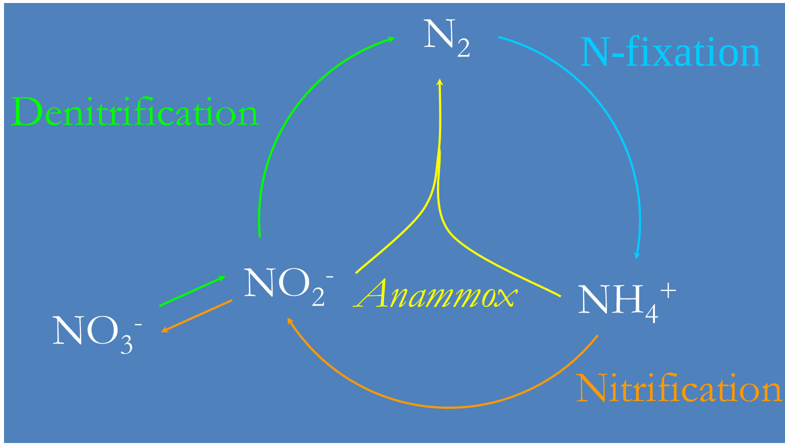
Nitrogen Removal 3.0: Integration of Anammox into Sidestream and Mainstream BNR Processes

Charles B. Bott, Ph.D., P.E., BCEE

Hampton Roads Sanitation District



HRSD

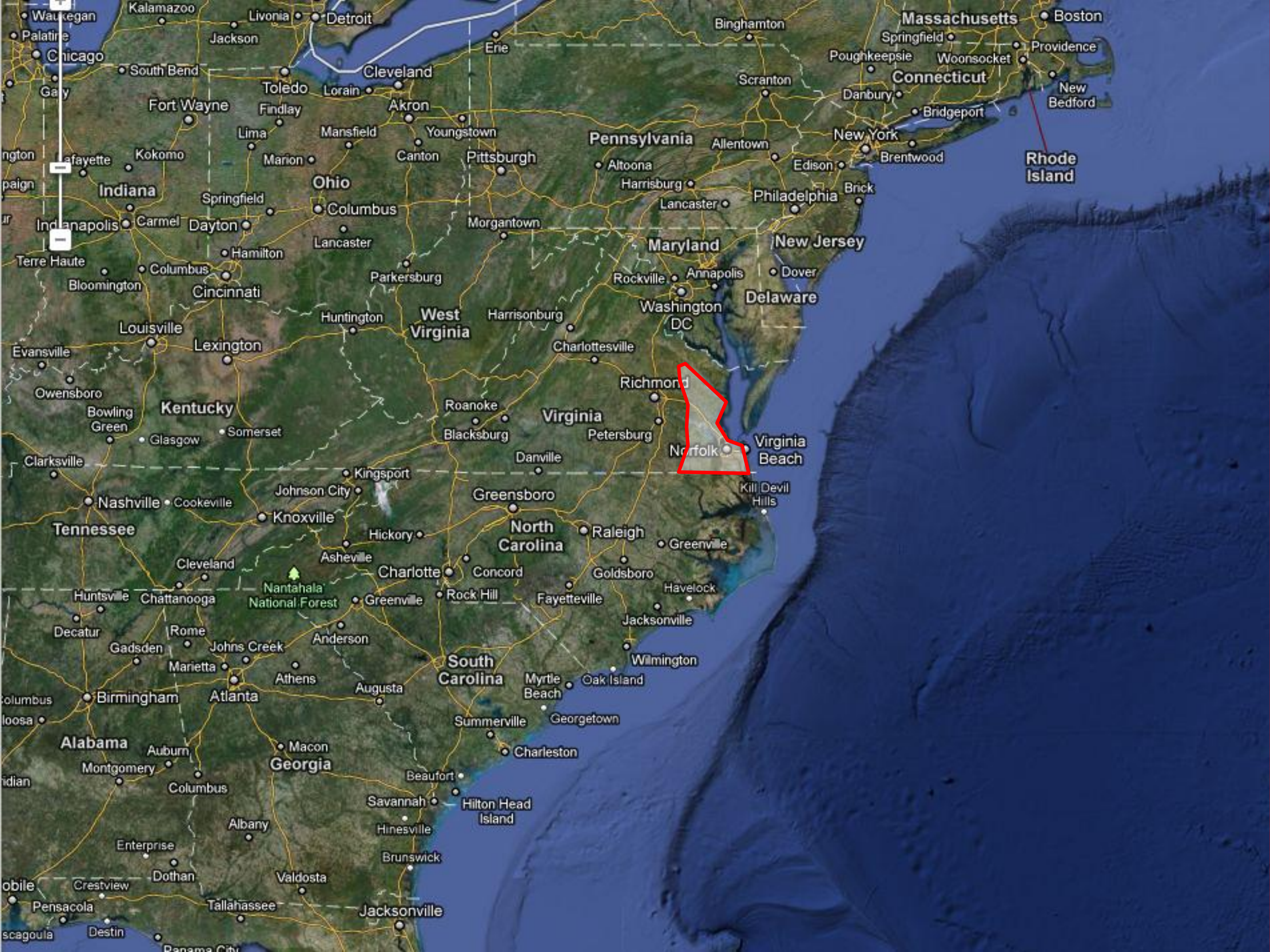
History

- 1925 – Dept of Health condemns a large oyster producing area
  - 30 million gallons per day of raw sewage discharged into Hampton Roads
- 1940 – HRSD was created by the VA General Assembly to eliminate sewage pollution in the Chesapeake Bay

POLLUTION IS POISON

AN EMPHATIC DENIAL

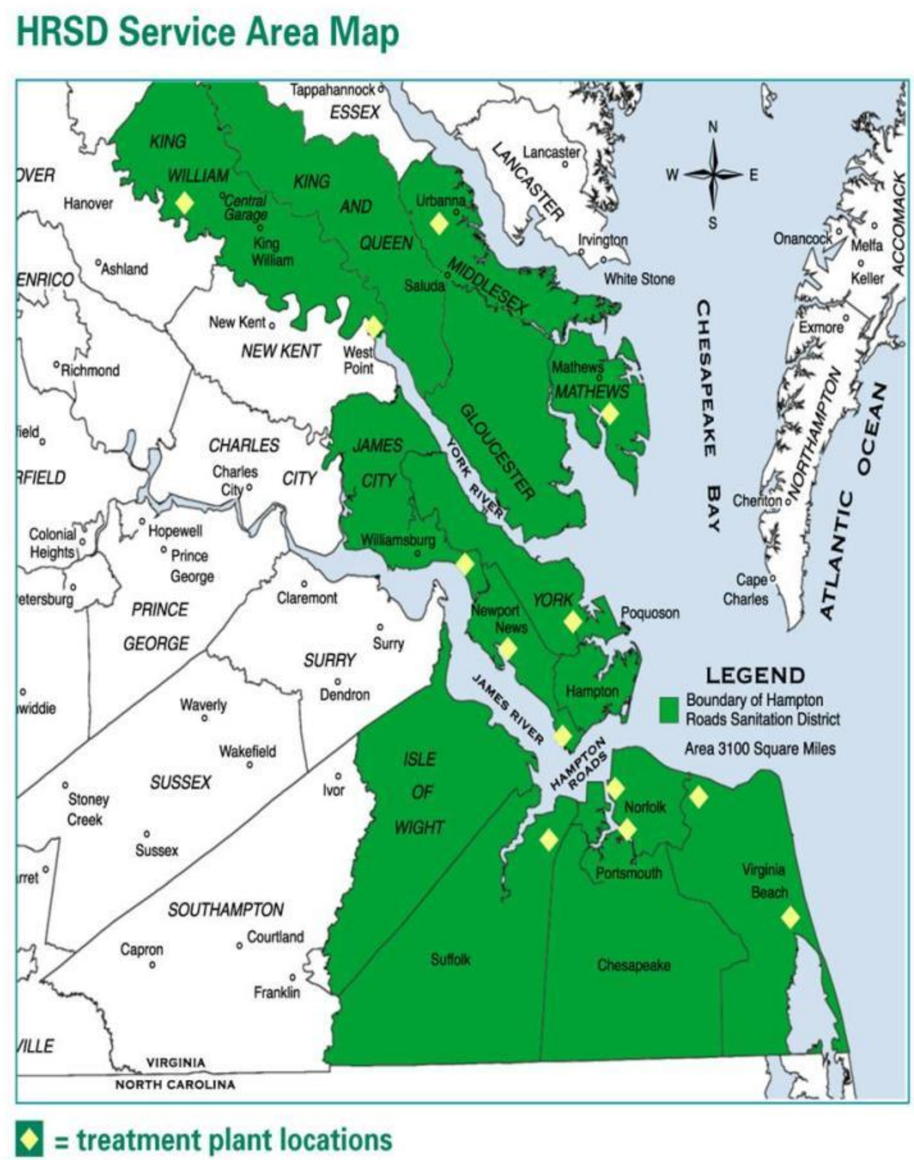
VOTE YES



Waukegan
Kalamazoo
Livonia
Detroit
Palatine
Jackson
Chicago
South Bend
Toledo
Cleveland
Lorain
Gary
Fort Wayne
Findlay
Akron
Lima
Mansfield
Youngstown
Lafayette
Kokomo
Marion
Canton
Pittsburgh
Indiana
Ohio
Springfield
Columbus
Indianapolis
Carmel
Dayton
Lancaster
Morgantown
Hamilton
Terre Haute
Columbus
Bloomington
Cincinnati
Parkersburg
Huntington
West Virginia
Harrisonburg
Louisville
Lexington
Evansville
Owensboro
Bowling Green
Kentucky
Glasgow
Somerset
Clarksville
Kingsport
Johnson City
Nashville
Cookeville
Knoxville
Tennessee
Hickory
Asheville
Cleveland
Charlotte
Concord
Huntsville
Chattanooga
Nantahala National Forest
Greenville
Rock Hill
Decatur
Rome
Gadsden
Johns Creek
Anderson
Marietta
Athens
Augusta
Birmingham
Atlanta
Alabama
Auburn
Montgomery
Columbus
Macon
Georgia
Albany
Enterprise
Dothan
Valdosta
Crestview
Mobile
Pensacola
Tallahassee
Destin
Panama City
Jacksonville
Brunswick
Hinesville
Savannah
Hilton Head Island
Beaufort
Charleston
Summerville
Georgetown
Myrtle Beach
Oak Island
South Carolina
Wilmington
Jacksonville
Havelock
Fayetteville
Goldsboro
Greenville
Raleigh
North Carolina
Greensboro
Danville
Kill Devil Hills
Norfolk
Virginia Beach
Petersburg
Virginia
Roanoke
Blacksburg
Richmond
Charlottesville
Washington DC
Rockville
Annapolis
Maryland
Dover
Delaware
New Jersey
Philadelphia
Lancaster
Harrisburg
Altoona
Pennsylvania
Allentown
Edison
Brick
New York
Brentwood
Scranton
Binghamton
Erie
Poughkeepsie
Danbury
Bridgeport
Connecticut
Springfield
Massachusetts
Boston
Woonsocket
Providence
New Bedford
Rhode Island

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

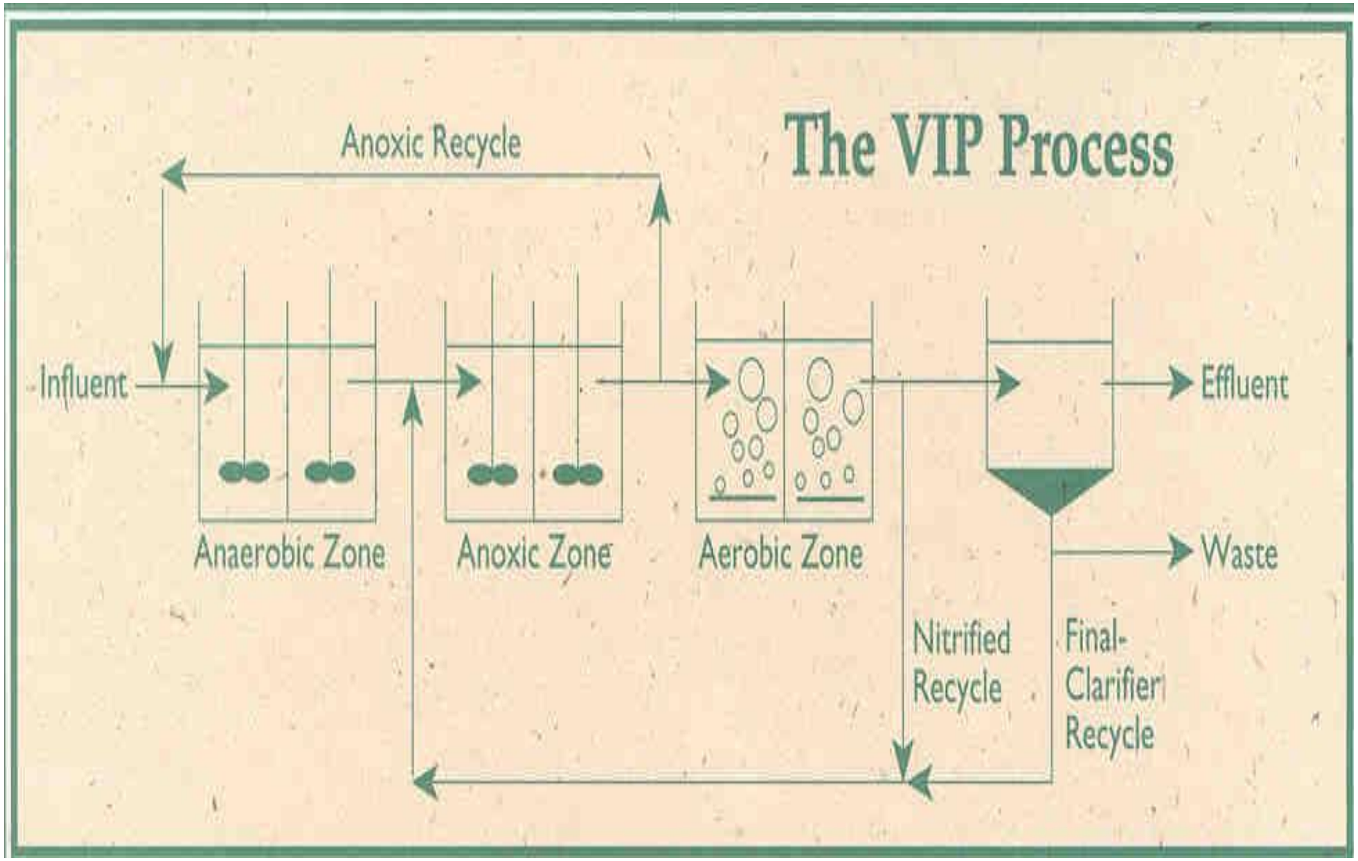


Outline

- Overview of BNR Upgrades at HRSD
- Conventional Nitrogen Removal Processes
    - Aside: Centrate Treatment
    - Aside: York River DEMON Process Upgrade
- Chesapeake-Elizabeth – Conventional Upgrade
- Chesapeake-Elizabeth – Pilot Study

Please stop me with questions…

The VIP® Process

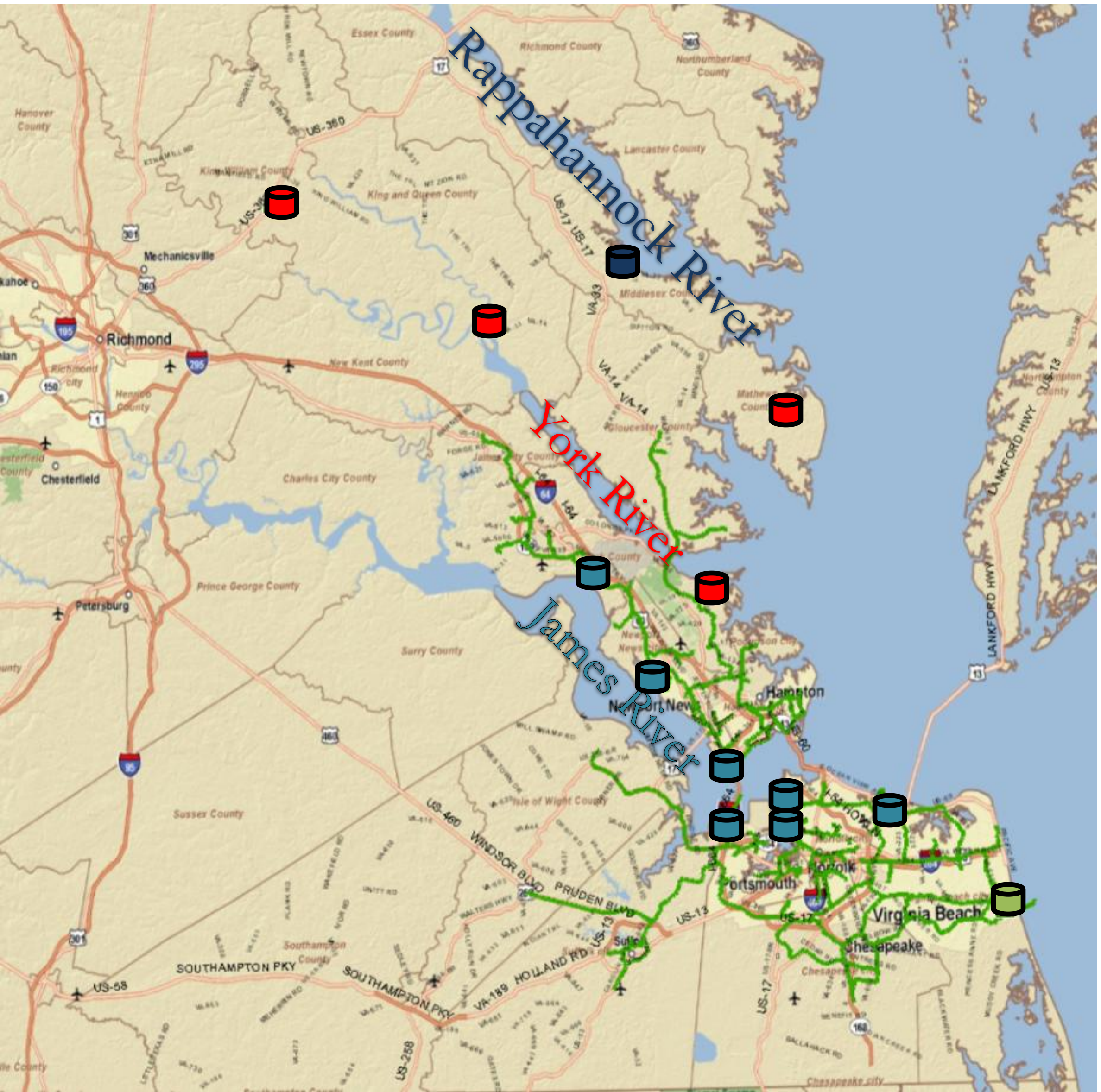


- It was developed and patented by HRSD and CH2M Hill Engineers
- Biologically removes Phosphorus and Nitrogen
- Its free for any one to use…

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
- Ammonia-based DO control systems (energy)
- Organic nitrogen sources and fate
- Cost effective Chemically Enhanced Primary Treatment (chemicals)
- Algae-based nutrient removal (chemicals, energy)
- Centrate treatment – anammox (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)
- Improvement of BNR process models (chemicals, energy, concrete)
- Urine separation (source separation)

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,
    - Upgrade at Boat Harbor (minimal N removal)
  - 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 ---- No change?
  - Rapid upgrade to add denite filters for 2011 compliance
  - Additional upgrade needed for cost-effective BNR and reliability

Motivation for this Discussion

- 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

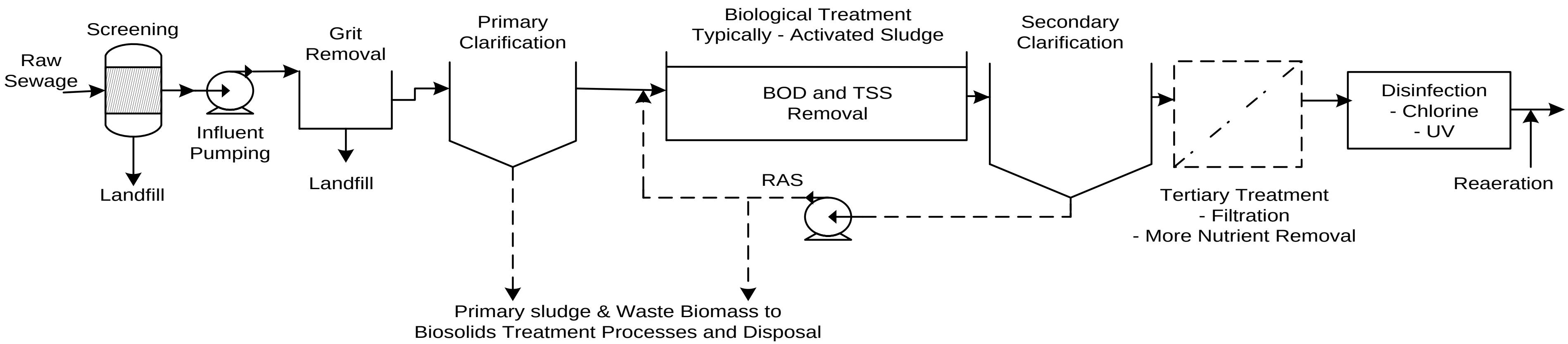
Wastewater Treatment 101 – Liquid Processes

Raw Sewage

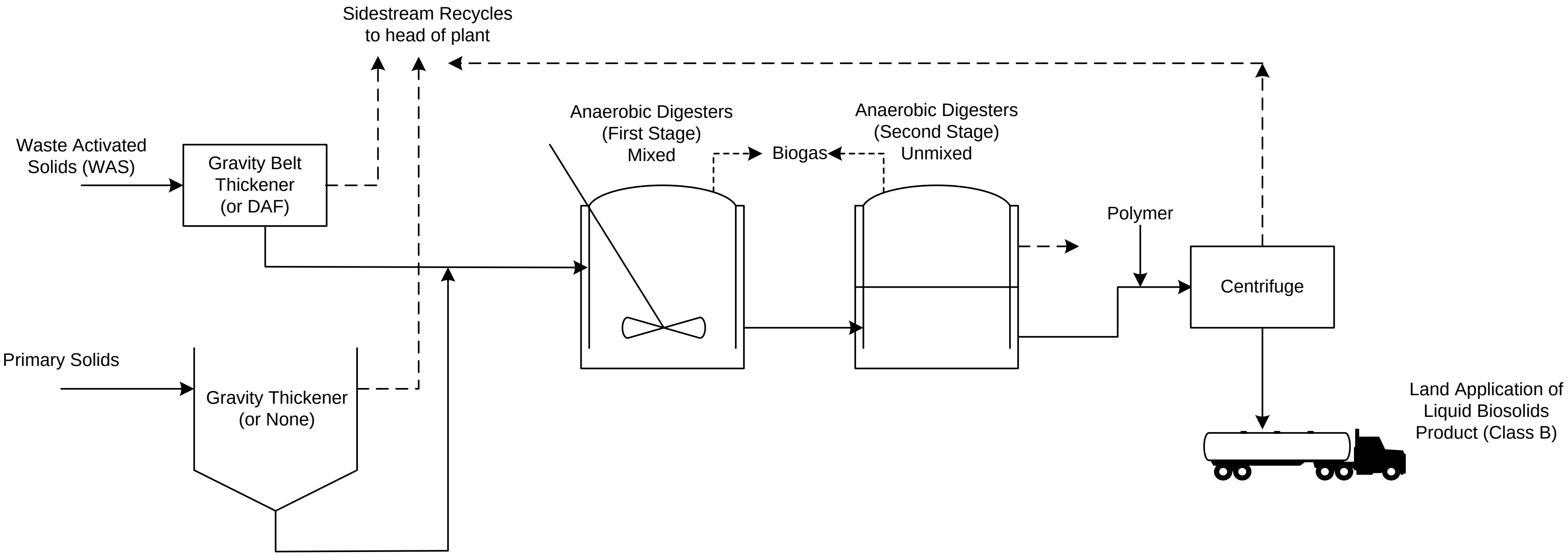
Raw Sewage Characteristics

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

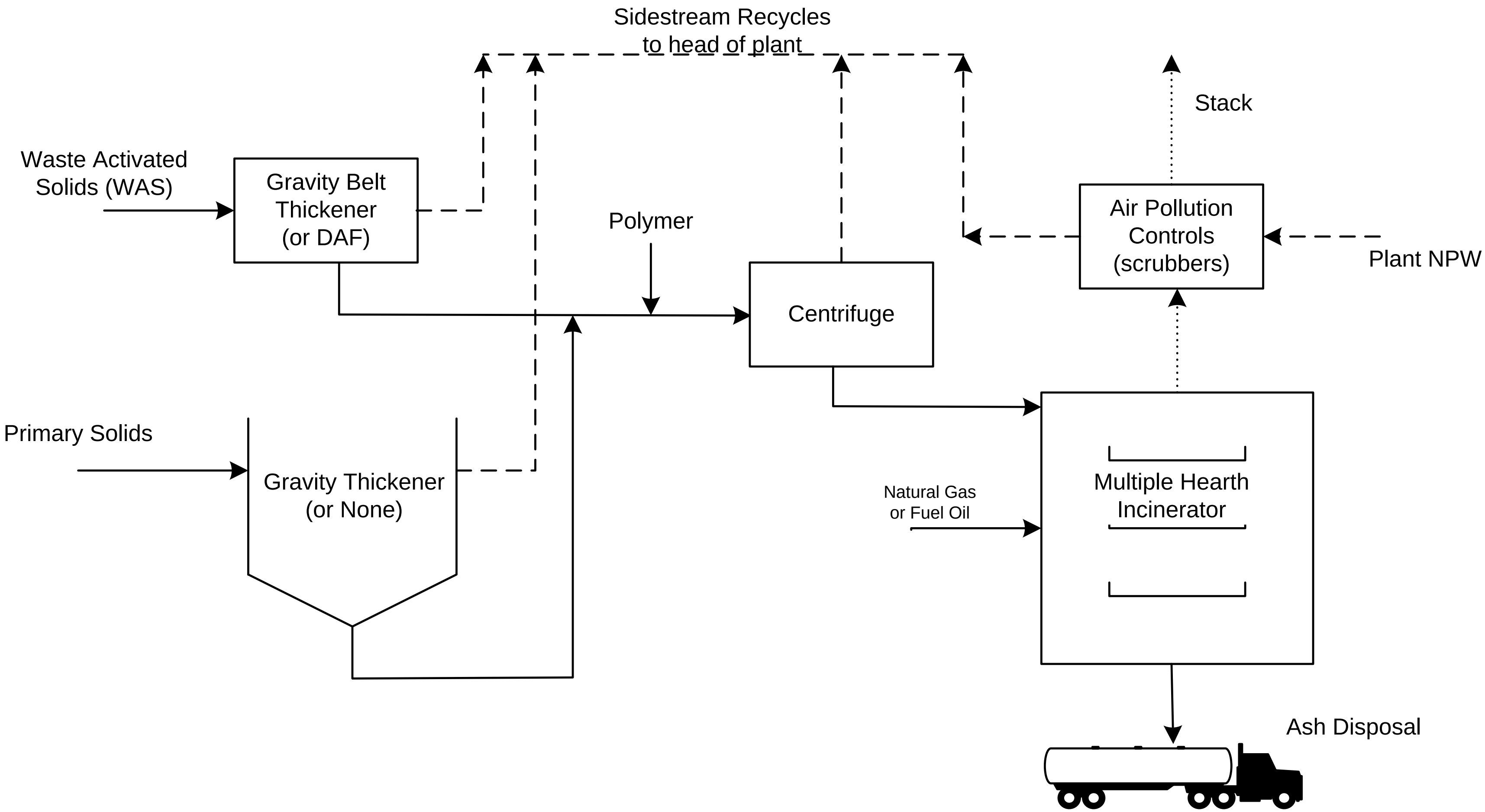
Wastewater Treatment 101 – Liquid Processes



Digestion Plant Example



Incineration Plant Example



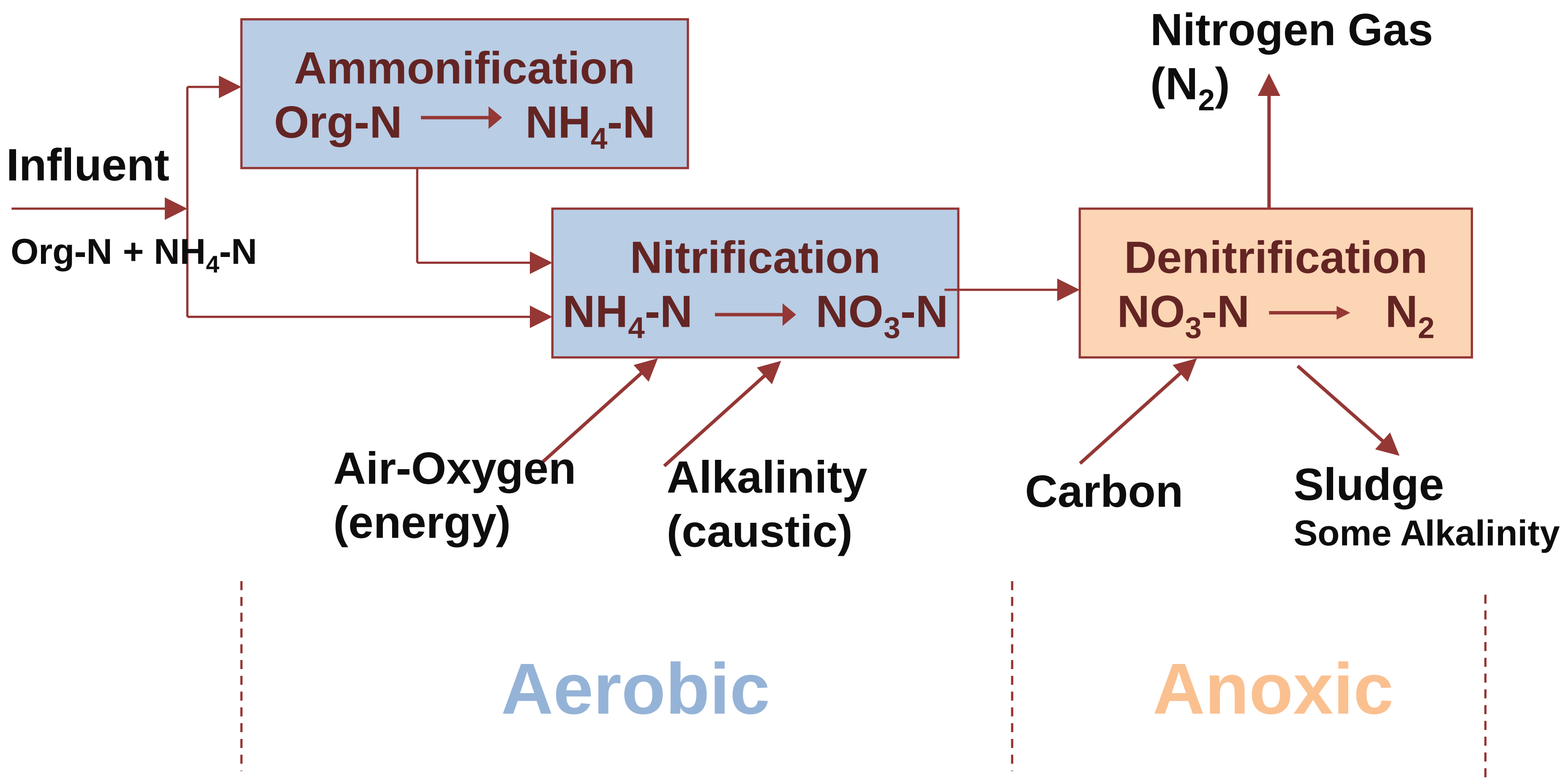
Forms of Nitrogen

- Total ammonia nitrogen (TAN) = NH_4^+-N + NH_3-N
- NO_2^- = nitrite
- NO_3^- = nitrate
- Organic Nitrogen (protein, nucleic acid, etc)
  - Soluble/dissolved
  - Particulate
- TKN = Total Kjeldahl Nitrogen = TAN + Org N
- NO_x-N = NO_2-N + NO_3-N
- TN = Total Nitrogen = TKN + NO_2-N + NO_3-N

(everything is expressed on an "as N" basis)

- Raw Sewage – TKN = TN = 30 to 45 mg/L
- Raw Sewage – NO_x-N ~ 0 mg/L

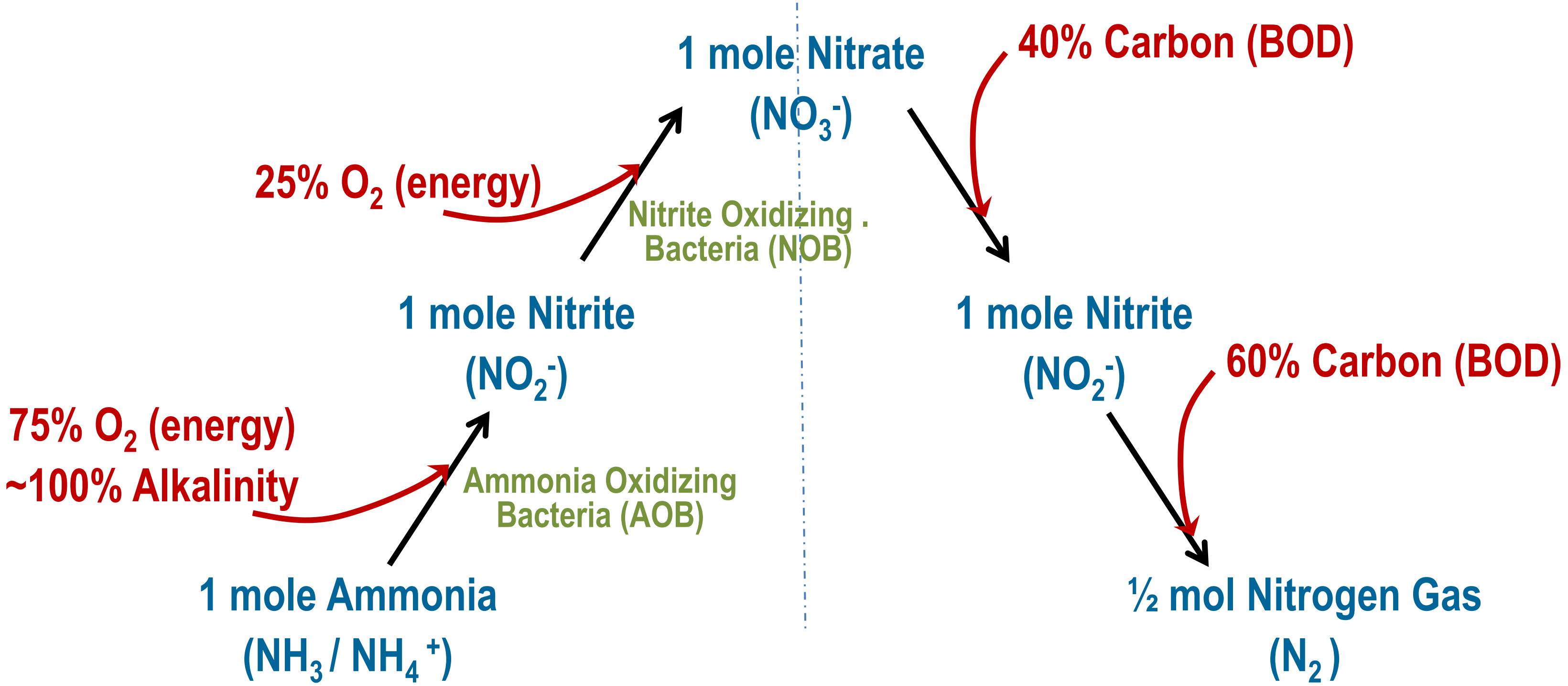
BNR-N consists of three processes



Conventional Nitrification-Denitrification

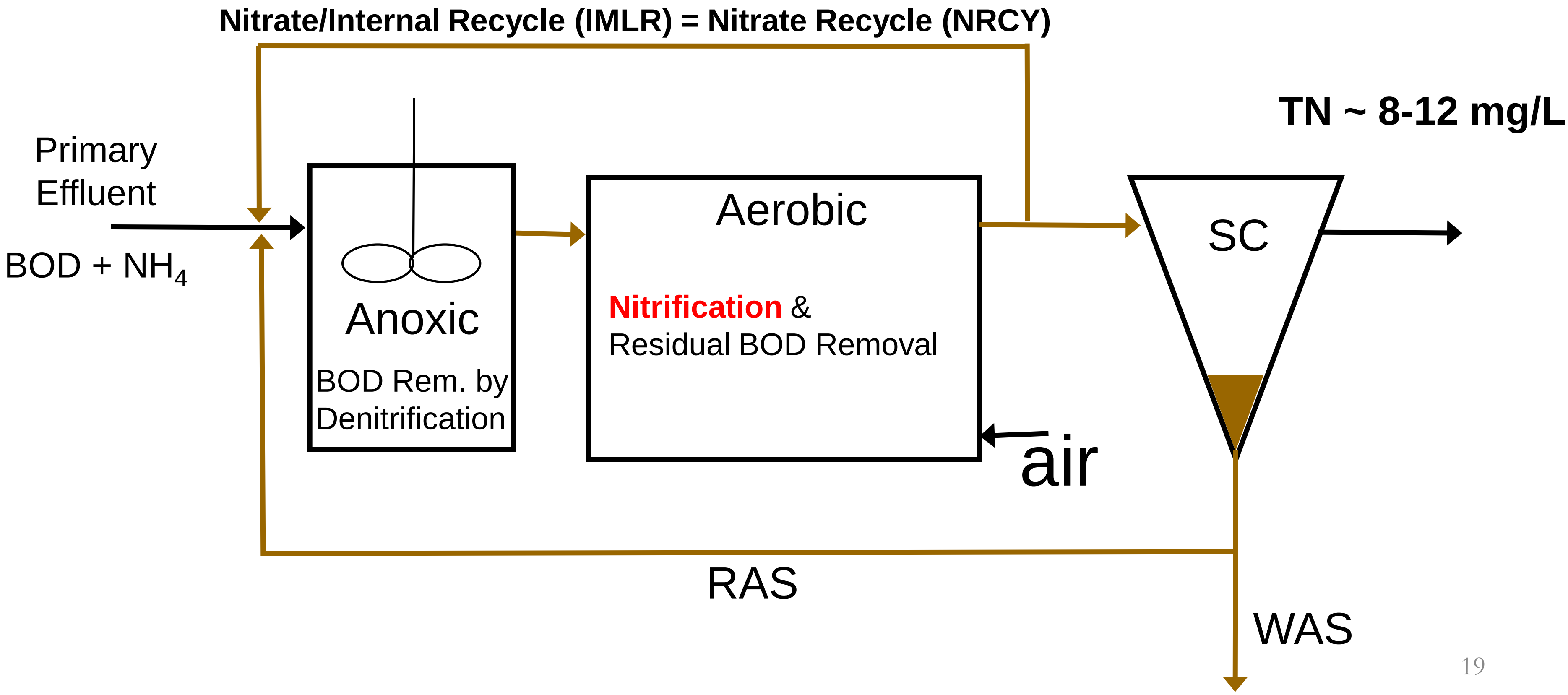
Autotrophic Bacteria
Aerobic Environment

Heterotrophic Bacteria
Anoxic Environment

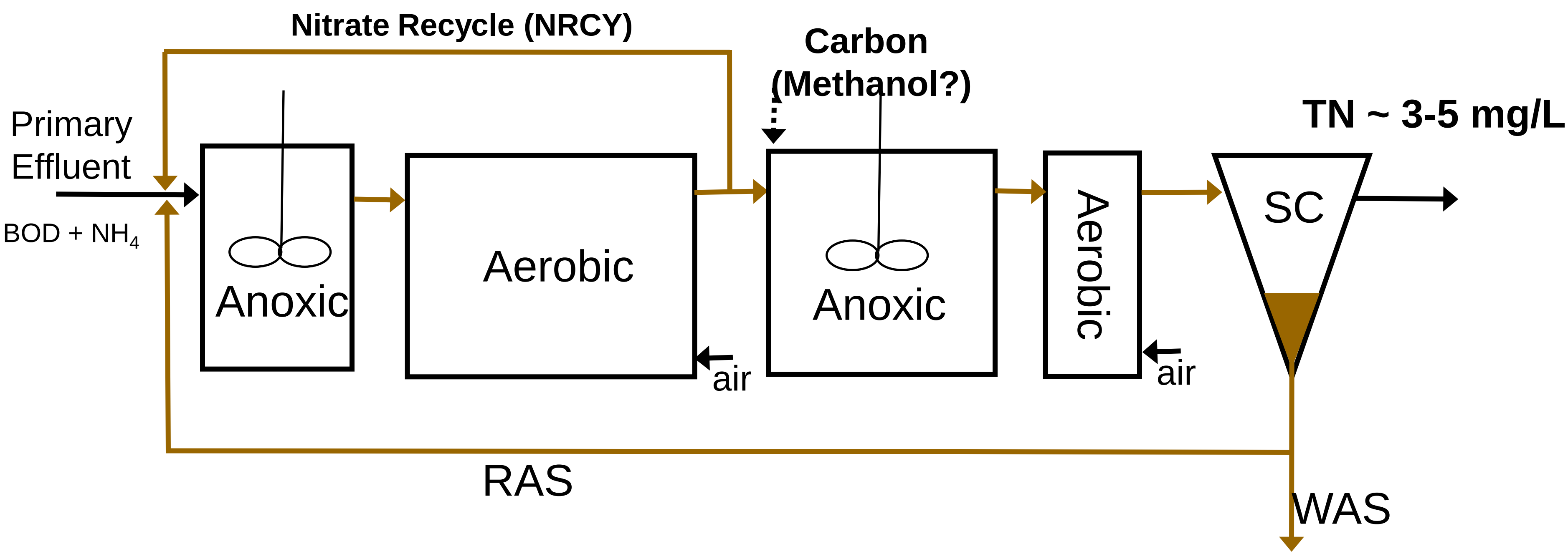


NITRIFICATION **DENITRIFICATION**

MLE Process (N Removal)



4-Stage Bardenpho (Better N Removal)



Let’s save a little energy and carbon…

Some New Vocabulary….

Autotrophic Bacteria
Aerobic Environment

Heterotrophic Bacteria
Anoxic Environment

1 mole Nitrate
(NO_3^-)

Nitratation

Nitrite Oxidizing .
Bacteria (NOB)

Denitratation

1 mole Nitrite
(NO_2^-)

1 mole Nitrite
(NO_2^-)

Nitritation

Ammonia Oxidizing
Bacteria (AOB)

Denitritation

1 mole Ammonia
(NH_3 / NH_4^+)

½ mol Nitrogen Gas
(N_2)

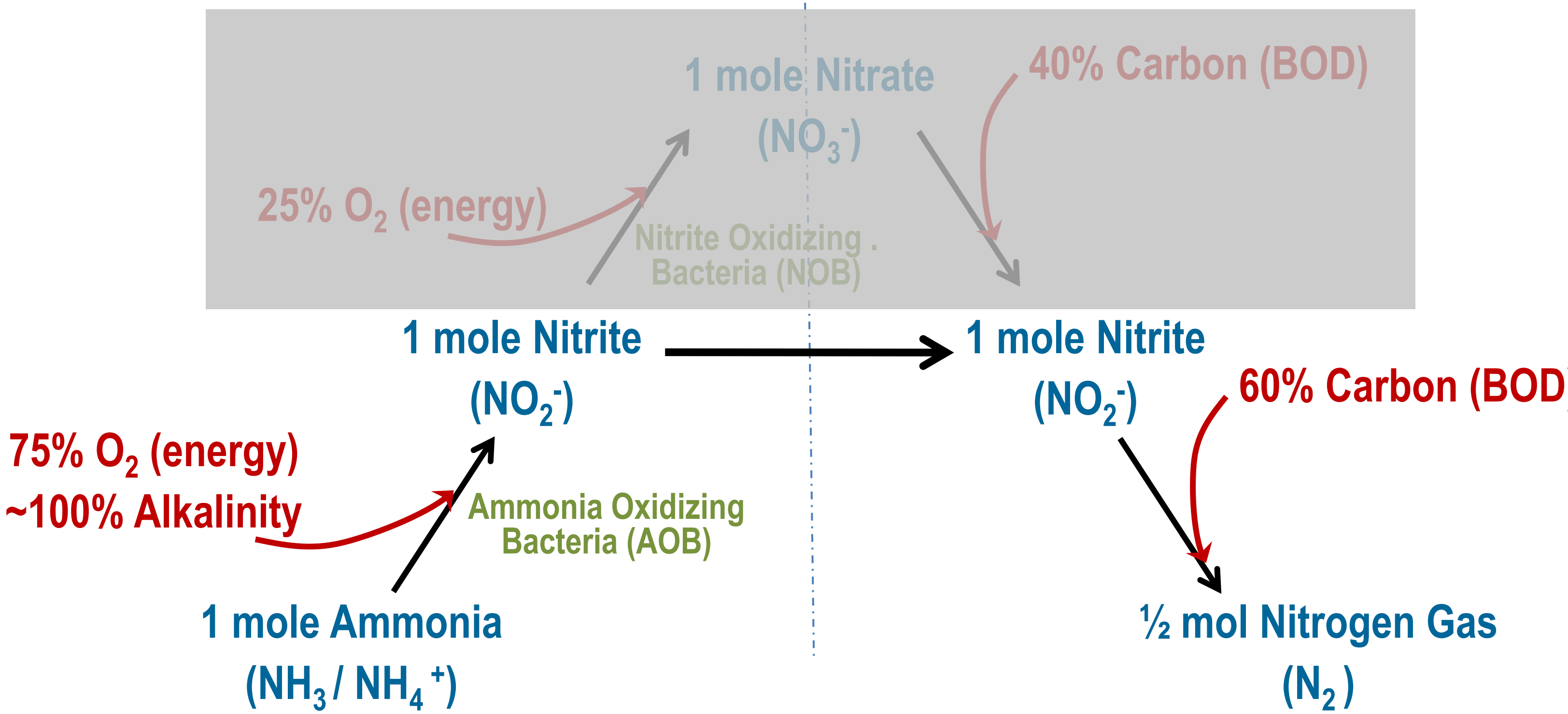
NITRIFICATION

DENITRIFICATION

Nitritation-Denitritation = “Nitrite Shunt”

Autotrophic Bacteria
Aerobic Environment

Heterotrophic Bacteria
Anoxic Environment



Advantages:

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

Can we implement this in the plant liquid stream?

Simultaneous Nitrification/Denitrification (SND)

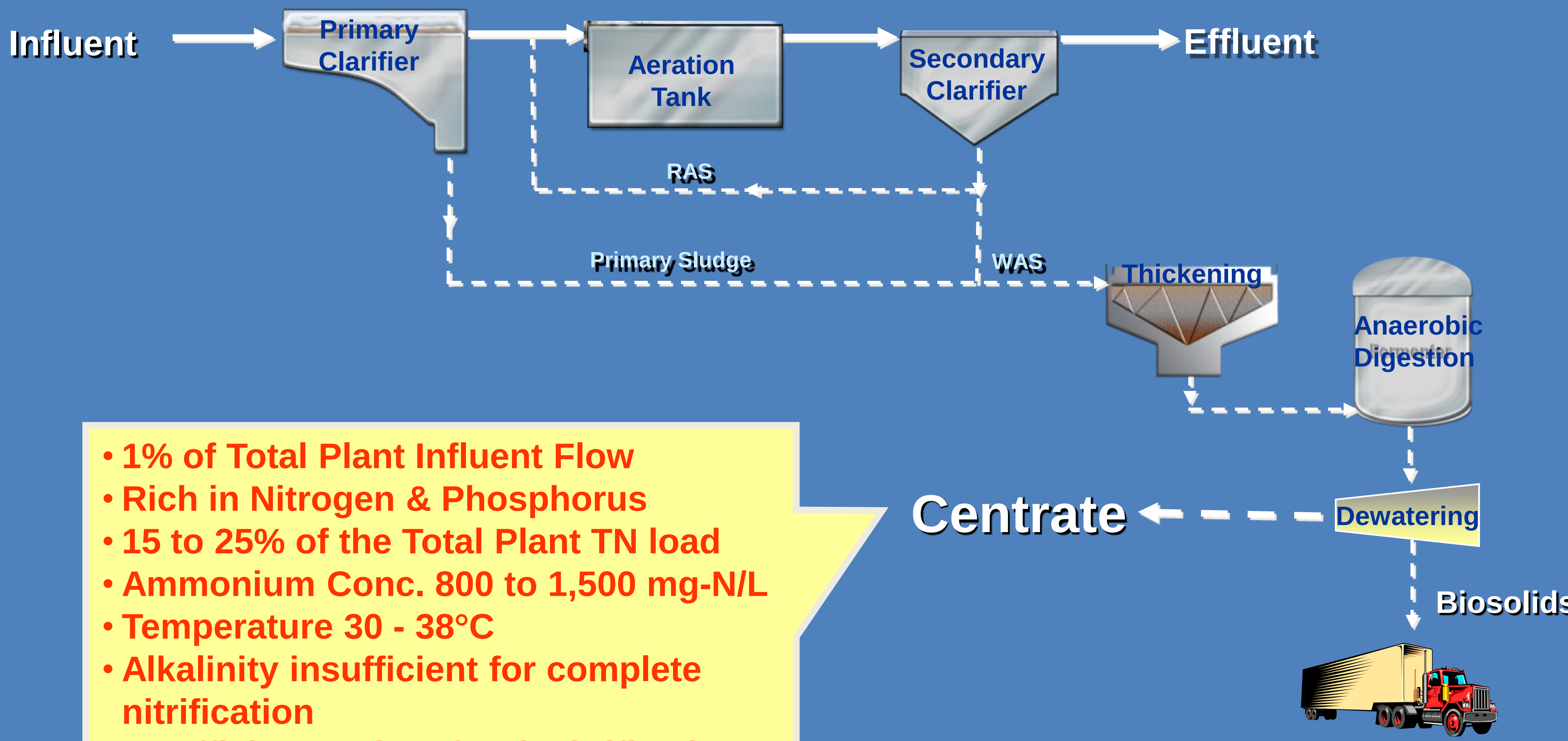
Orbal® Oxidation Ditch
Source: Siemens

Process has not been purposefully implemented in larger plants…

- Large aeration tank volume required
- Sophisticated instrumentation & controls
- Uncertain design
- Uncertain operation
- Risk of poor mixed liquor settling

Let’s now move to another part of the treatment plant…

Recycle Streams with High Ammonia - CENTRATE



- 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

Centrate Treatment Options

Biological - N

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

Nitritation / Denitritation
- Chemostat
- SBR
- Post Aerobic Digestion

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

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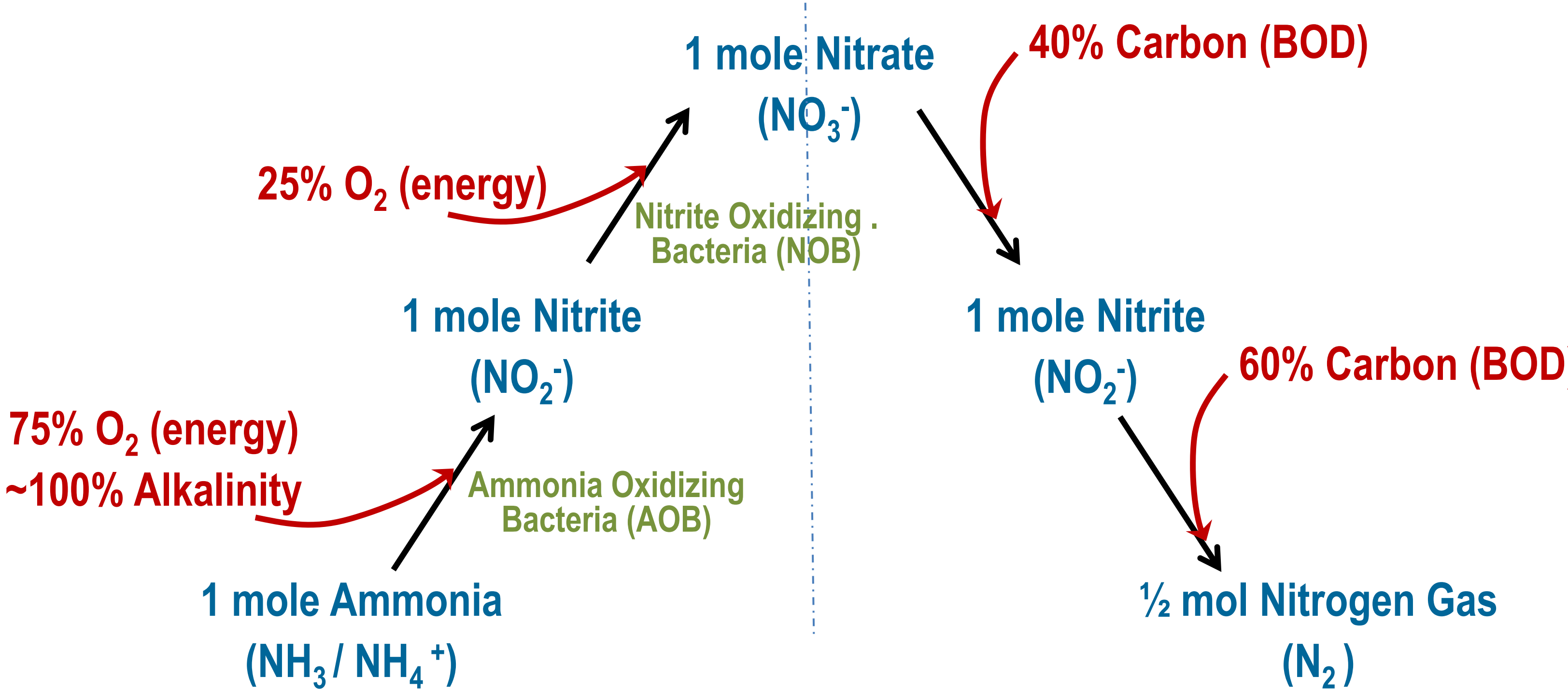
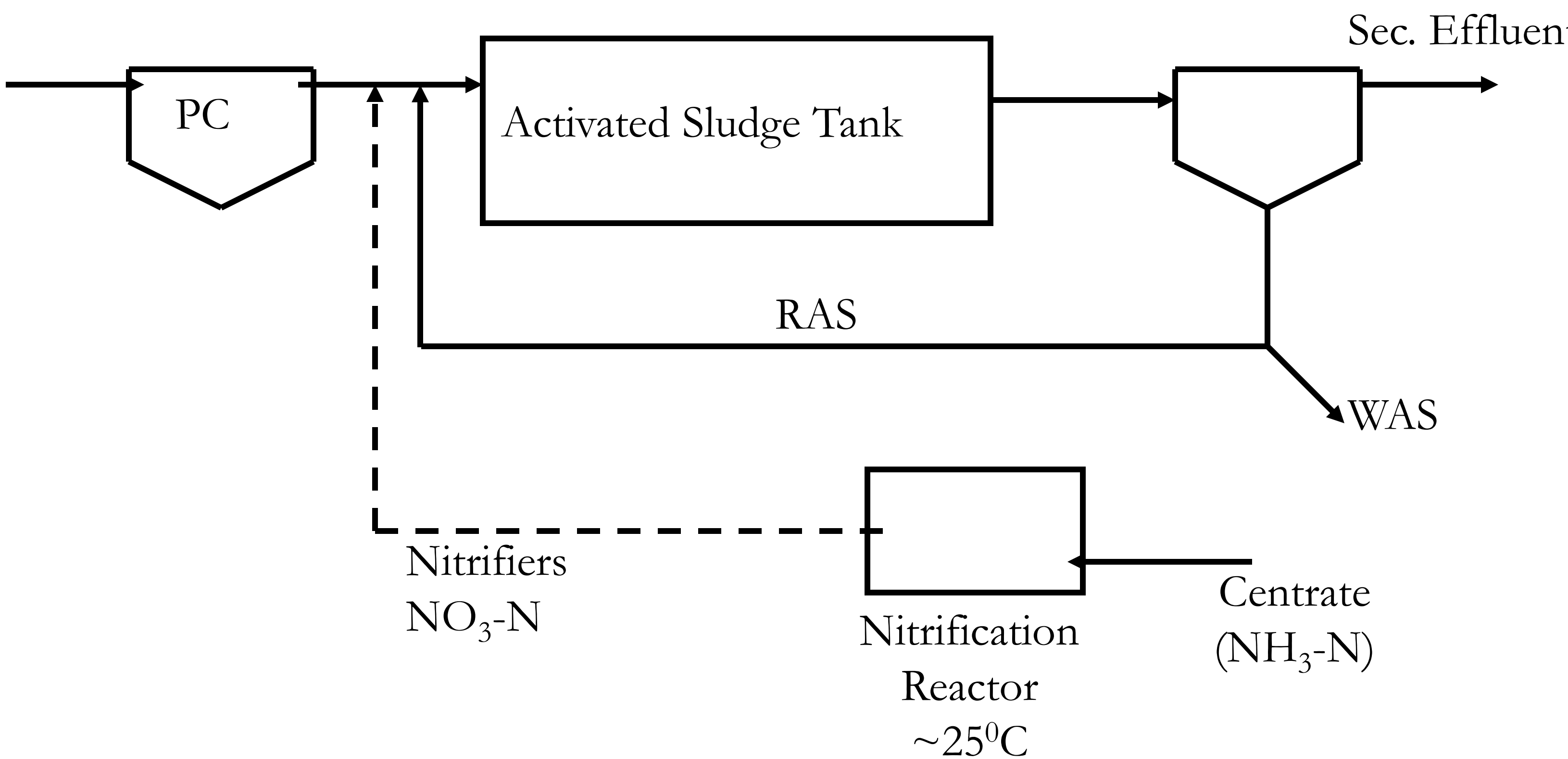


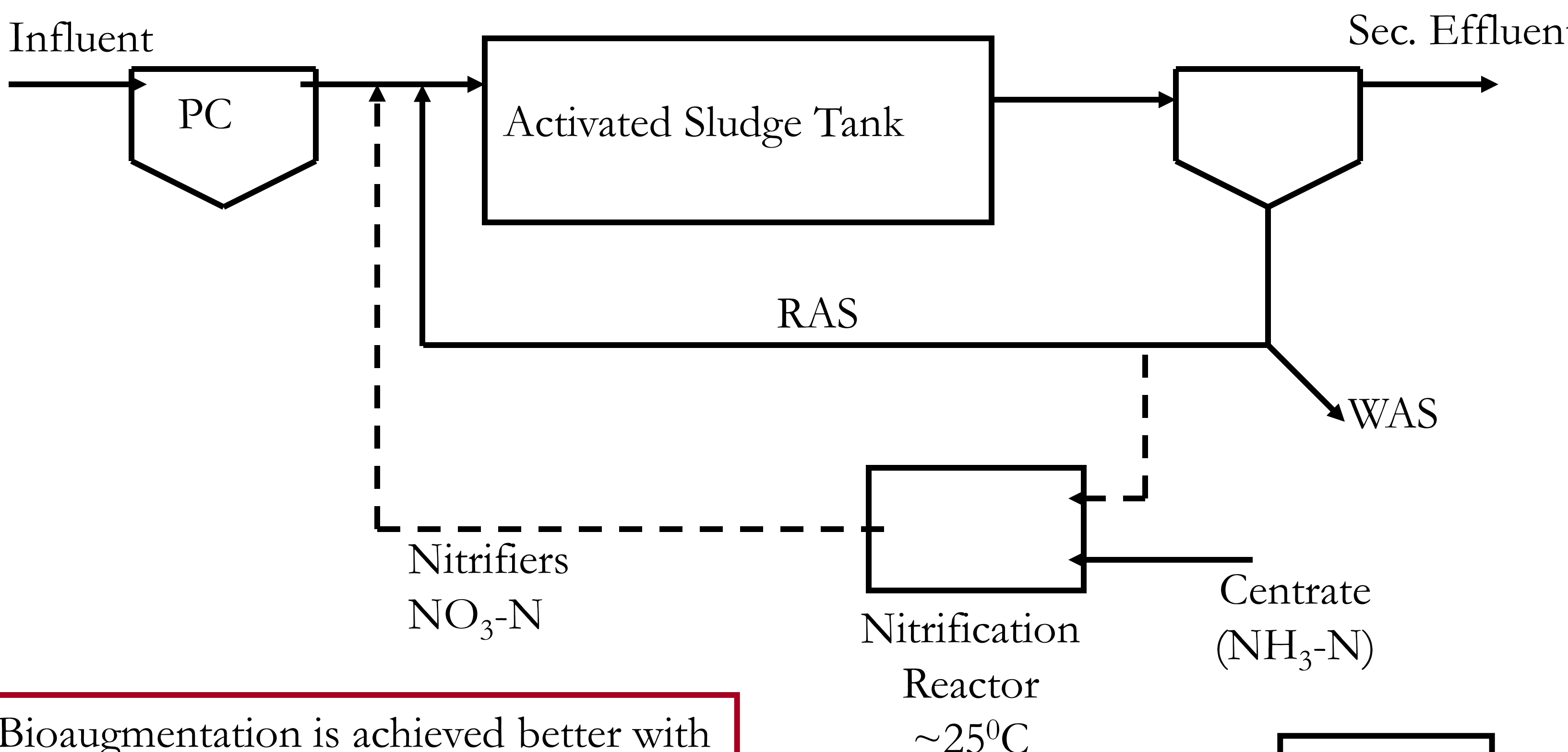
InNitri Process was the First Bioaugmentation Concept



Expected bioaugmentation benefit not fully realized
- Temperature change
- Poor capture of recycle stream nitrifiers
- Predation

Peter Kos
M2T Tech License

BABE Process – (SBR Mode of Operation)
Bio**A**ugmentation **B**atch **E**nhanced



Bioaugmentation is achieved better with This process

Delft U.
DHV
STOWA

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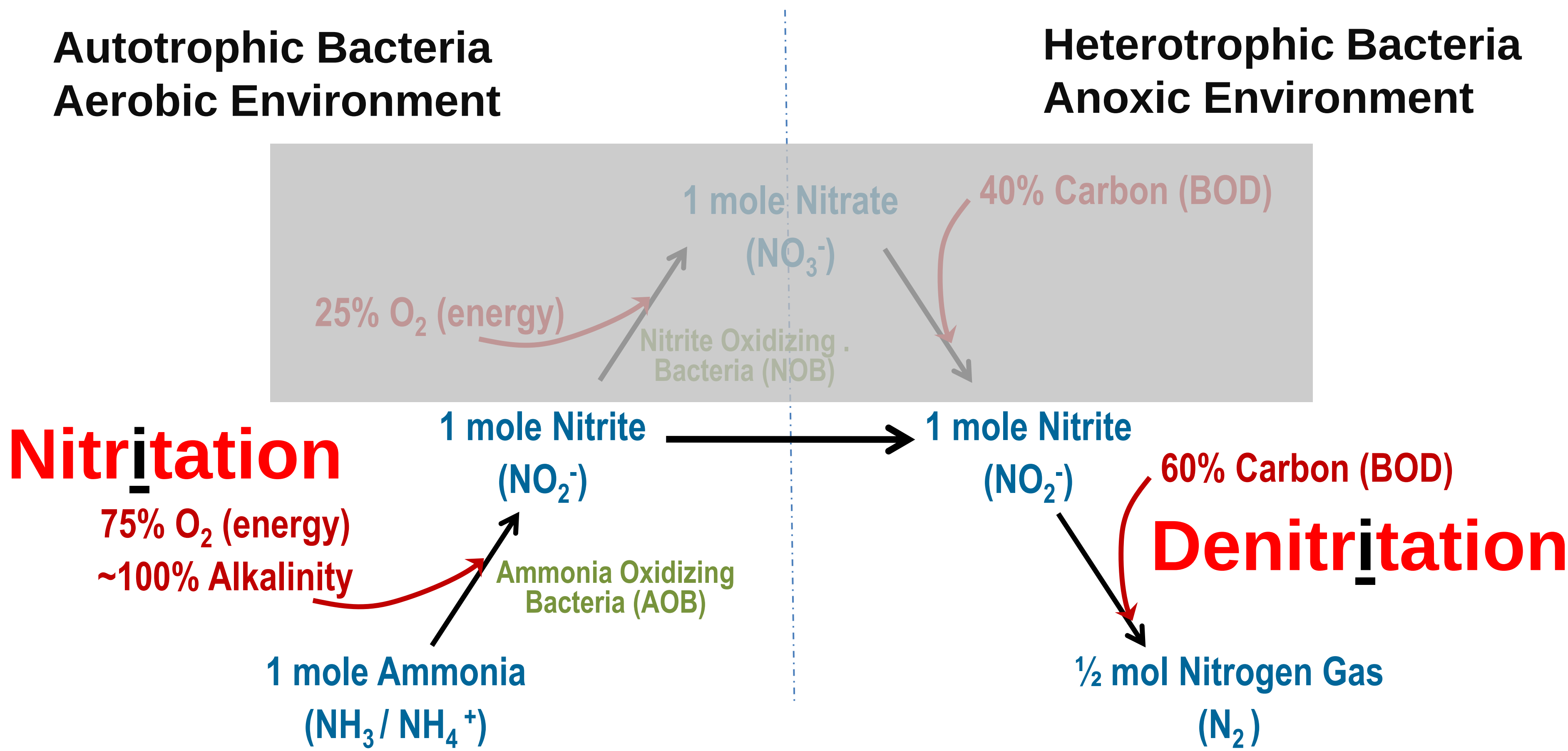
Nitritation-Denitritation = "Nitrite Shunt"



Advantages:

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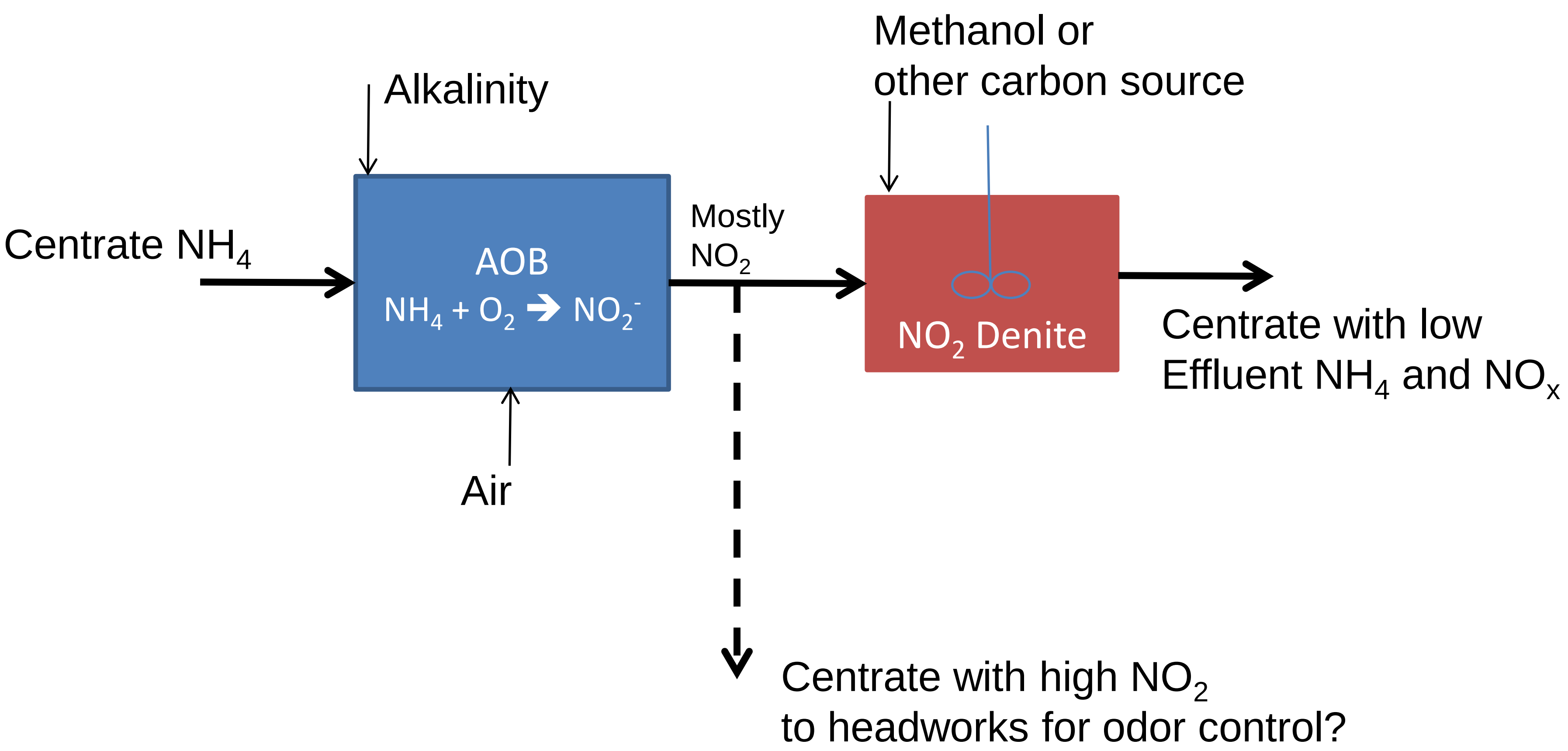
- 40% reduction in carbon (e^- donor) demand
- 40% reduction in biomass production

Nitritation (SHARON) - Denitritation



Centrate Treatment Options

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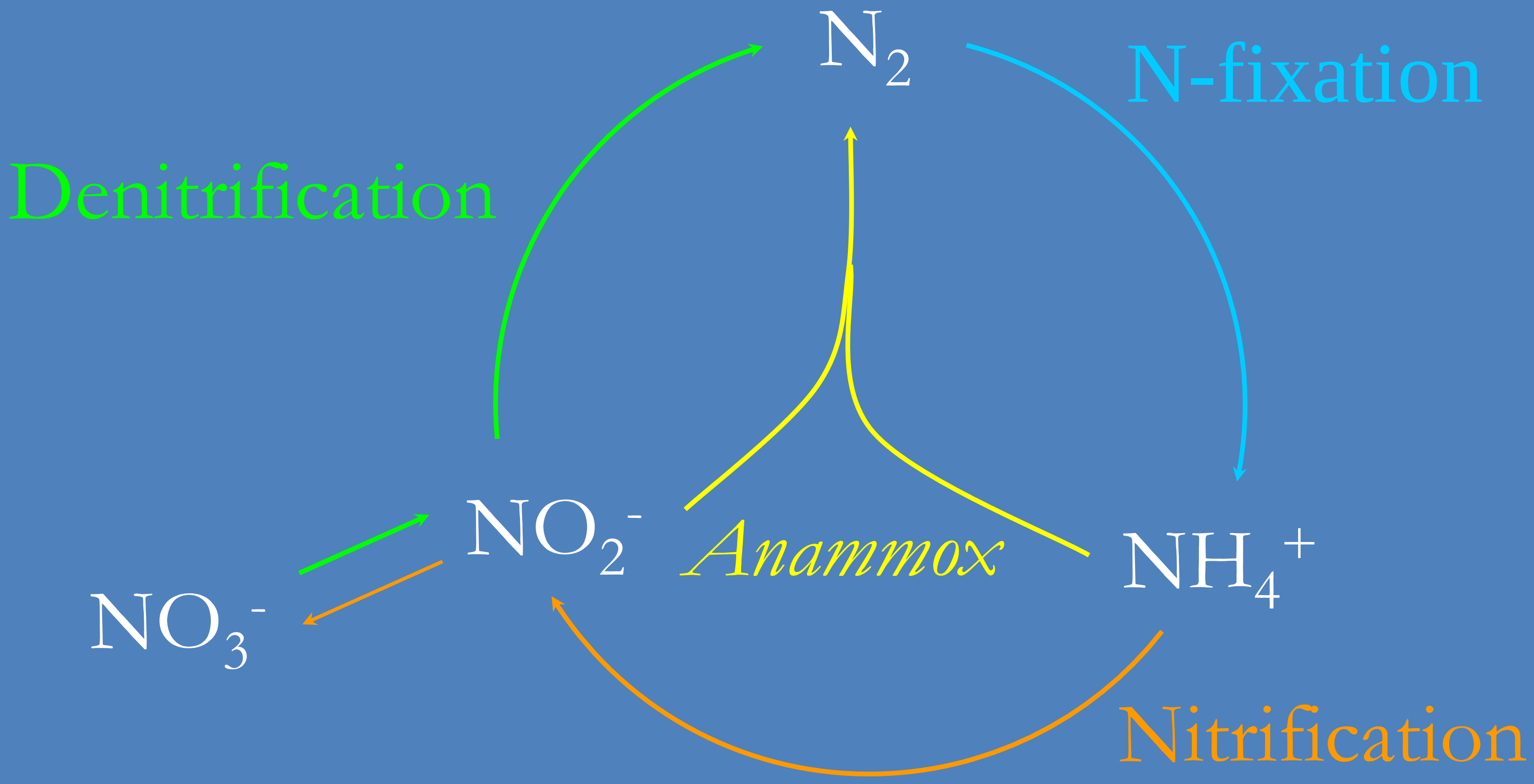
The N-Cycle



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

free enthalpy -360 kJ/mol

Partial Nitritation-Anammox = "Deammonification"

ANAMMOX

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

$$NH_4^+ + 1.32\,NO_2^- + 0.066\,HCO_3^- + 0.13\,H^+ \rightarrow$$

$$0.26\,NO_3^- + 1.02N_2 + 0.066\,CH_2O_{0.5}N_{0.15} + 2.03\,H_2O$$

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

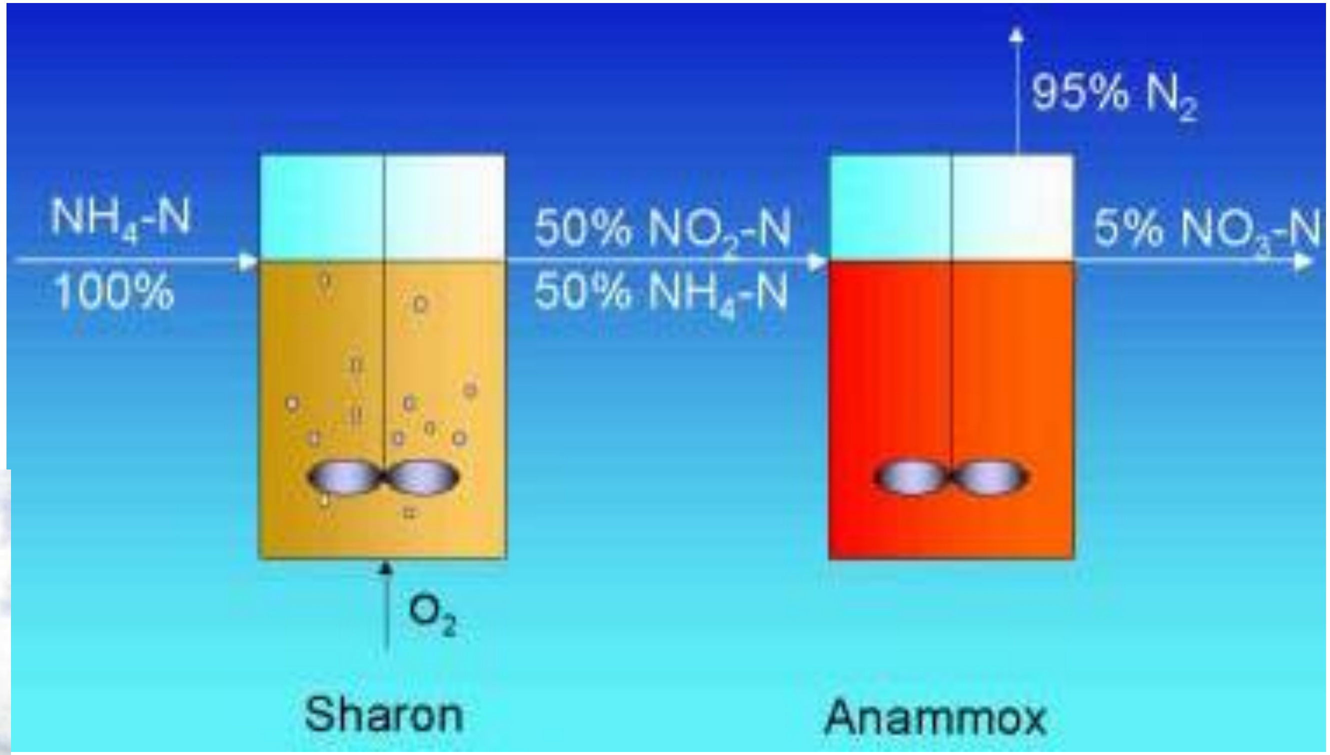
½ mol Nitrogen Gas (N_2) + a little bit of nitrate (NO_3^-)

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

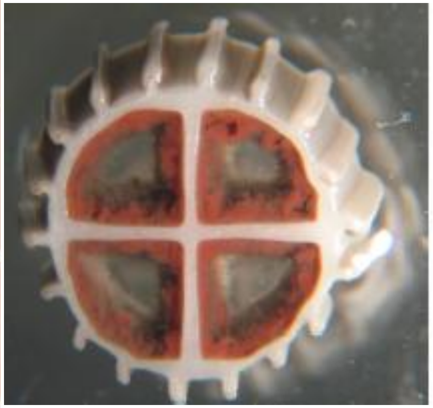
- Two Step Anammox Process
  - Dokhaven, Rotterdam (NL)



One-Step Centrate Deammonification

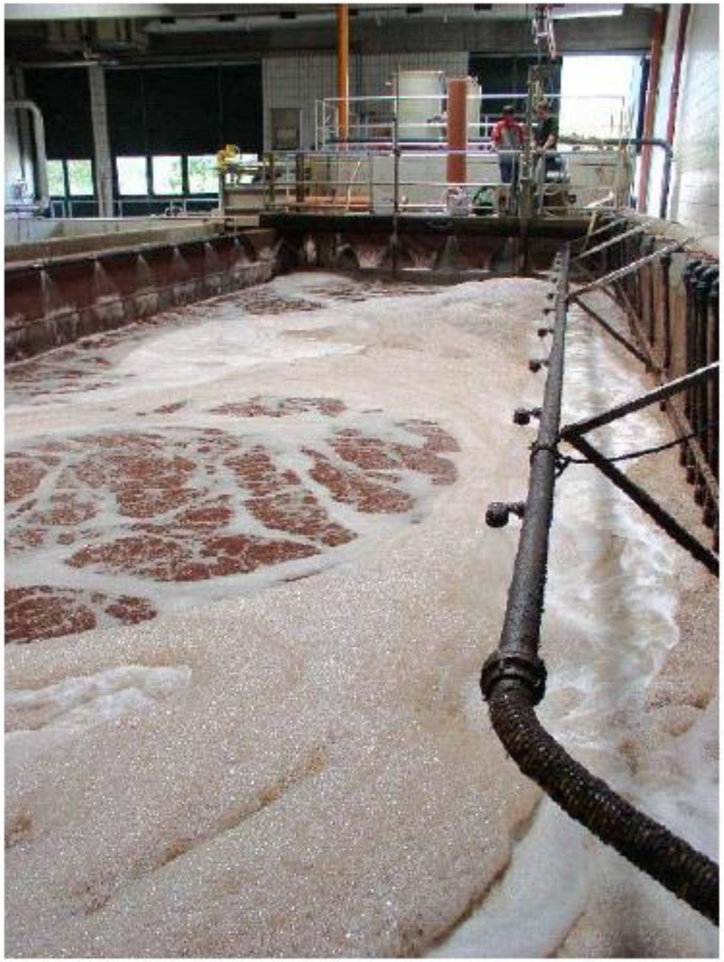
- **CANON - Paques Granular Sludge**
  - Olburgen, Netherlands
- **SBR-Type Process (DEMON)**
  - Strass, Austria + ~18 others
- **Attached growth process**
  - Hattingen, Germany
    - Deammon
  - Veolia Pilot- Malmo, Sweden
    - AnitaMox

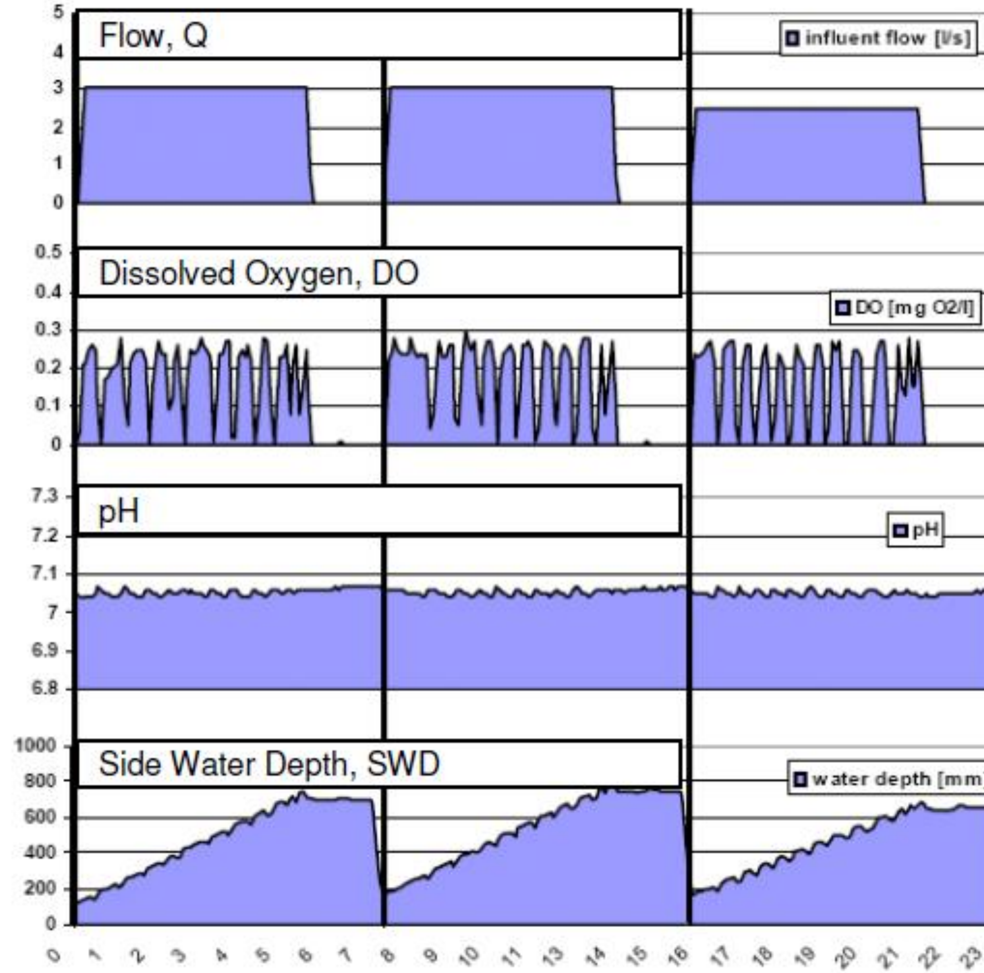
Partial Nitritation and Anammox - combined in a single reactor



Deammonification SBR – the DEMON™ Process

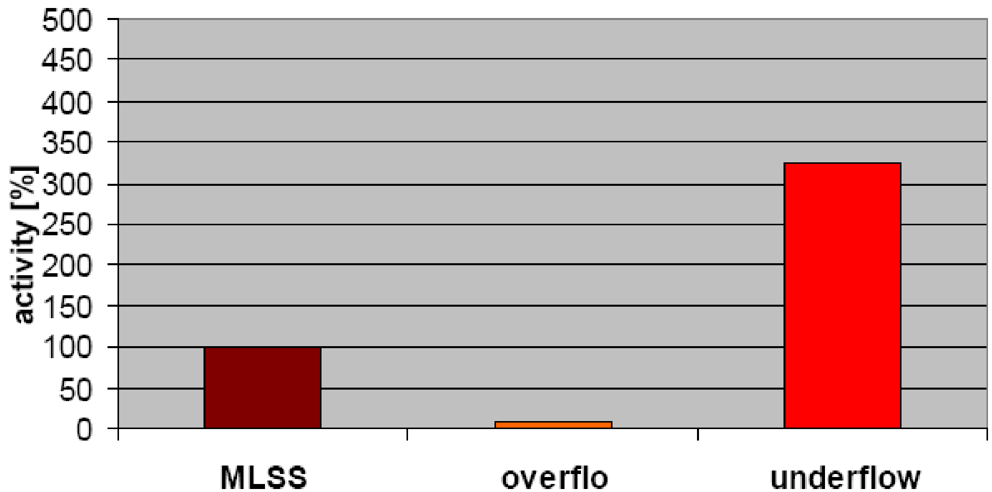
DEMON™ at Strass WWTP, Austria

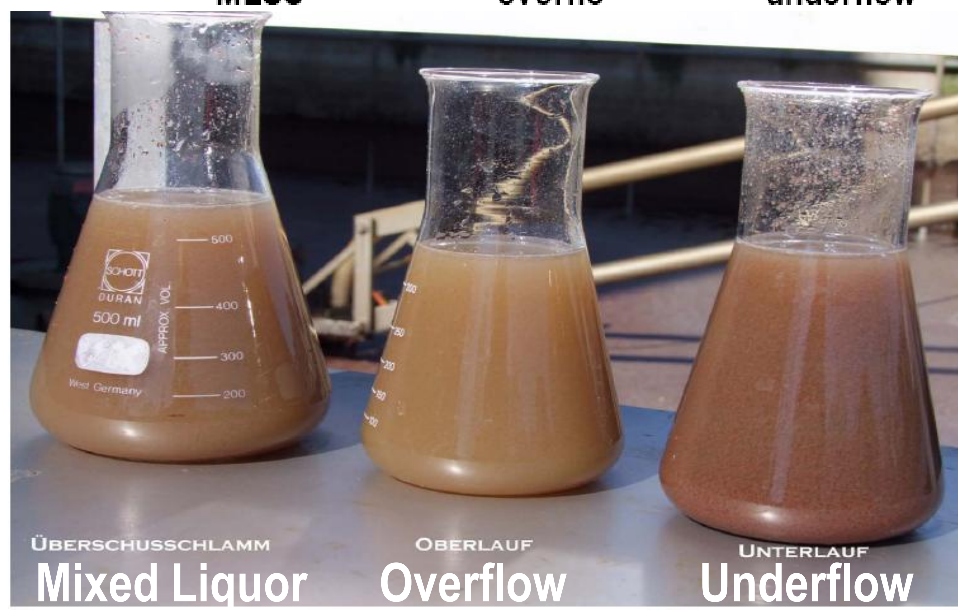




Picture/Figure by: Wett, B., Murthy, S., Takacs, I., Hell, M., Bowden, G., Deur, A., O'Shaughnessy, M. (2007). Key Parameters for Control of DEMON Deammonification Process. Wat. Practice. **1**(5). 1-11.

Cyclone for selecting for DEMON® Granules





Deammonification Experience: DEMON® Process

Operational:

- Strass, Austria
- Glarnerland, Switzerland
- Thun, Switzerland
- Plettenberg, Germany
- Heidelberg, Germany
- Apeldoorn, Netherlands

Several under construction;

- Croatia
- Austria
- Germany

Strass (A)

Apeldoorn (NL)

Heidelberg (D)

Thun (CH)

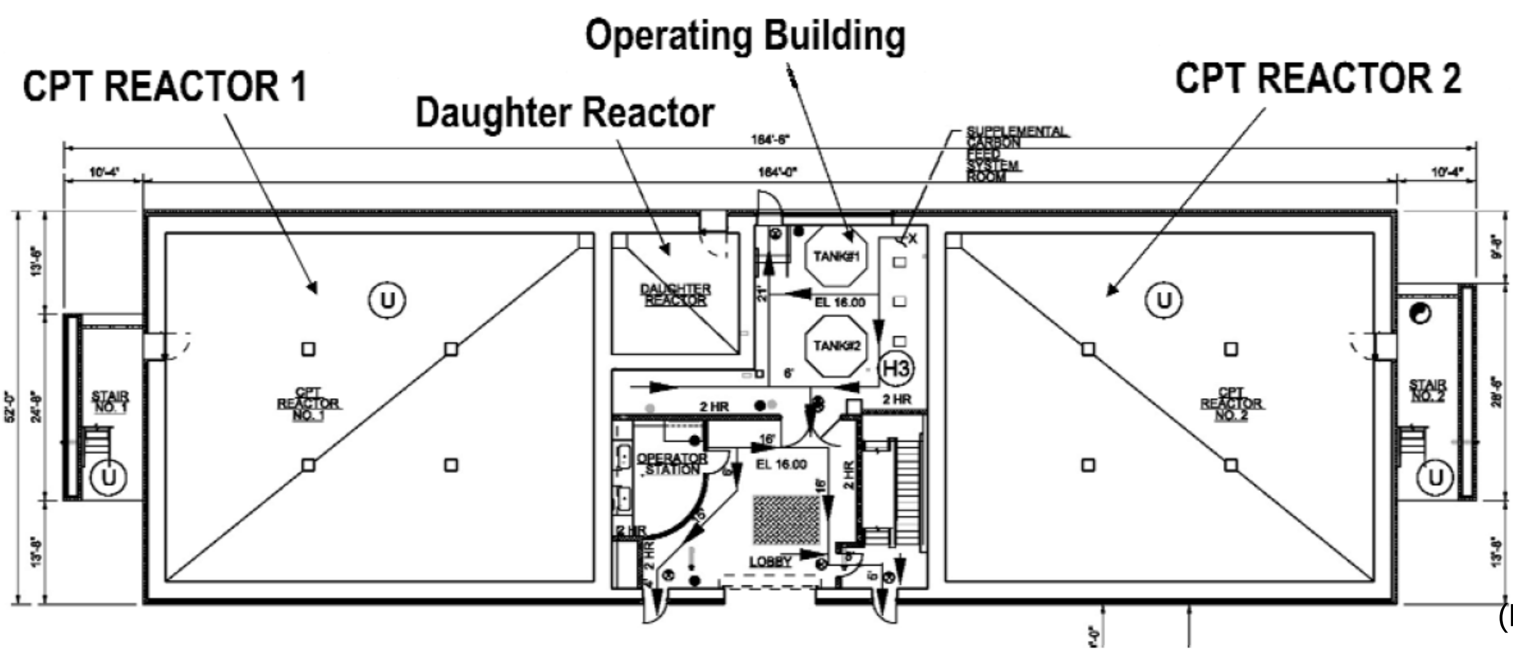
- By 2011 more centrate Demon facilities (>20) than conventional Nitrification/Denitrification
- Cyklar-Stulz & Grontmij providing turnkey services and now World Water Works in US

Sidestream Deammonification (Anammox) What's the benefit?

- Remove about 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:
  - Slow process startup (US plant)
  - Requires robust process control
  - *Process has been adequately demonstrated in Europe*
  - *We need just **one** in North America (anywhere)…*

ASA, UOSA, DCWater – Universal SBR

- Flexible SBR process for centrate treatment
  - Nitrification (+ Alkalinity)
  - Nitritation (+ Alkalinity)
  - Nitrification-Denitrification (with carbon + Alkalinity)
  - Nitritation-Denitritation (with carbon + Alkalinity)
  - Partial Nitritation-Anammox (DEMON)



(Daigger et al, 2011)

HRSD York River WWTP - DEMON

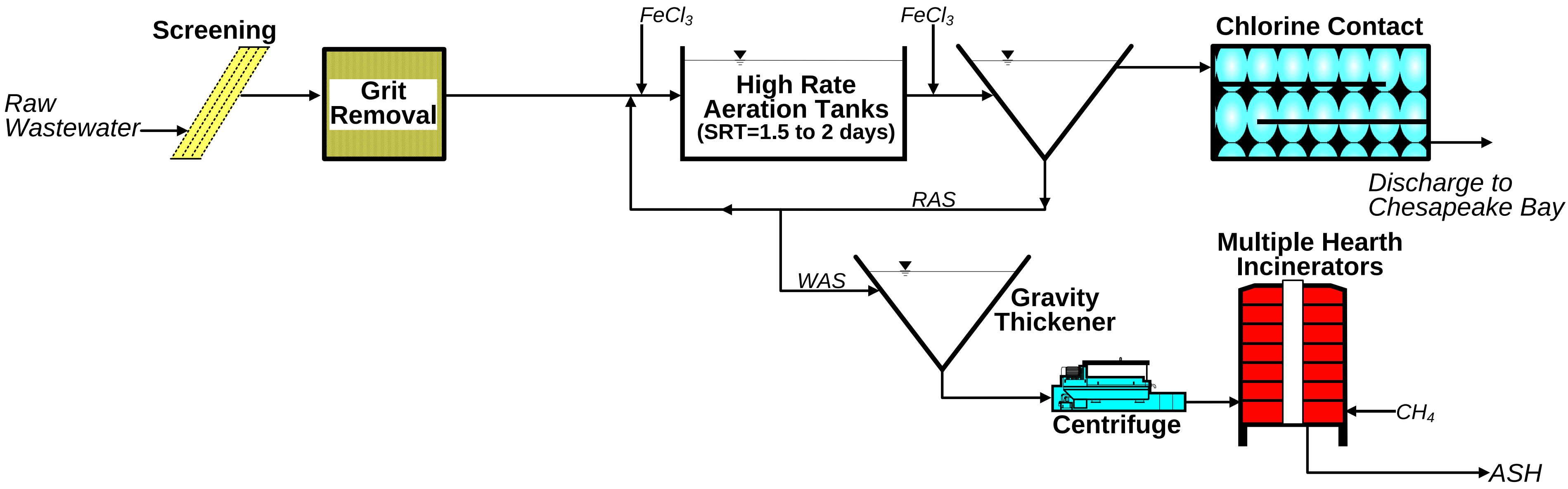
- World Water Works, Inc. now has an exclusive license from Cyklar-Stulz to market DEMON in the US
- WWW offered to install DEMON **at no cost to HRSD**:
  - Decanter, aeration upgrades, instrumentation and controls, DCS hardware, other modifications
  - Anammox seed sludge transported from Europe
- Installation occurring now
- Startup expected January 2012

York River Treatment Plant
DEMON Under Construction

Now let's discuss the Ches-Eliz TP

Chesapeake-Elizabeth Treatment Plant

- 24 MGD design, 15-21 MGD operating

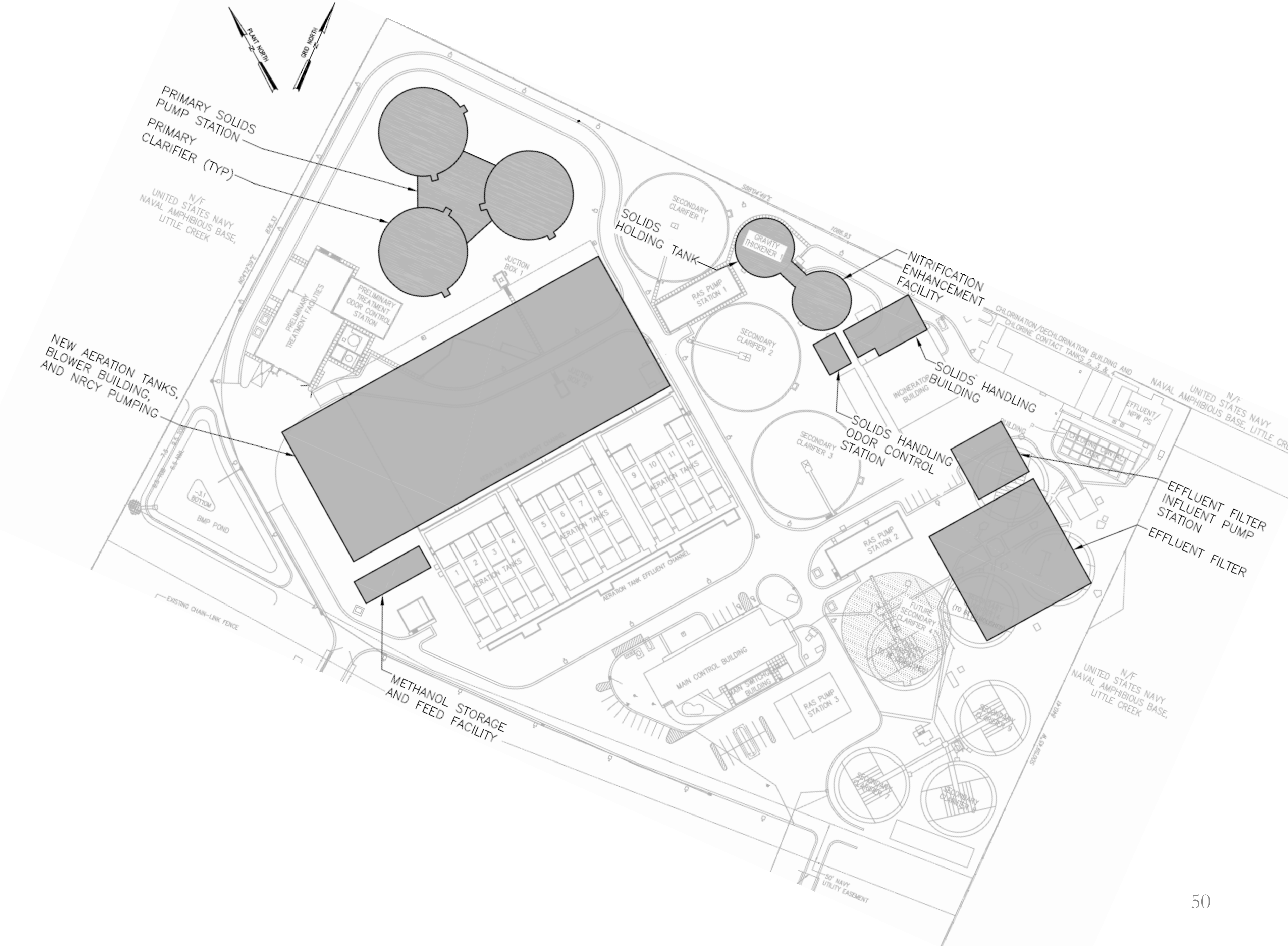


Chesapeake – Elizabeth WWTP

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)

- Approximate $125-150M capital cost
- 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?


PLANT NORTH
GRID NORTH
PRIMARY SOLIDS PUMP STATION
PRIMARY CLARIFIER (TYP)
N/F UNITED STATES NAVY NAVAL AMPHIBIOUS BASE, LITTLE CREEK
SOLIDS HOLDING TANK
GRAVITY THICKENER
NITRIFICATION ENHANCEMENT FACILITY
SOLIDS HANDLING BUILDING
SOLIDS HANDLING ODOR CONTROL STATION
NEW AERATION TANKS, BLOWER BUILDING, AND NRCY PUMPING
EFFLUENT FILTER INFLUENT PUMP STATION
EFFLUENT FILTER
METHANOL STORAGE AND FEED FACILITY
SECONDARY CLARIFIER 1
SECONDARY CLARIFIER 2
SECONDARY CLARIFIER 3
RAS PUMP STATION 1
RAS PUMP STATION 2
RAS PUMP STATION 3
PRELIMINARY TREATMENT FACILITIES
PRELIMINARY TREATMENT ODOR CONTROL STATION
AERATION TANKS
AERATION TANK EFFLUENT CHANNEL
MAIN CONTROL BUILDING
MAIN SWITCHGEAR BUILDING
INCINERATOR BUILDING
FUTURE SECONDARY CLARIFIER 4
CHLORINATION/DECHLORINATION BUILDING AND CHLORINE CONTACT TANKS 2, 3 &
EFFLUENT/ NPW PS
N/F UNITED STATES NAVY NAVAL AMPHIBIOUS BASE, LITTLE CRE
BMP POND
EXISTING CHAIN-LINK FENCE
50' NAVY UTILITY EASEMENT

BNR Pilot Testing at the Chesapeake-Elizabeth Treatment Plant

Ches-Eliz Nutrient Removal Pilot Study

- – 4 year study
- – Collaboration through Water Environment Research Foundation (WERF) project:
  - DCWater
  - One Swiss and one Austrian wastewater utility
  - American Water
  - Developers of the DEMON process
  - ODU, Virginia Tech, Columbia University (NY), University of Innsbruck (Austria)
  - Two US engineering firms – HDR and Black & Veatch
  - Several other US wastewater utilities

Concepts for Pilot Testing

1. Two stage "A/B" process:
   - A stage – high rate activated sludge for 60-70% COD removal
   - B stage – MLE in SND mode (N removal 2.0)
2. Two or Three stage process:
   - activated sludge for COD removal
   - partial nitritation – Anammox (Deammonification) (N removal 3.0)
3. Two or Three stage process (energy positive):
   - Anaerobic treatment (CH_4 gas generation) for COD removal
   - partial nitritation – Anammox (Deammonification) (N removal 3.0)

Chesapeake – Elizabeth WWTP

Potential Benefits – Compared to Baseline BNR Alternative

1. Two stage "A/B" process:
   - Reduced capital cost and footprint
   - Increased sludge production
   - Similar energy use
   - Slightly increased chemical use
2. Two or Three stage process with Deammonification:
   - Potential reduction in capital cost
   - Similar sludge production
   - Footprint uncertain
   - Significant reduction in chemical and energy use
   - Potentially energy neutral
3. Two or Three stage process with Anaerobic Treatment & Deammonification:
   - Energy positive treatment
   - Minimal chemicals
   - Minimal sludge production
   - Significant O&M cost savings
   - Likely increased capital cost and footprint requirement

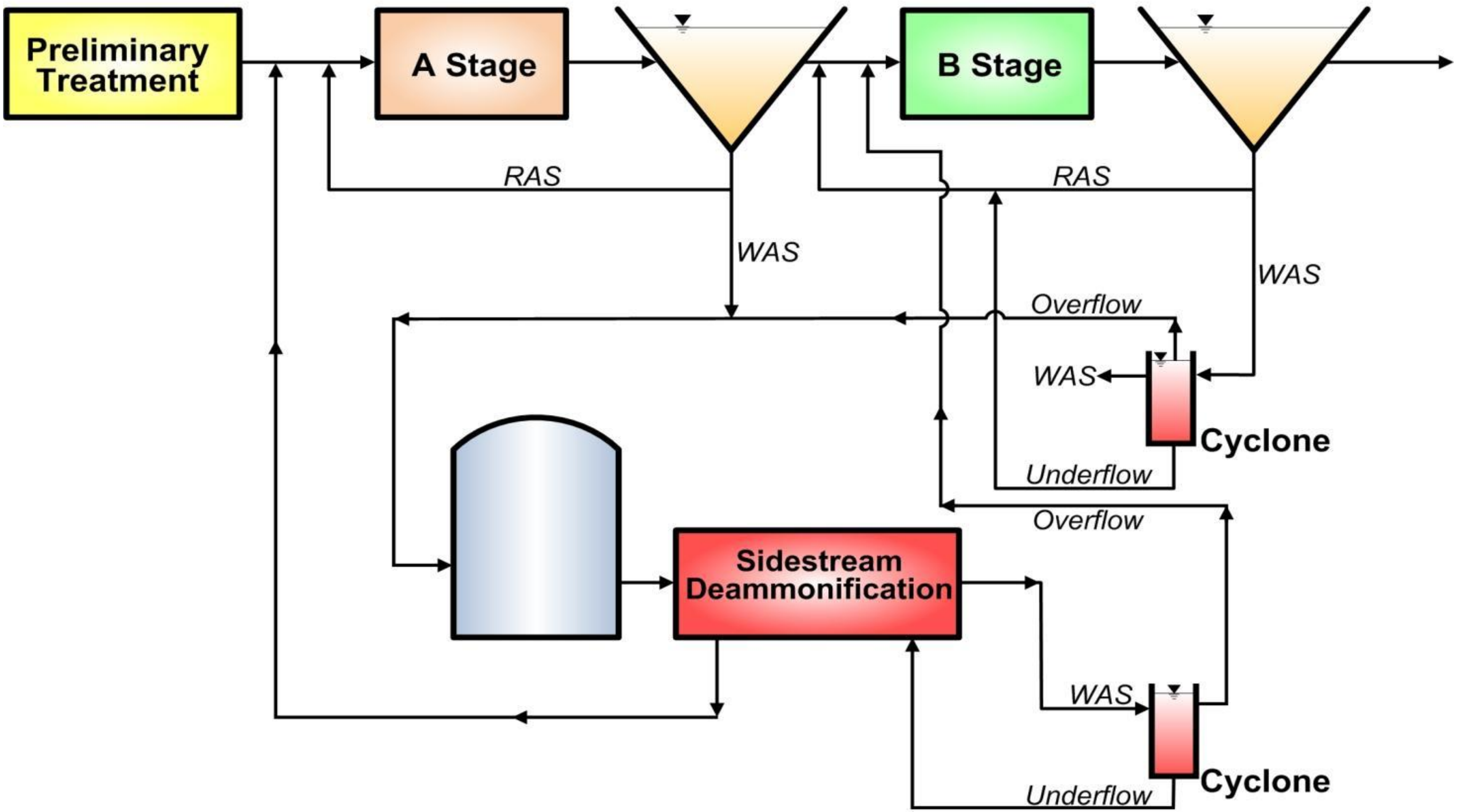
Mainstream Deammonification

- Very challenging….
- Primary objective: Eliminate competition for NO_2^-
- Selective retention of Anammox bacteria is critical
- Risk is high that this process will not work, but reward is very high…
  - Reduce capital cost by ~$20-40M
  - Reduce chemical cost by $1-2M/yr (no increase above current conditions)
  - Reduce energy cost by ??? (depends on A-stage)

Mainstream Deammonification Status – Worldwide

- Strass, Austria – ~10 MGD
  - Full-scale conversion complete and testing in progress
- Glarnerland, Switzerland - ~15 MGD
  - Full-scale testing of one train in progress
  - Not designed as currently envisioned
  - Testing has been moderately successful

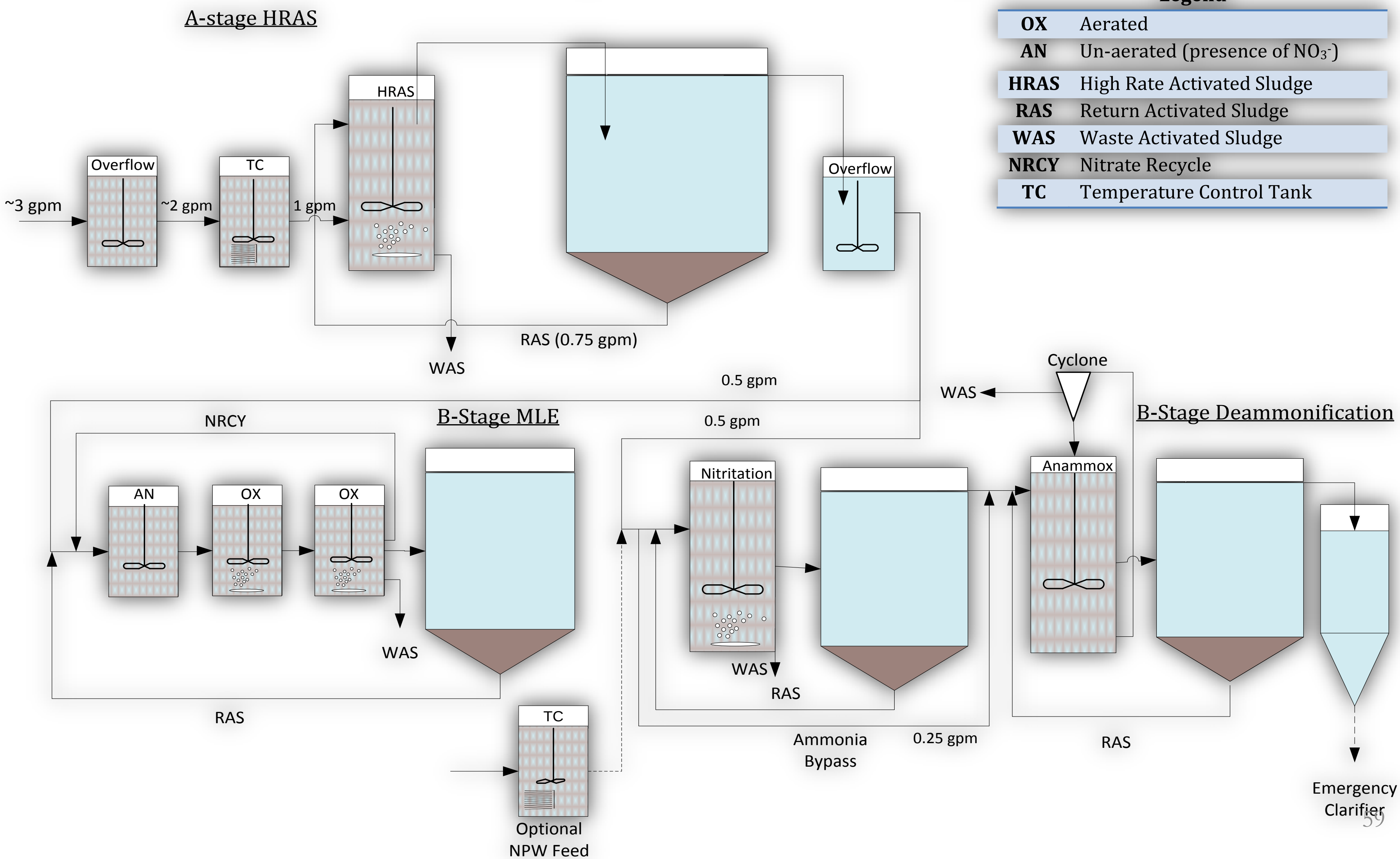
STRASS WWTP DEMONSTRATION (Full-Scale)



Pilot System Schematic

Hampton Roads Sanitation District
Chesapeake Elizabeth Pilot Study

Legend	
OX	Aerated
AN	Un-aerated (presence of NO_3^-)
HRAS	High Rate Activated Sludge
RAS	Return Activated Sludge
WAS	Waste Activated Sludge
NRCY	Nitrate Recycle
TC	Temperature Control Tank

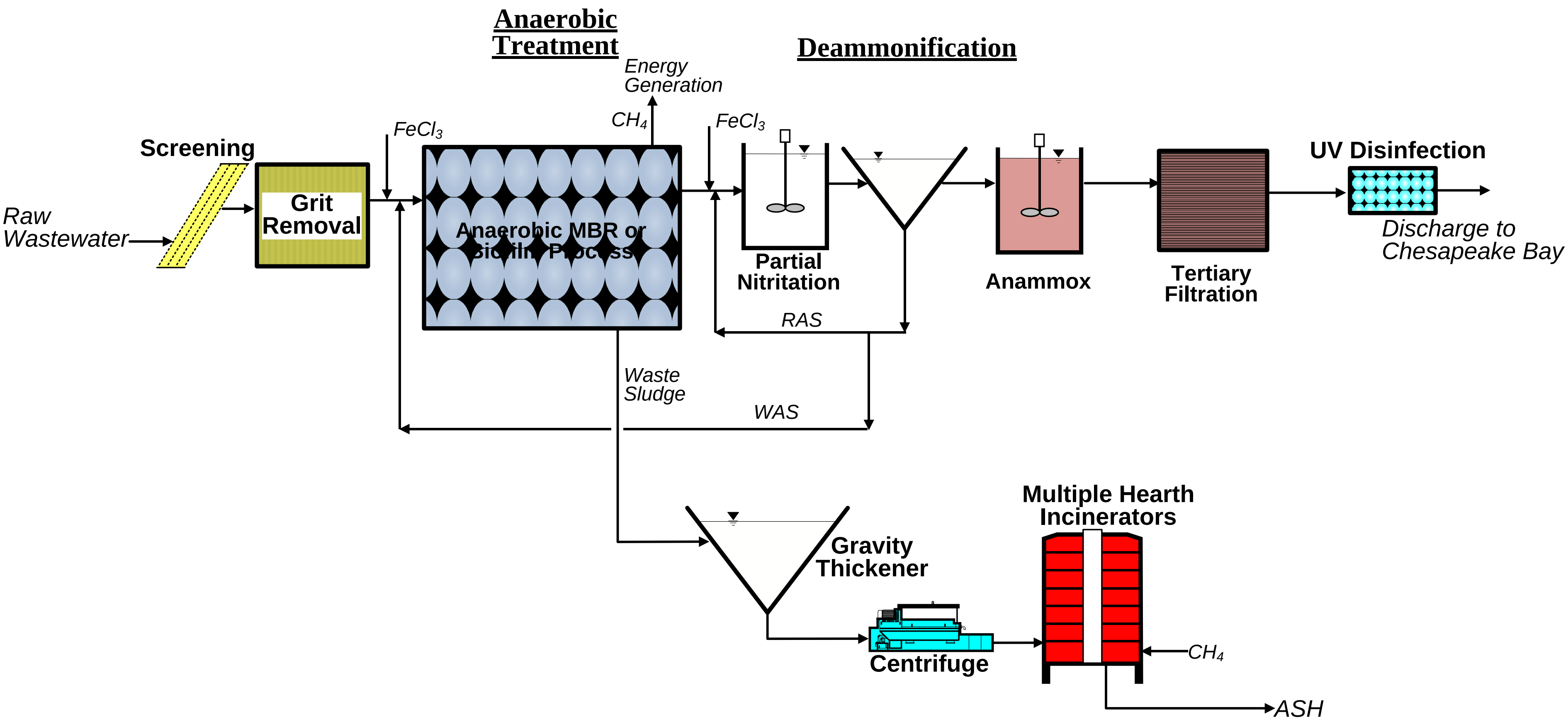


A-Stage HRAS

B-Stage MLE

B-Stage Deammonification

Ideal Configuration…



If this works…

- Capital cost may be about the same - $125-150M
- Reduce chemical cost by $1-2M/yr (no increase above current conditions)
- **Energy positive plant with TN removal is possible:**
  - Current energy use at Ches-Eliz = $1.25M/yr (electricity and natural gas)
  - Projected increase with conventional BNR ~ $1.0M/yr
  - Savings ~ $2.25M/yr
  - Energy production??

Questions?

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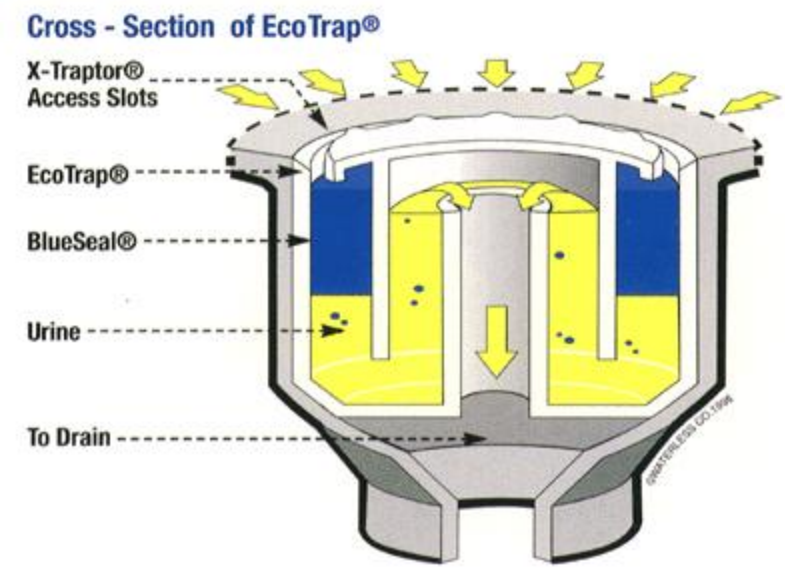
Source Separation in the HRSD Main Office



New HRSD Operations Center Complex

What is Source Separation?

- Separation of concentrated urine stream from gray and black water
- Urine contains >70% of the TKN and >60% of the TP in <1% of raw sewage flow
- Management of urine separate from sewage:
  - Separate high strength urine treatment → biologically convert NH_4 to N_2, precipitate OP using $FeCl_3$ or alum
  - NH_4 recovery – stripping and production of $(NH_4)_2SO_4$ or NH_4NO_3 fertilizer
  - Recover OP using lime – apatite or hydroxyapatite solids
  - Evaporation
  - Electrodialysis + ozonation
  - Best - Recover NH_4 and OP by struvite precipitation ($MgNH_4PO_4$-$6H_2O$)

Motivation for Source Separation

- This is a truly sustainable solution for the wastewater industry and nutrient removal
  - Environmental benefits
  - Financial benefit for wastewater utility
- This has not been done in the US – demonstration or otherwise

WERF
Water Environment Research Foundation
Collaboration. Innovation. Results.

Source Separation and Treatment of Anthropogenic Urine

Co-published by
IWA Publishing

INFR4SG09b

SOURCE SEPARATION AND TREATMENT OF ANTHROPOGENIC URINE

by:
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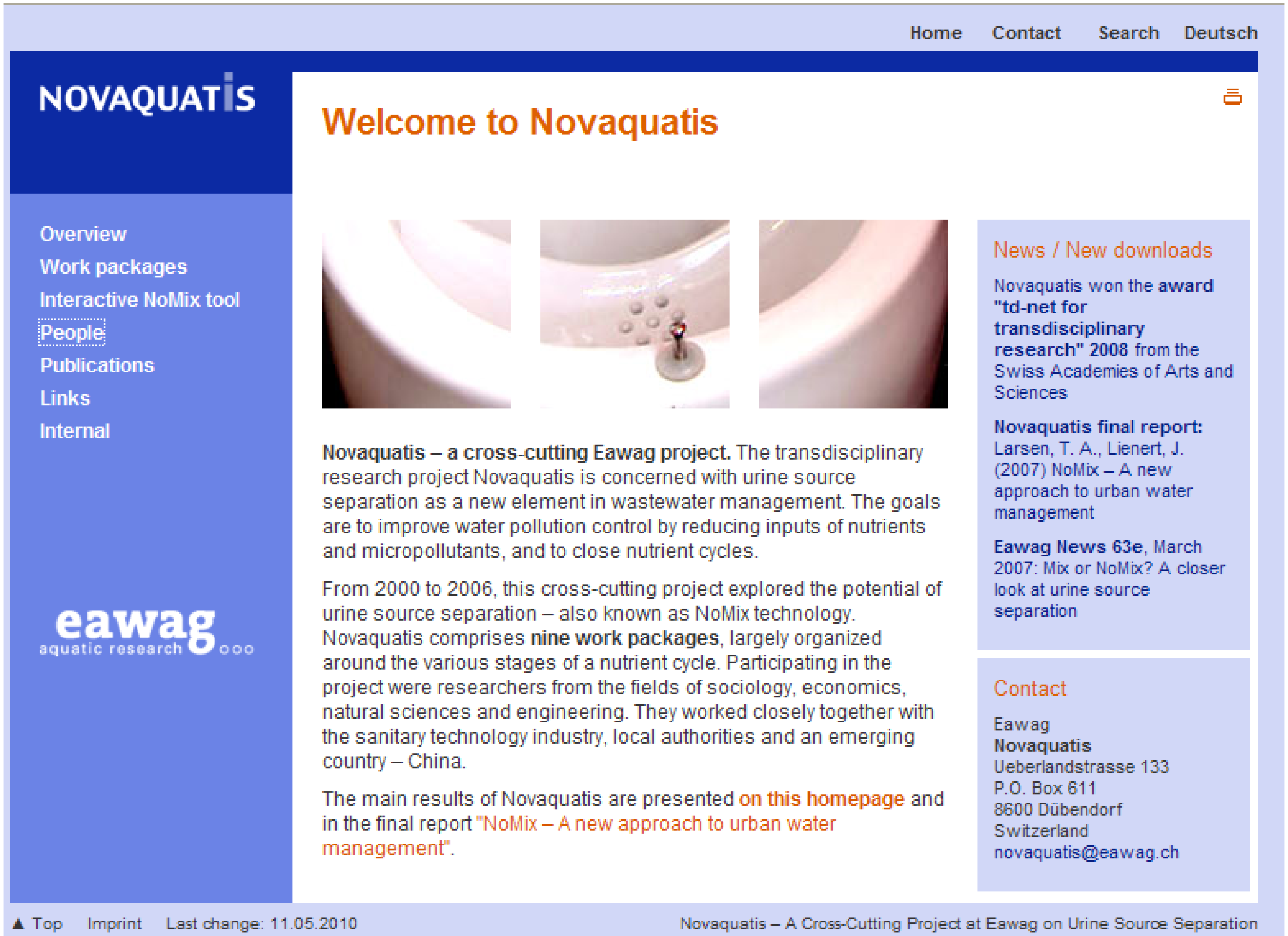
Colorado State University

2011

WERF

Examples from Around the World

- EAWAG, Switzerland



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NOVAQUATIS

Welcome to Novaquatis

- Overview
- Work packages
- Interactive NoMix tool
- People
- Publications
- Links
- Internal

eawag aquatic research

Novaquatis – a cross-cutting Eawag project. The transdisciplinary research project Novaquatis is concerned with urine source separation as a new element in wastewater management. The goals are to improve water pollution control by reducing inputs of nutrients and micropollutants, and to close nutrient cycles.

From 2000 to 2006, this cross-cutting project explored the potential of urine source separation – also known as NoMix technology. Novaquatis comprises **nine work packages**, largely organized around the various stages of a nutrient cycle. Participating in the project were researchers from the fields of sociology, economics, natural sciences and engineering. They worked closely together with the sanitary technology industry, local authorities and an emerging country – China.

The main results of Novaquatis are presented on this homepage and in the final report "NoMix – A new approach to urban water management".

News / New downloads

Novaquatis won the **award "td-net for transdisciplinary research" 2008** from the Swiss Academies of Arts and Sciences

Novaquatis final report: Larsen, T. A., Lienert, J. (2007) NoMix – A new approach to urban water management

Eawag News 63e, March 2007: Mix or NoMix? A closer look at urine source separation

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▲ Top Imprint Last change: 11.05.2010 Novaquatis – A Cross-Cutting Project at Eawag on Urine Source Separation

Examples from Around the World

- Several tall buildings in Japan + struvite recovery
- Stockholm suburban development – 160 people
  - Swedish Goal: 60% of P recycled from wastewater by 2015

Examples from Around the World

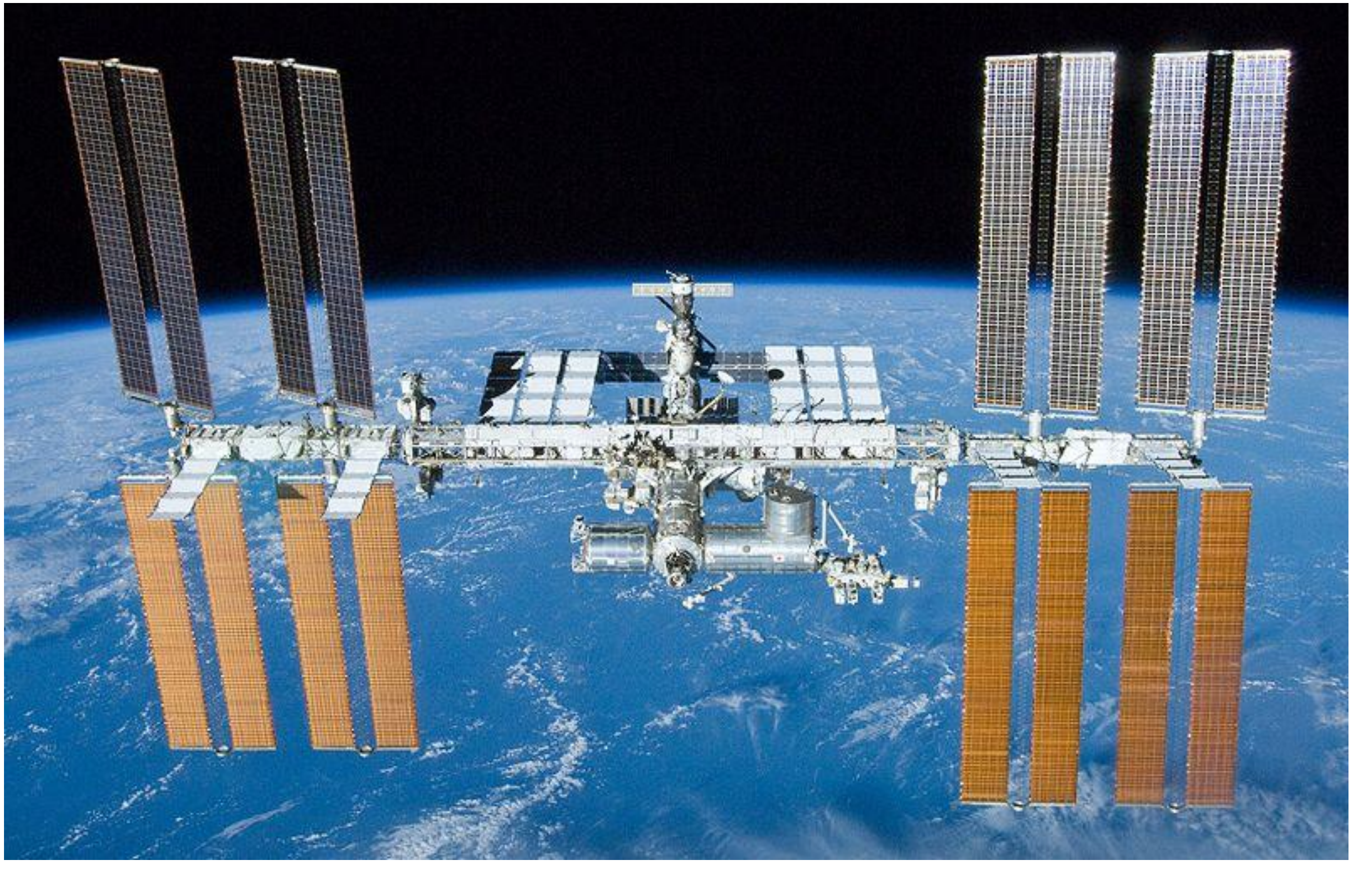
- German Technical Cooperation (GTZ) - Sustainable Sanitation- ECOSAN
- Office building with 56 No-mix toilets + 25 waterless urinals → 8000 L/week urine
- Struvite production

Figure 2-15 Struvite Produced from Urine at GTZ Headquarters (M. Winker, 2010).
Reprinted with permission from GTZ.

Figure 2-16 MAP (Struvite) Reactor at GTZ Headquarters (M.Winker, 2010).
Reprinted with permission from GTZ.

Examples from Around the World

- International Space Station…



Examples from Around the World

- Direct use of urine as a fertilizer in developing countries – promoted by Swedish Water Institute

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Human Urine Safe, Productive Fertilizer

By Carolyn Colwell
HealthDay Reporter
Monday, October 8, 2007; 12:00 AM

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MONDAY, Oct. 8 (HealthDay News) -- Cash-strapped farmers shouldn't look far for a source of free fertilizer, according to a new study that finds human urine to be a great source of nitrogen and other minerals.

The "yuck" factor aside, scientists who used urine to help raise a bumper crop of cabbages

urine ➔ fertilizer

DIY KIT

LEED Certification

- Currently no credit for source separation
- All water-related criteria providing LEED points either provide no benefit to the **<u>wastewater utility</u>** or make treatment more difficult & expensive

- Discussion ongoing with USGBC

The Concept for the Operations Center Building

- Install waterless urinals in male bathrooms
  - Install separate drain line from urinals to collection tank located outside mechanical room with valve (?) allowing redirection to main sewer
- Install separate “yellow water” and ”black water“ drain lines in female bathrooms
  - Install normal toilets for now – yellow water line connected to main sewer for now
  - Flush toilets with reclaimed gray water or stormwater
- “Test Drive” one urine separating toilet

The Concept for the Operations Center Building

- Size collection tank to contain 2-4 weeks of urine (men) with provisions to expand for women
- pH control system & H_2SO_4 feed
- GAC or acid trap odor control for tank (NH_3)
- Pump and truck load out station
- Ability to offload truck into centrate tanks at Nansemond Plant – Ostara process

Back of the Envelope – Ops Center

- 100 adult men in building for 8 hours/day
- 0.75 L/day/person ➔ 75 L/day = 600 gal/month
- Urine characteristics:
  - 4300 mg/L NH_4-N
  - 1000 mg/L OP
- Assume 80% conversion of OP in urine to struvite
  - ~1.0 lb/day struvite produced
- Future → Follow Ostara by Anammox centrate treatment process for NH_4 removal….

Back of the Envelope – 10,000 people

- 1 MGD sewage flow & 5000 gpd urine
- Raw sewage:
  - Normal BOD & COD
  - TKN = 8-12 mg/L
  - TP = 1-2 mg/L
- BNR is probably not required at the WWTP – borderline & depends on TN and TP limit
- Urine characteristics:
  - 4300 mg/L NH_4-N
  - 1000 mg/L OP
- Assume 80% conversion of P in urine to struvite
  - 230 lbs/day struvite produced
- Follow struvite recovery process by Anammox treatment and precipitate remaining OP with $FeCl_3$ or alum….

Other Issues

- **<u>Public acceptability….</u>**
- If WW utility personnel can't deal with this, there is no hope…
- This gives us a clear mechanism to demonstrate the cost of nutrient removal…
- Of course, scale-up and residential collection are big challenges…
- Potential to eliminate the need for BNR and provide a potentially valuable fertilizer product
- This project is clearly a demonstration project and R&D platform
  - K^+ recovery potential? K-struvite?
  - Impact of elevated K^+ on Ostara process?
  - Microconstituents – estrogens and pharmaceuticals concentrated in urine
  - Odor, pipe scale, urea hydrolysis

HRSD Current R&D Efforts in BNR

- Supplemental carbon for denitrification (chemicals)
  - AOB conversion of methane to methanol
  - Reduced S compounds
  - Ethanol used for fuel blending
- Ammonia-based DO control systems (energy, chemicals)
- Organic nitrogen sources and fate
- Cost effective CEPT (chemicals)
- Algae-based nutrient removal (chemicals, energy)
- Centrate treatment – anammox (chemicals, energy)
- Nitrite accum. and excessive chlorine demand (chemicals)
- IFAS process development and modeling
- Nitrification inhibition
- BNR process reliability and stochastic methods
- Improvement of BNR process models
- Urine separation (source separation)