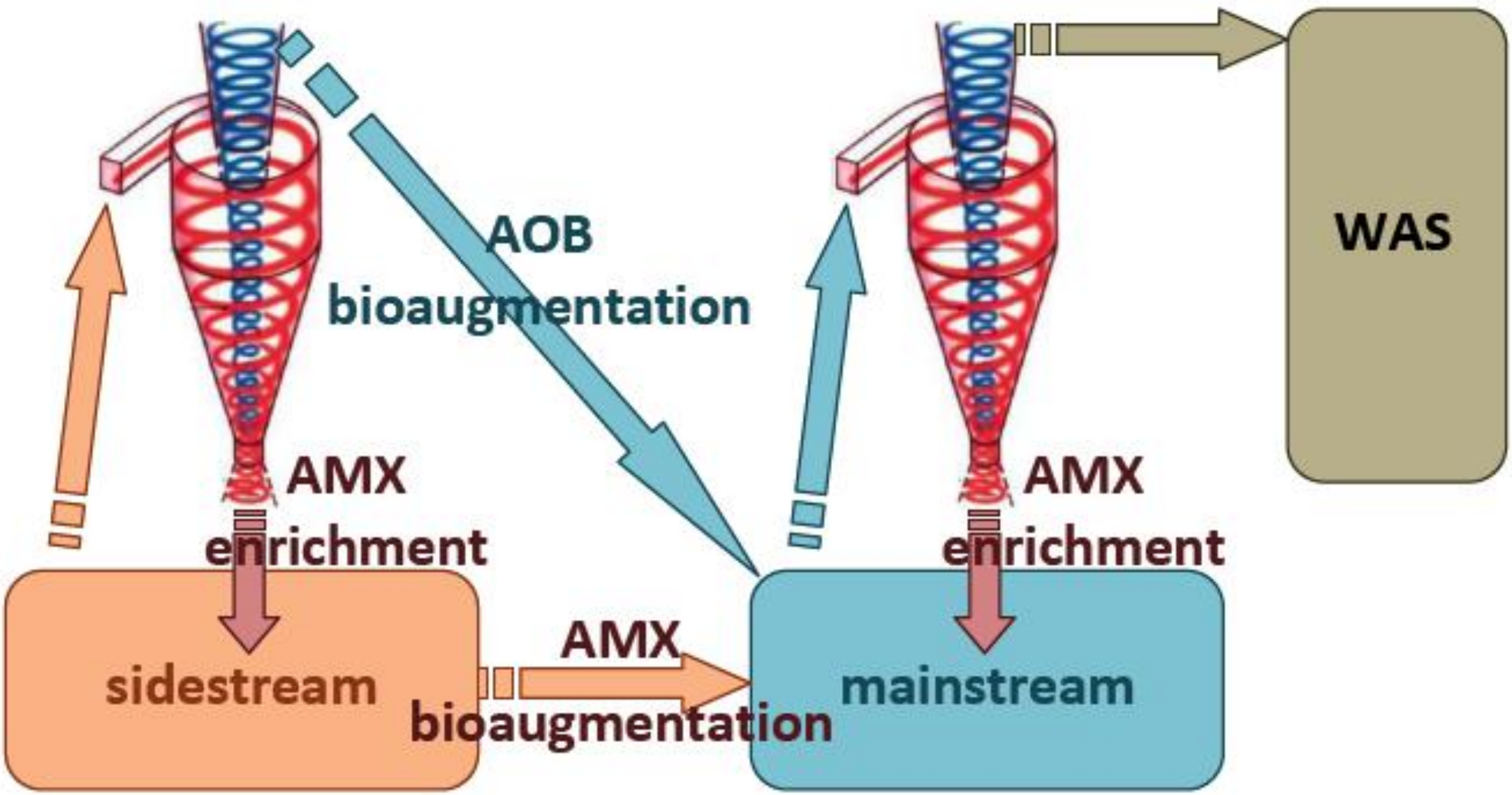
Figure 4 : Upgraded Nitrification / Denitrification Reactor



Sequential Oxic/Anoxic Operation

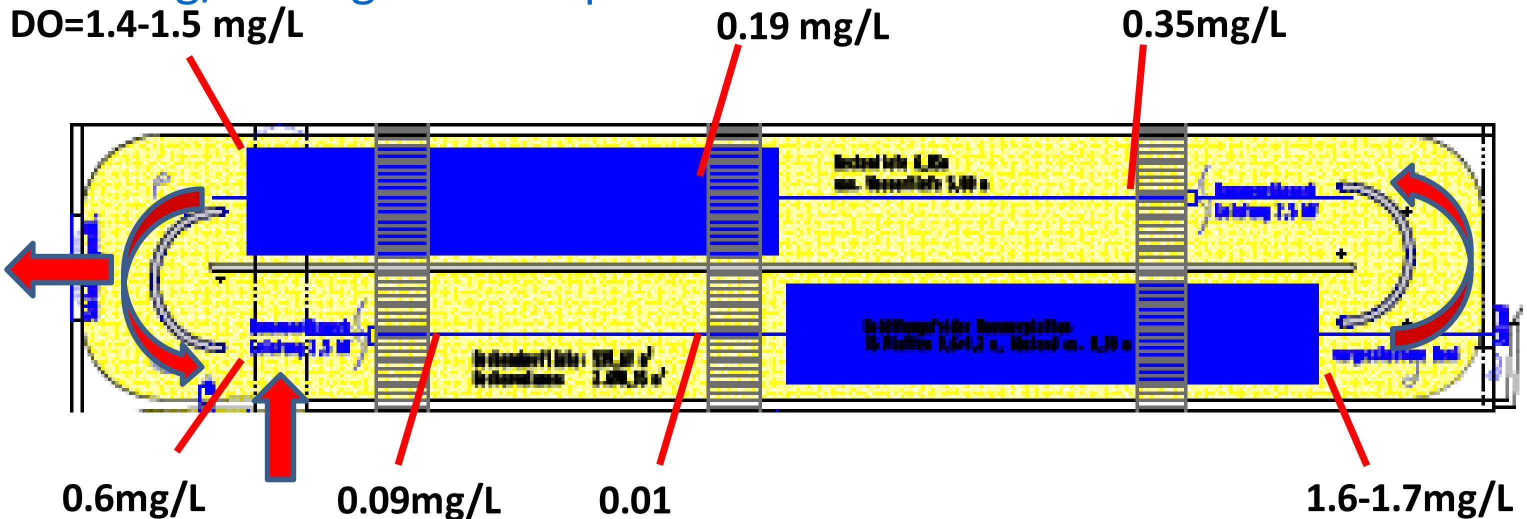
STRASS WWTP DEMONSTRATION (Full-Scale)




AOB
bioaugmentation
WAS
AMX
enrichment
AMX
enrichment
AMX
bioaugmentation
sidestream
mainstream

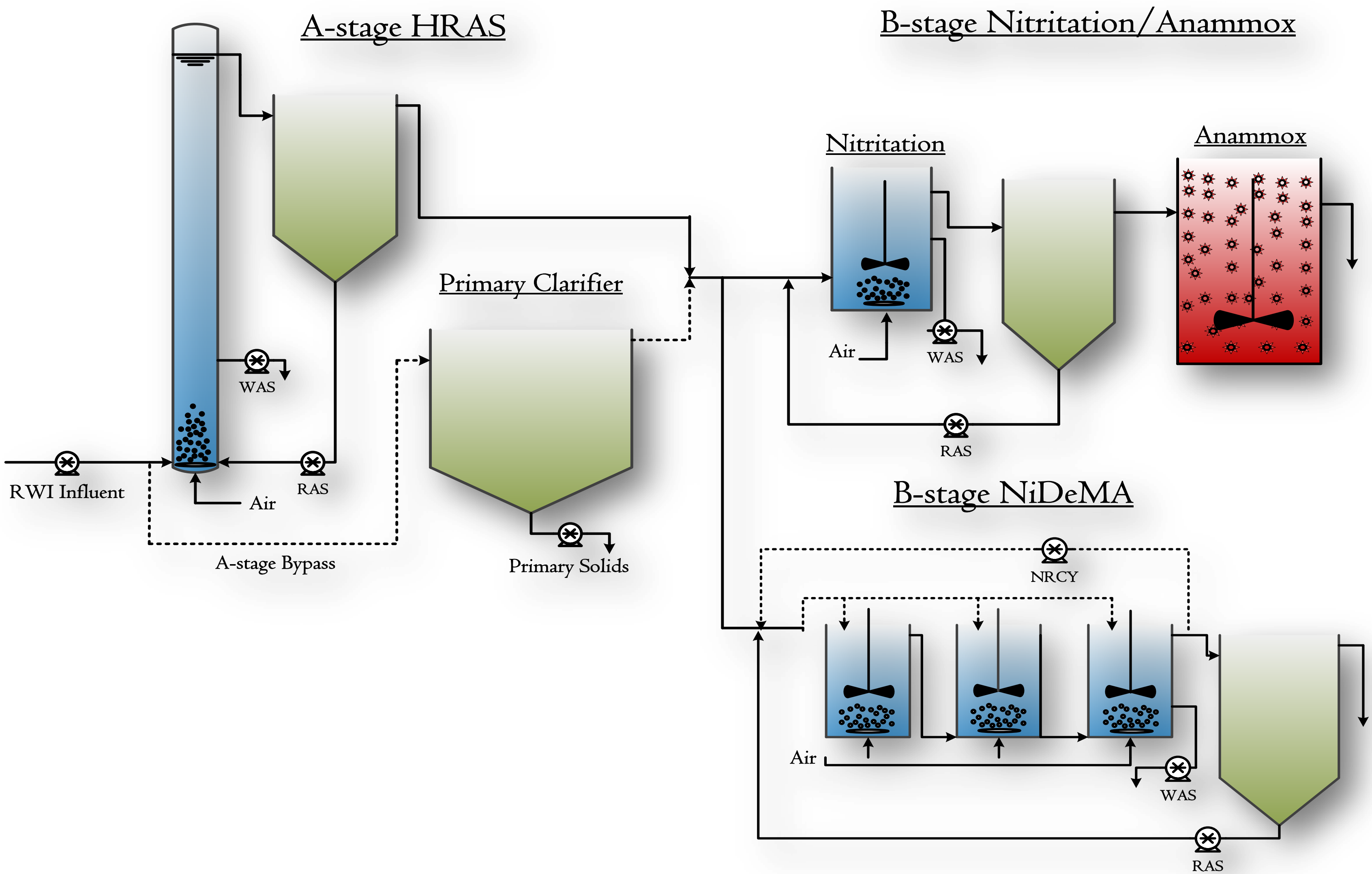
Strass Demonstration

- Carousel type aeration tank at Strass WWTP providing a DO-range of 0 to 1.7 mg/L along the flow-path.



Cyclones installed at the B-stage in Strass, Cyclone A (left), Cyclone B since early September 2011 (right).

HRSD Mainstream 2.0 & 3.0 Pilot



A-stage (High Rate Activated Sludge Process)

Parameters	
HRT	30 min
Influent Flow	341 liter/hr (1.5 gpm)
SRT	0.25 days (Target)
Temperature	25 ˚C
RAS	100%
Aeration	20 min "Air ON", 10 min "Air OFF"
Dissolved Oxygen	<0.1 mg/L (near zero)

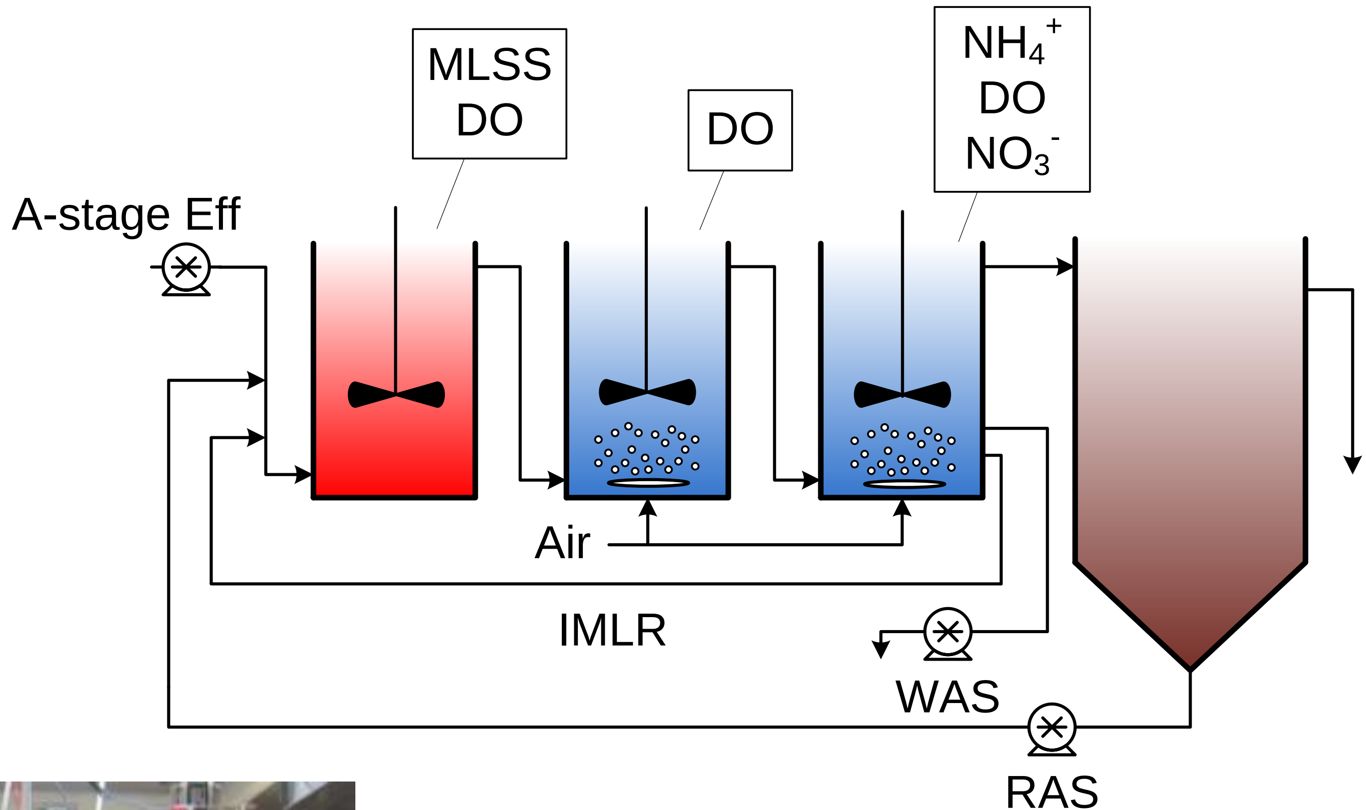
The goal:

Optimize carbon removal to provide influent that is amenable for maximum nitrogen removal in B-stage processes at wide range of operating conditions and temperature.

A-Stage

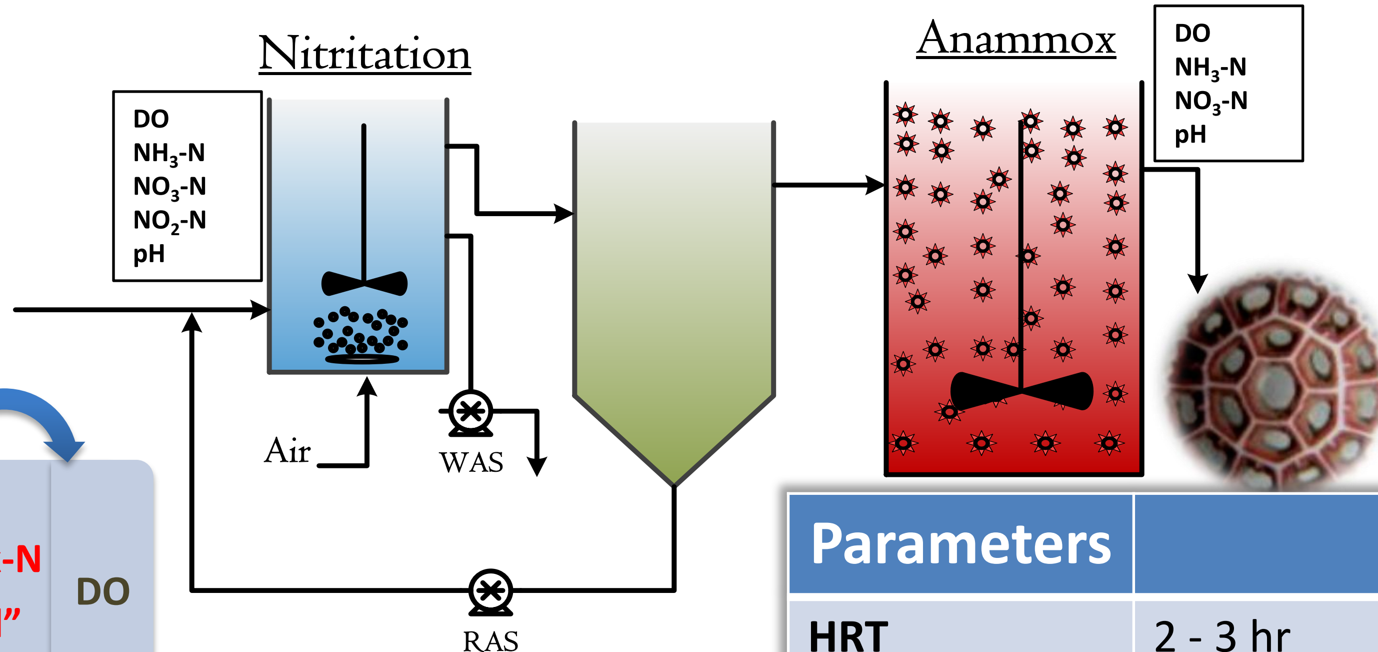
B-Stage MLE ➡ Transition to NiDeMA

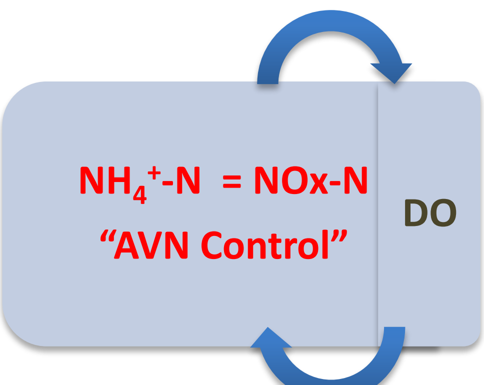
Parameter	Value
HRT (hrs)	3.3-4.2
SRT (days)	4-15
Temp (°C)	12-25
RAS (%Q)	50-150
IMLR (%Q)	100-400



Nitritation Denitritation through Modulating Aeration

Partial Nitritation/Denitritation + Anammox MBBR





The goals:

Nitritation/Denitritation Process:

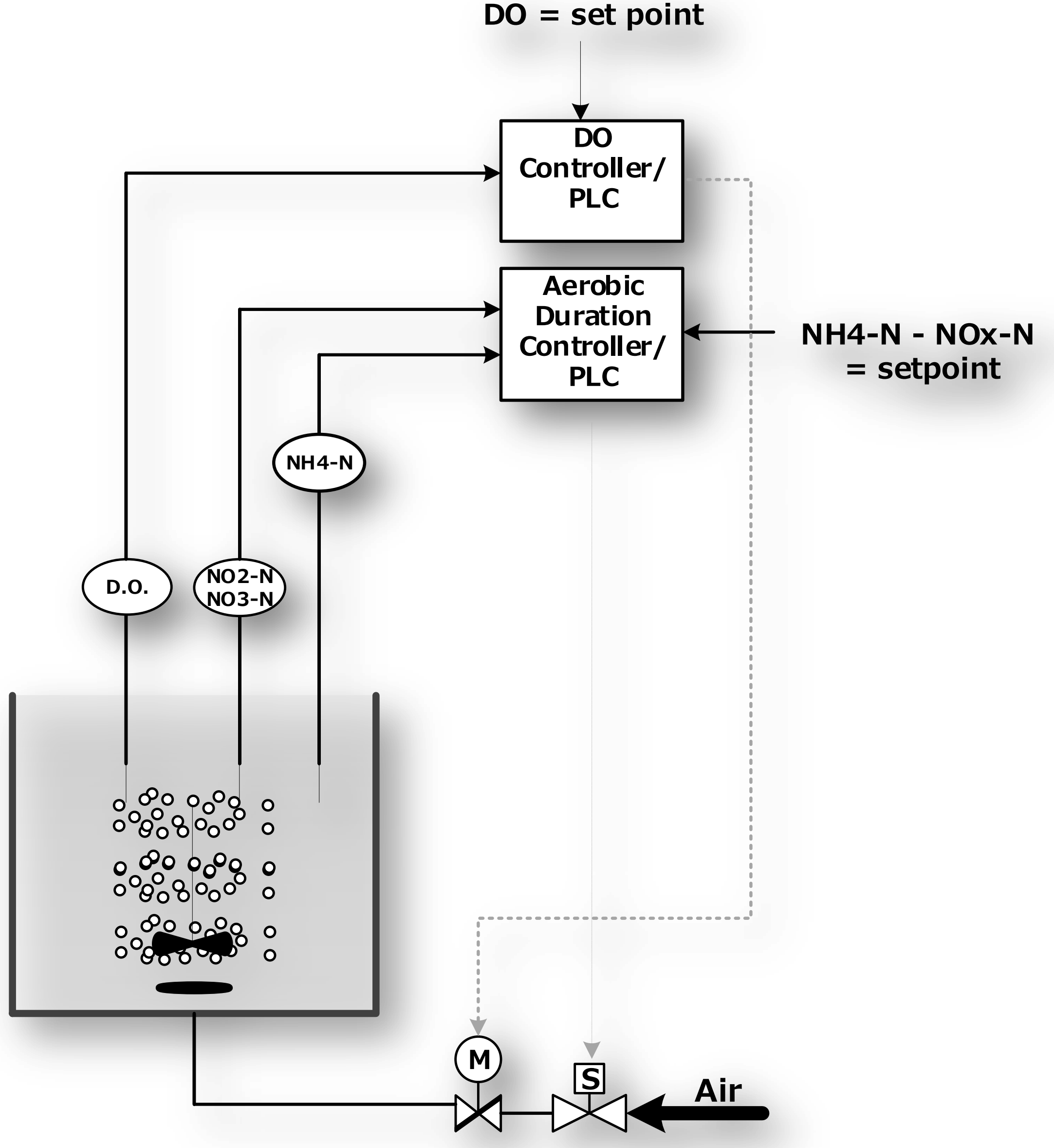
- **Maximum TN removal possible**
- **Effluent = half ammonia + half nitrite**

Anammox MBBR

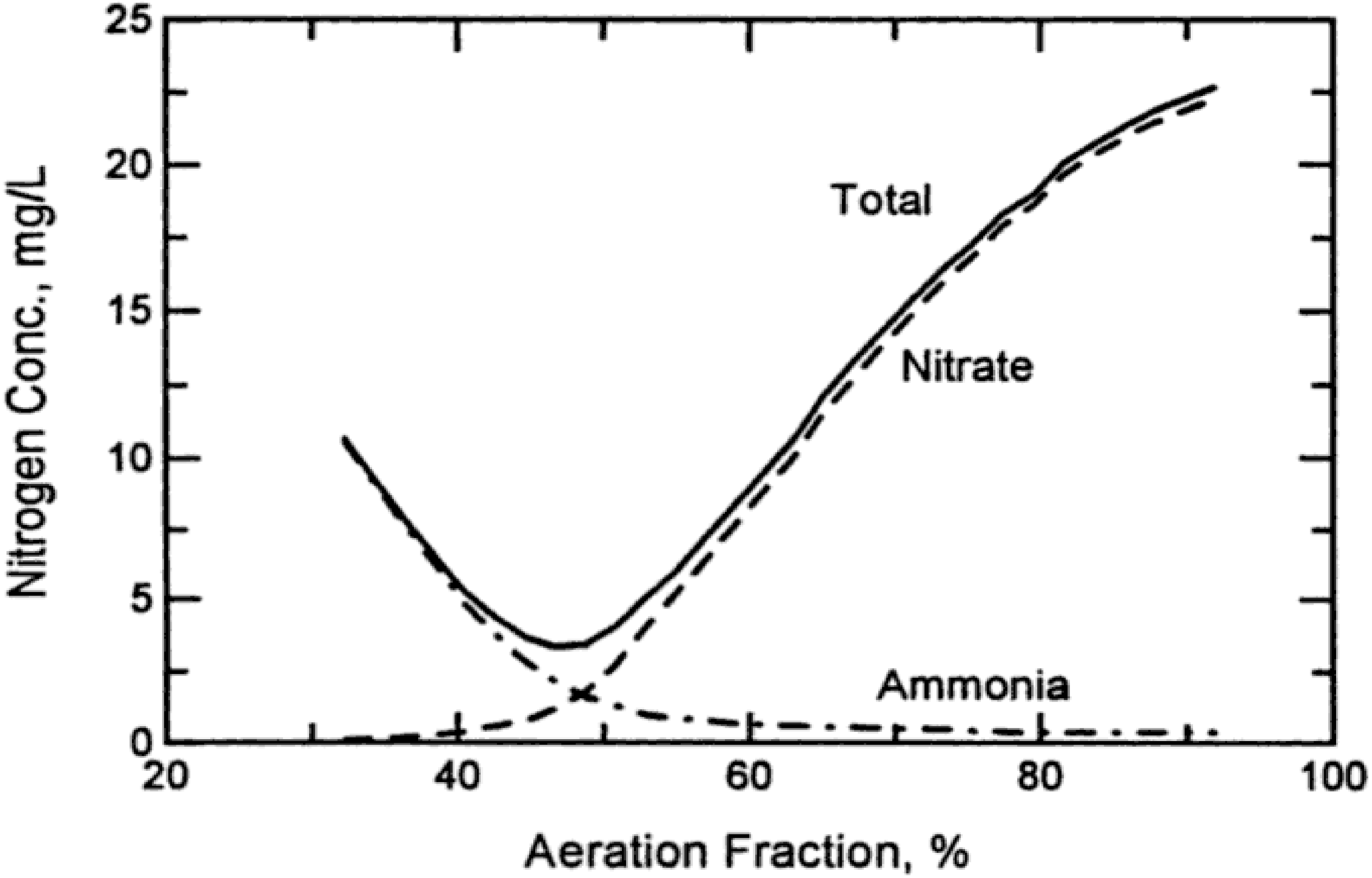
- **Polish residual ammonia and nitrite**

Parameters	
HRT	2 - 3 hr
Influent Flow	114-159 liter/hr (0.5-0.7 gpm)
SRT	5 days (Target)
Temperature	25 ˚C
RAS	100%
pH	6.8-7.0
MLSS	3500±500 mg/L

Ammonia vs NOx (AVN) control



An intermittently aerated bioreactor provides optimum N removal….

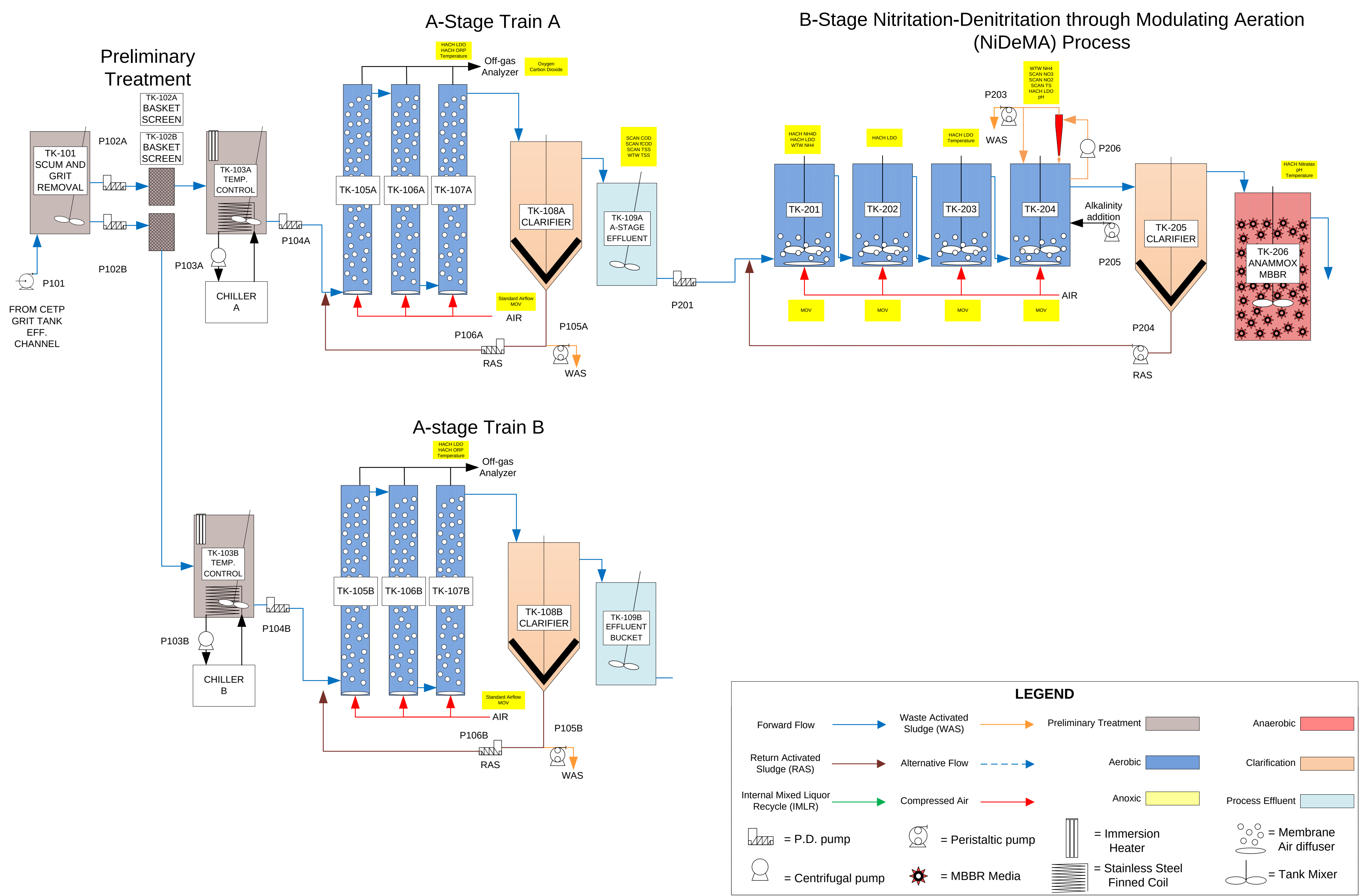


Grady et al (2011) *Biological Wastewater Treatment, 3rd Edition*

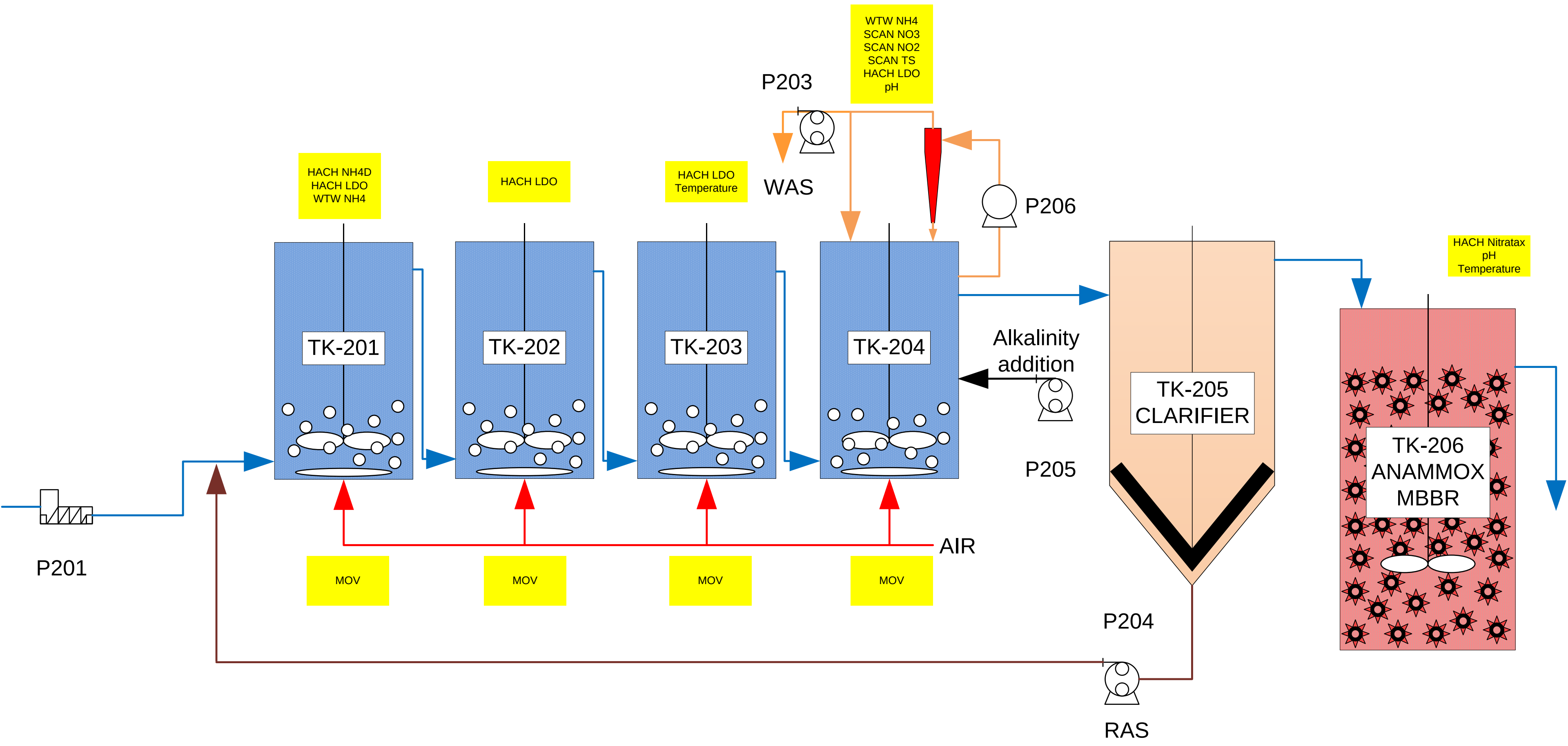
Batchelor, B (1983). Simulation of single-sludge nitrogen removal. *Journal of Environmental Engineering*


Tank 302
Nitritation
Tank 305
Anammox MBBR
Deammonification

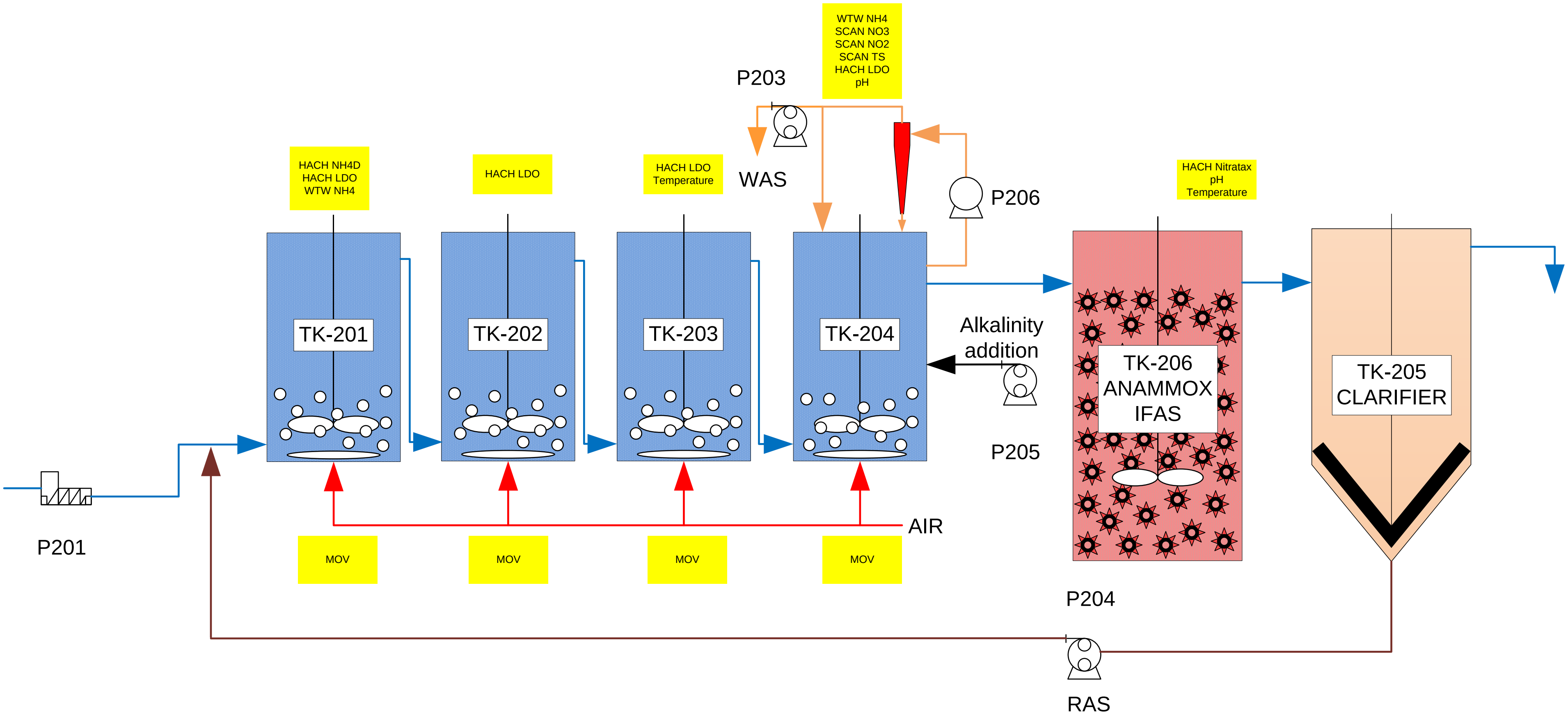
Hampton Roads Sanitation District
Chesapeake Elizabeth Nutrient Removal Pilot Study
Process Flow Schematic



B-Stage Nitritation-Denitritation through Modulating Aeration (NiDeMA) Process



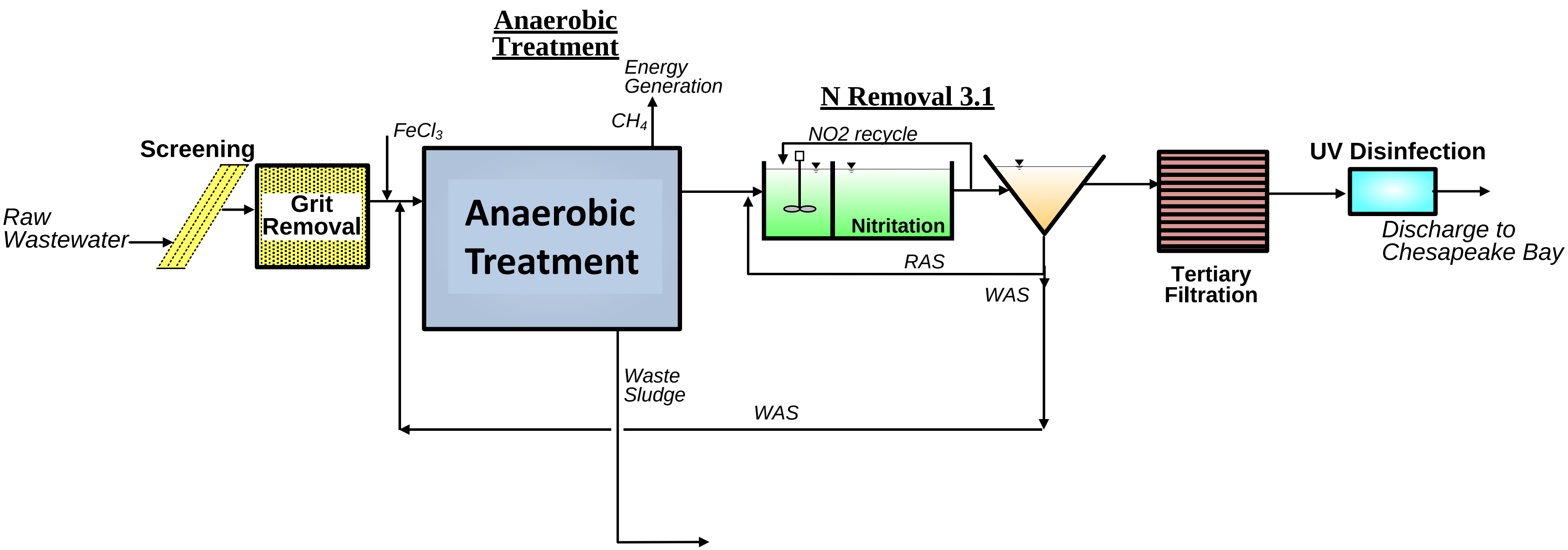
B-Stage Nitritation-Denitritation through Modulating Aeration (NiDeMA) Process



Point Source Needs

- Funding to bring Mainstream 2.0 & 3.0 to implementation
  - Carbon redirection (energy and concrete)
    - Very High Rate Activated Sludge
    - Anaerobic Treatment
  - NOB Suppression or Out-Selection
  - Anammox bioaugmentation and retention
  - GHG emissions (NO and N2O)
- *Critical emerging issue* – dewaterability at plants doing biological P removal and anaerobic digestion
- Regulatory space to innovate
  - Recognize variability
  - Manage risk
  - Statistically based permit limits
  - State acceptance of emerging technologies
  - Technology Vs water quality based limits
  - Longer testing and shake down periods
- Trace organics, pharmaceuticals, and pollutants of emerging concern
- Urine separation??

The future...?

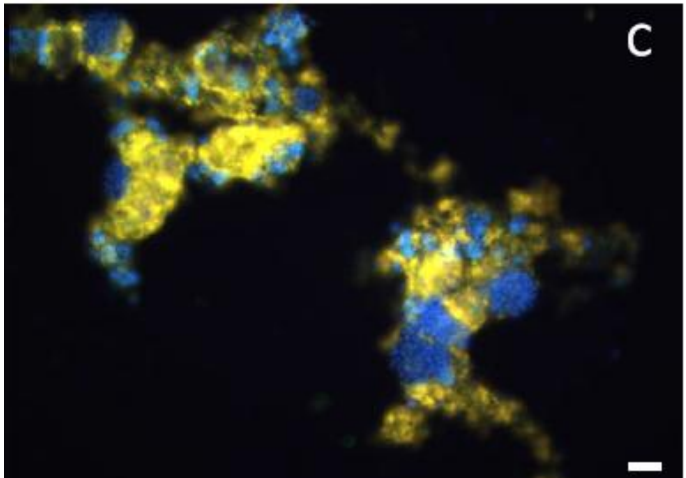


- AOB – Nitritation (NOB out-selection needed)
- Sulfide-driven Autotrophic Denitritation/Denitratation
- Nitrite + Methane – Methanotrophic Denitritation (damo)
- Is Anammox required??

N-DAMO

- Corollary – ammonia
  - NH_4^+ oxidation by ammonia monooxygenase requires O_2
  - Anaerobic NH_4^+ oxidation was thought impossible until anammox was discovered
    - NH_4^+ oxidation through hydroxylamine and hydrazine
- Methane Oxidation
  - CH_4 oxidation by methane monooxygenase requires O_2
  - Anaerobic methane oxidation was thought impossible – would be problematic…
  - Mixed results on methane use for heterotrophic denitrification
- N-DAMO
  - $3\ CH_4 + 8\ NO_2^- + 8\ H^+ \rightarrow 3\ CO_2 + 4\ N_2 + 10\ H_2O$

(Raghoebarsing et al, 2006)



(Luesken et al, 2011)

Questions?

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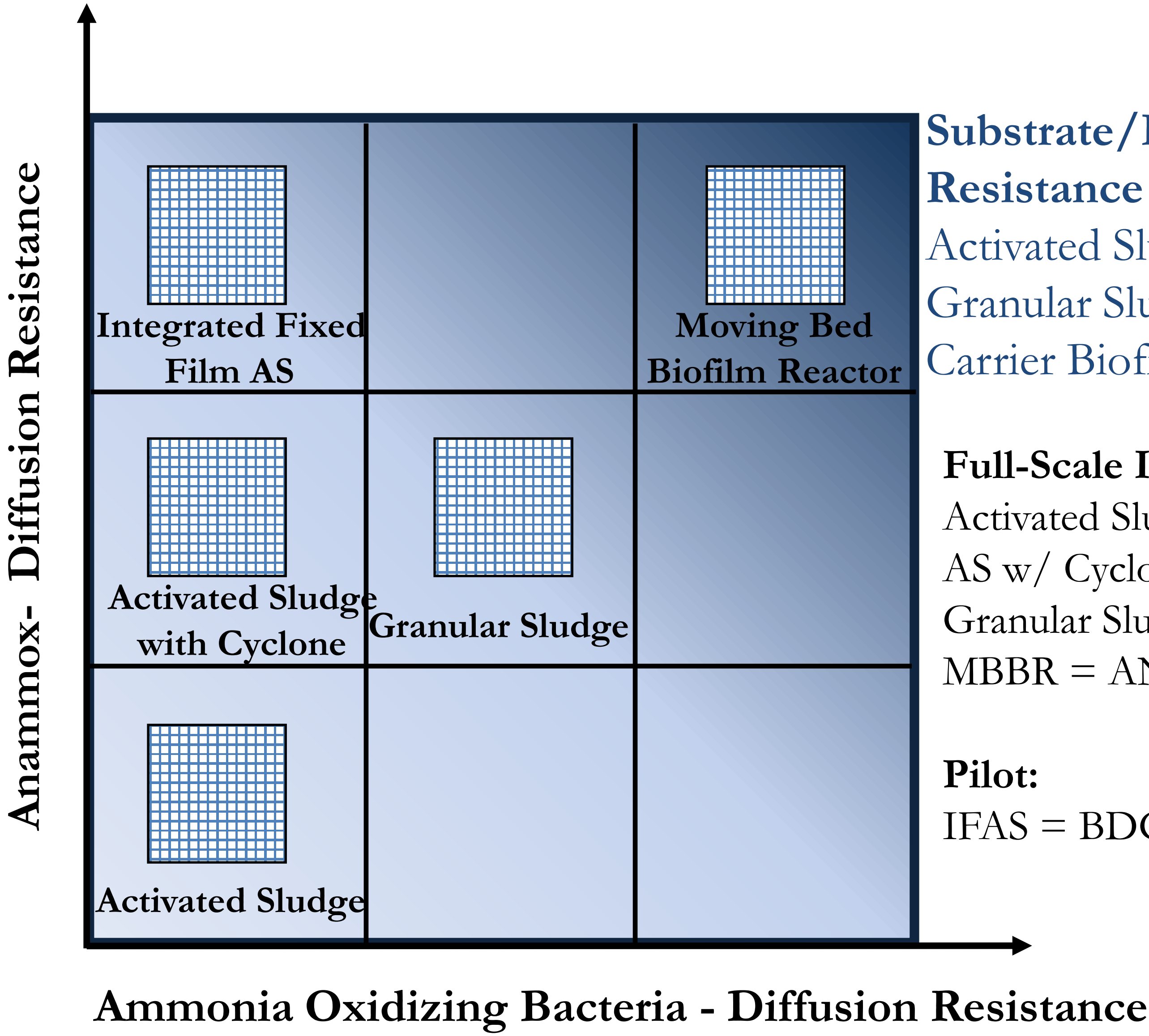
– 757-460-4228

HRSD

Sidestream Process Niche Environments



Substrate/Inhibitor Diffusion Resistance

Activated Sludge – Lowest
Granular Sludge- Moderate
Carrier Biofilm- Highest

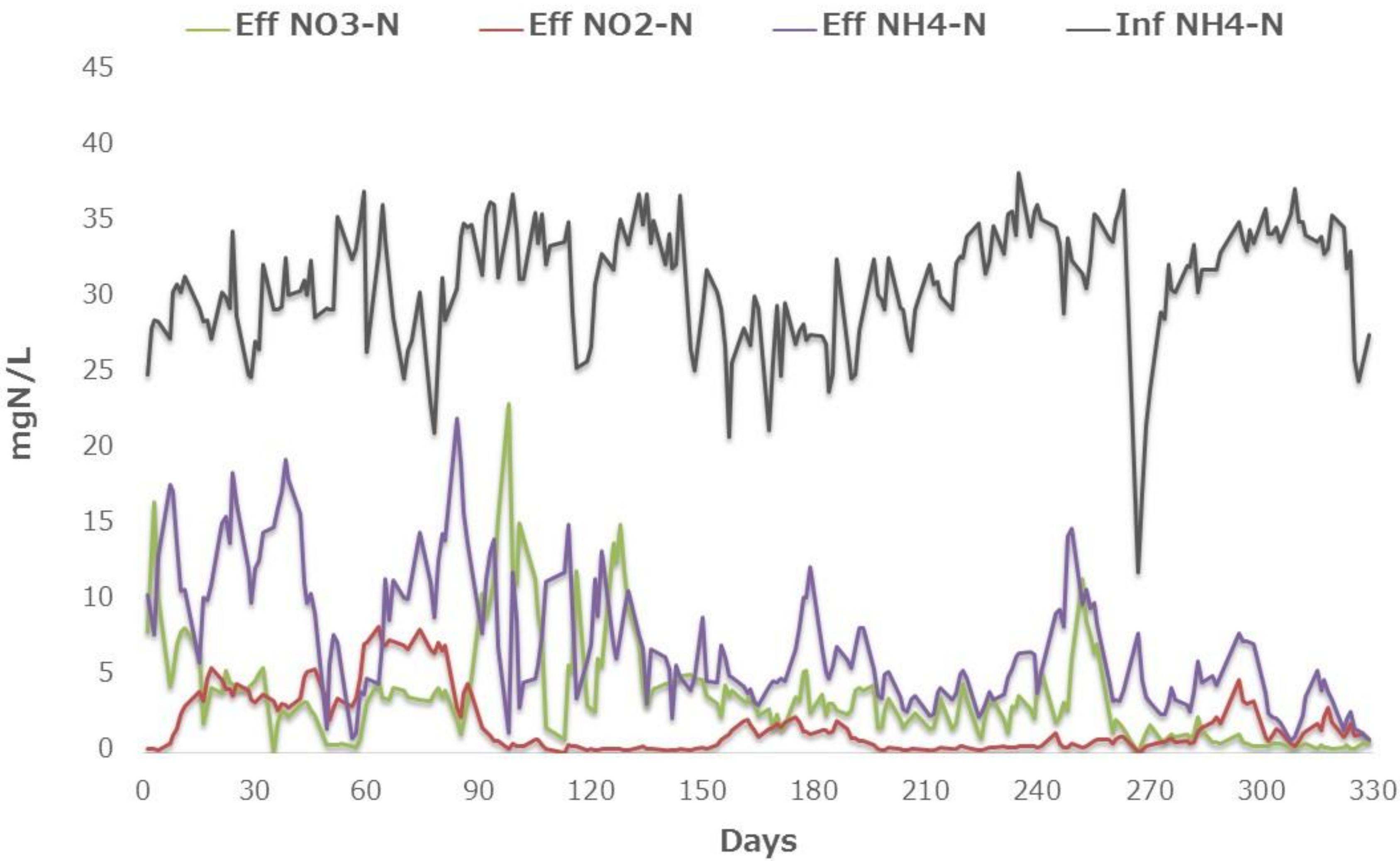
Full-Scale Implementation:

Activated Sludge = DEMON (pre-cyclone)
AS w/ Cyclone = DEMON
Granular Sludge= CANON/Anammox
MBBR = ANITA Mox, Deammon

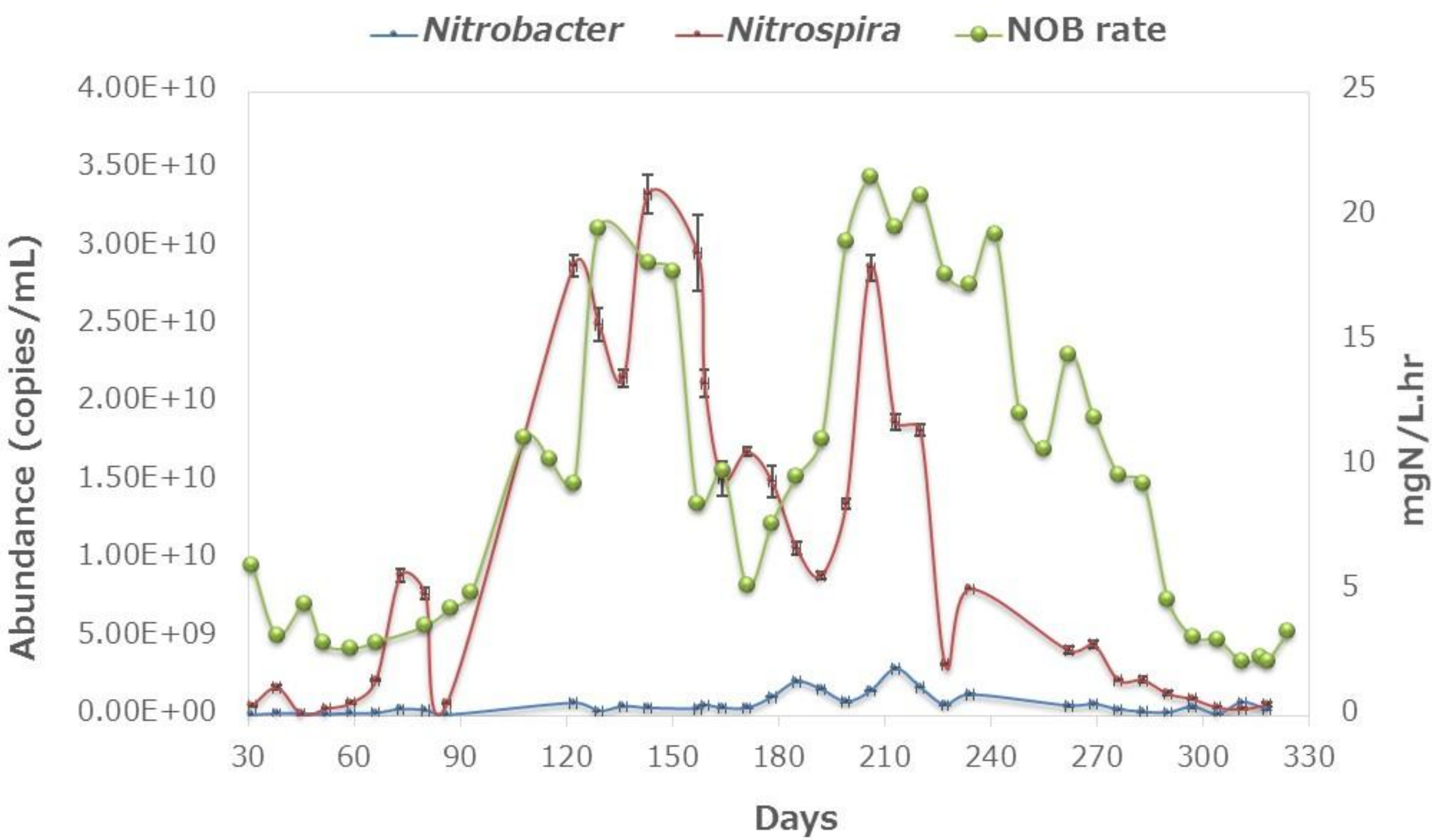
Pilot:

IFAS = BDG Configuration & Veolia

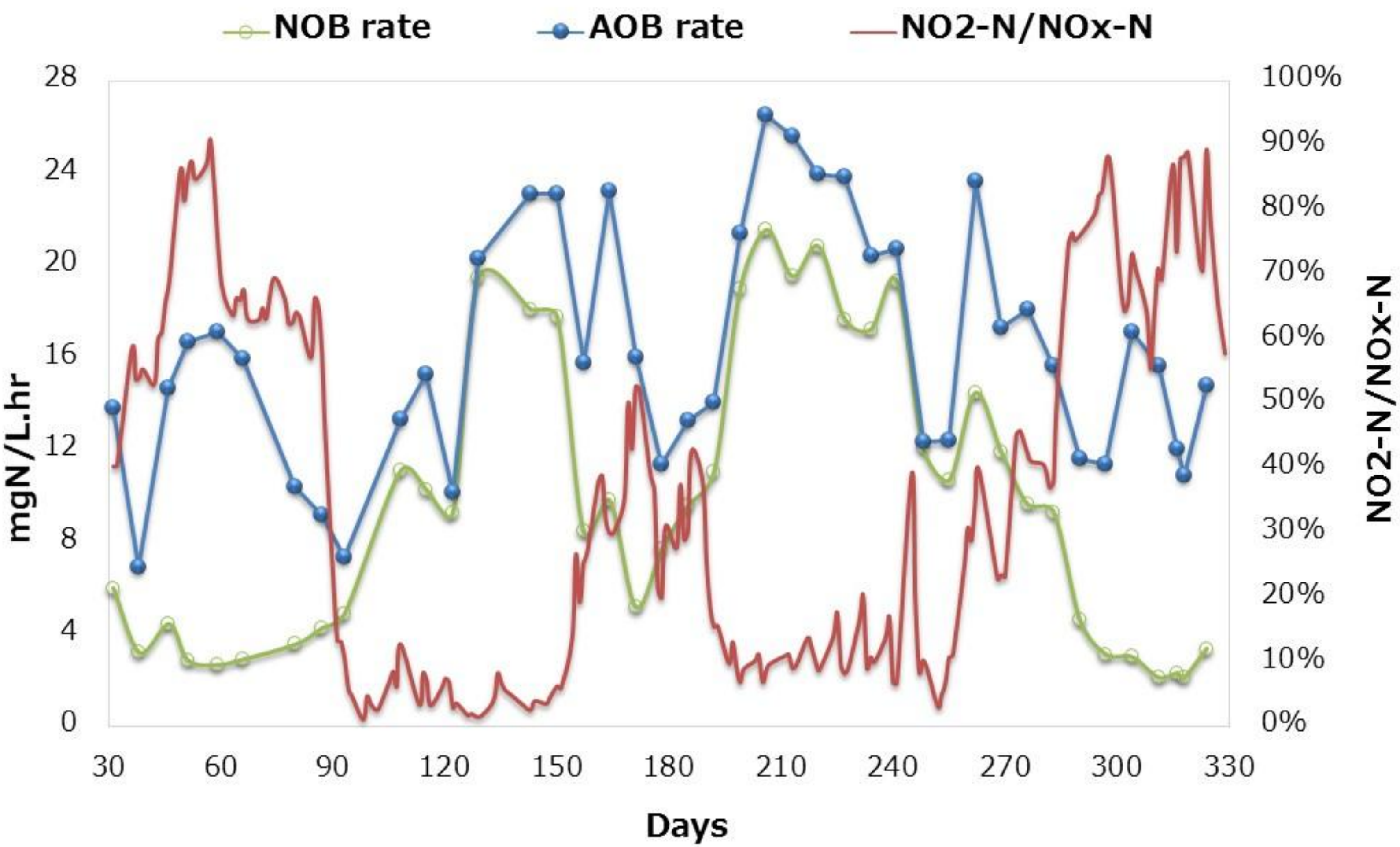
Nitrogen removal in nitrite-shunt



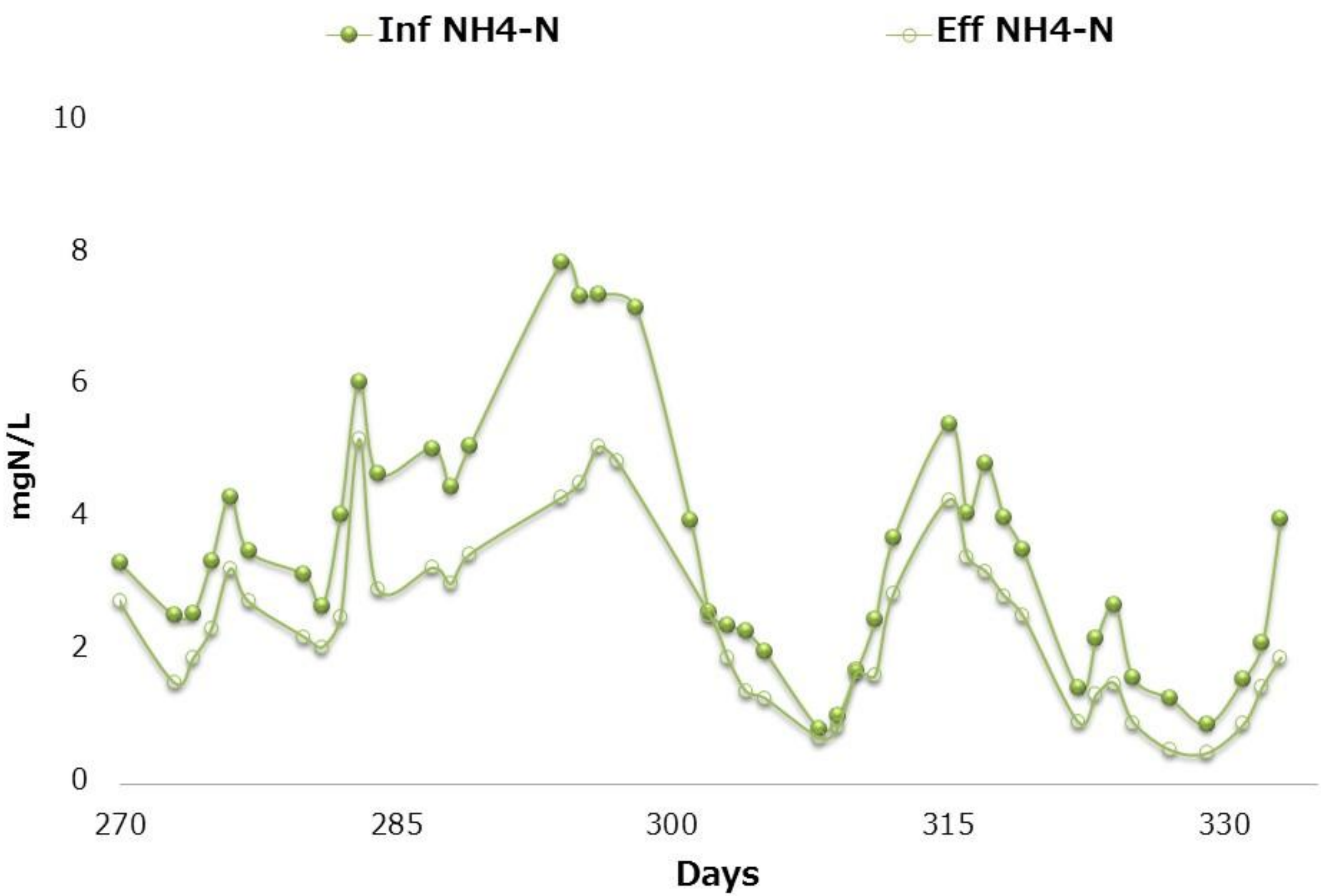
NOB rates vs NOB population



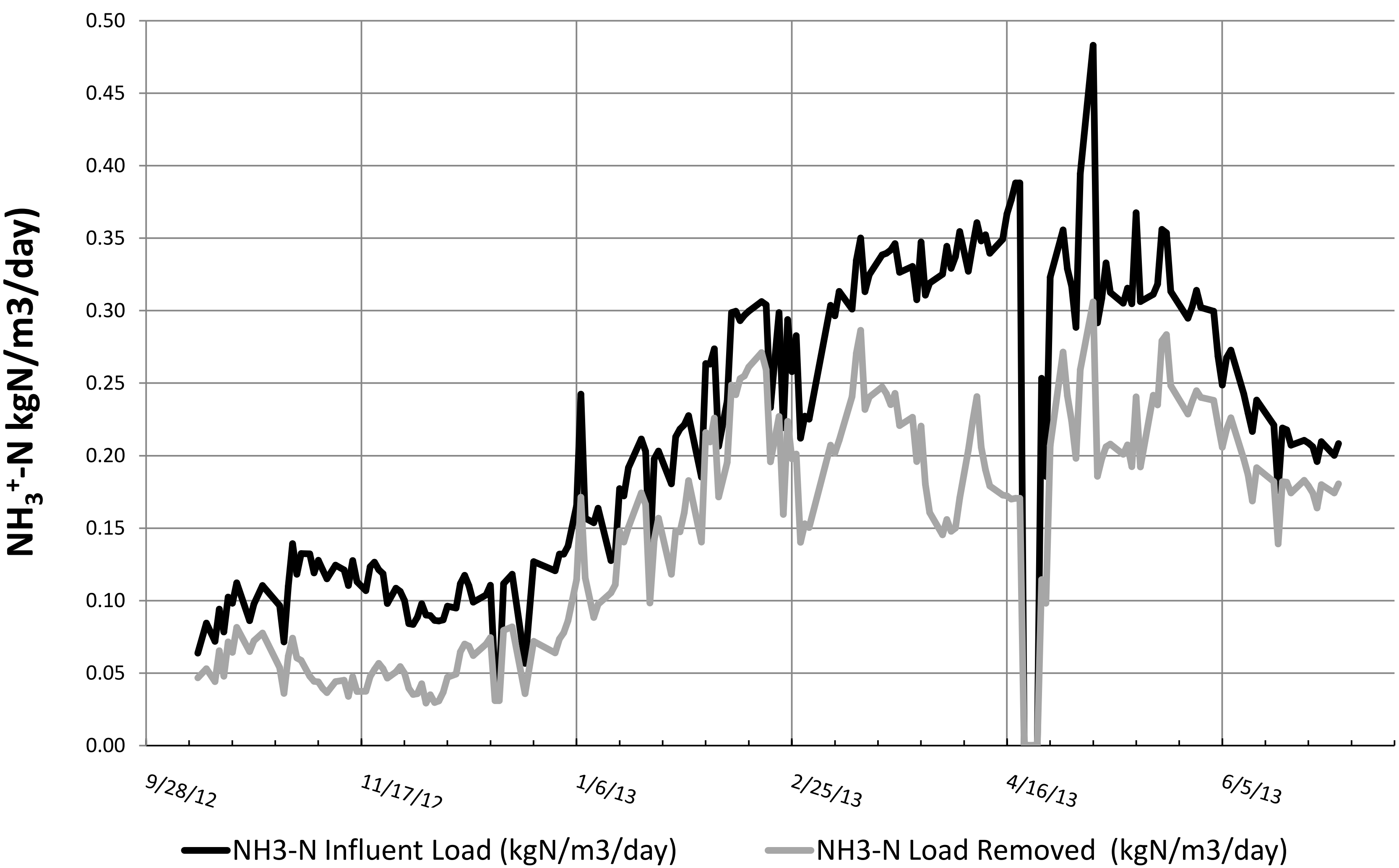
AOB and NOB rates



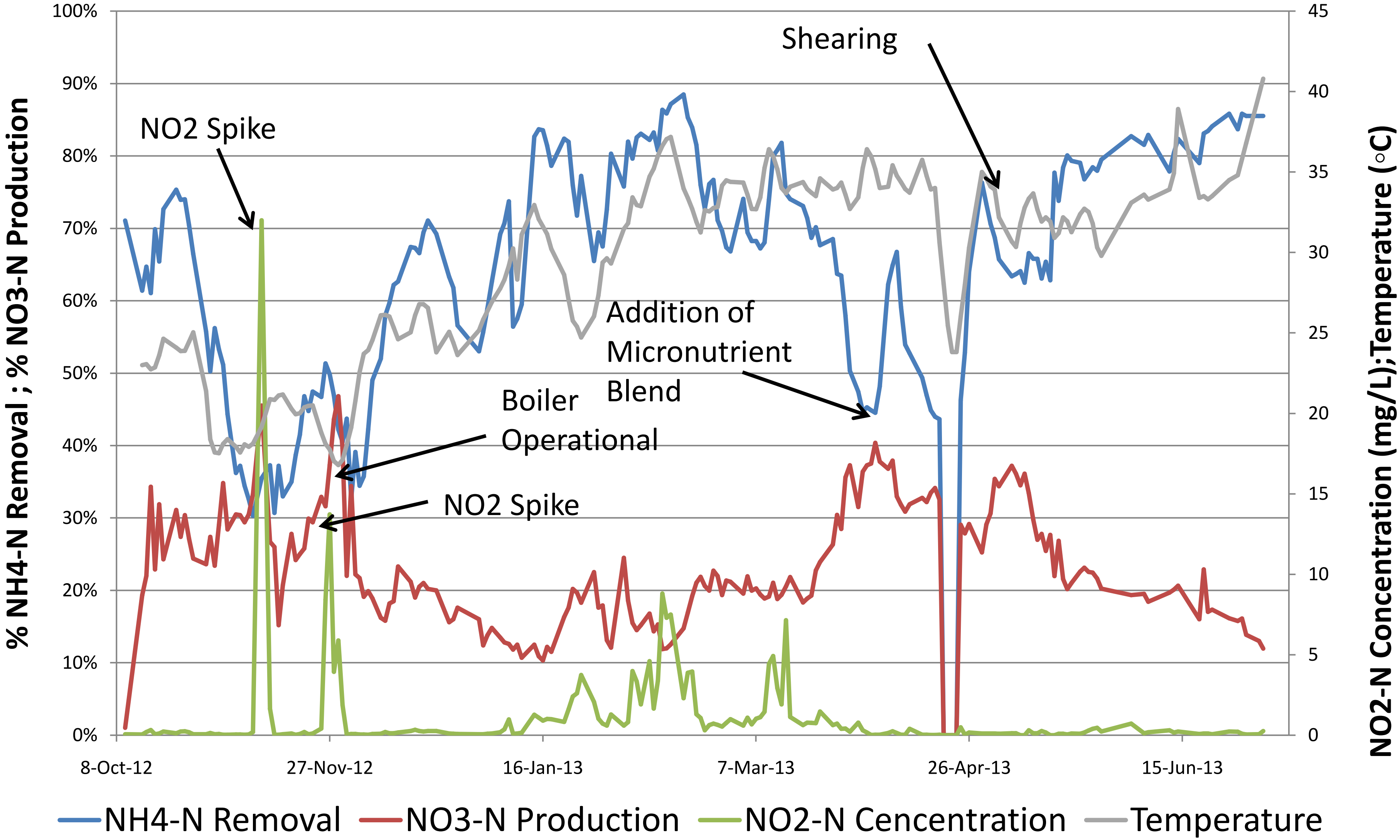
AMX polishing



NH4 Load and Removal



Process Efficiency



The People

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