2016 Kappe Lecture "Maximizing Process Intensification and Resource Recovery-from Theory to Practice
Friday (November 4) 12:30 noon to 1:30 p.m. University of South Florida (Tampa)
Sudhir Murthy, Ph.D., P.E., BCEE Innovations Chief, DC Water

AMERICAN ACADEMY OF ENVIRONMENTAL ENGINEERS AND SCIENTISTS®

USF UNIVERSITY OF SOUTH FLORIDA COLLEGE OF BUSINESS

Dr. Sudhir Murthy is the Innovations Chief at DC Water where he leads the development and implementation of their innovation strategy. Dr. Murthy creates, defines, and translates research and development into new or improved facilities, products, services or revenue concepts. He has led the concept development for several programs that has led to nearly $1 billion in engineered facilities. In the past five years, DC Water has won four Research Grand Prizes from the American Academy of Environmental Engineers and Scientists. Dr. Murthy is a Professional Engineer, a Board Certified Environmental Engineer, and has received several Water Environment Federation awards including the Ralph Fuhrman Medal for Academia-Practitioner Collaboration, the George Gascoigne Medal for Wastewater Treatment Operational Improvement and the Camp Applied Research Award.

The Kappe Lecture Series was inaugurated by the Academy of Environmental Engineers & Scientists in 1989 to share the knowledge of today's practitioners with tomorrow's environmental engineers and scientists. This program was inspired by a grant from the estate of Stanley E. Kappe, P.E., DEE, who served as the Academy's Executive Director from 1971 to 1981.

twitter

Tweet your comments and thoughts about resource intensification and recovery of valuable resources from wastewater during the lecture using **#Reclaim** and **#Kappe2016** to the @USouthFlorida for **the @AAEESdotORG Kappe Lecturer, Dr. Sudhir Murthy @DCWater on November 4 (Friday), 12:30 – 1:30 Tampa FL time.**

The Kappe Lecture at the University of South Florida is supported by the USF Department of Civil & Environmental Engineering and the Center for Reinventing Aging Urban Infrastructure for Nutrient Management and Reclaim, a global network of researchers and practitioners dedicated to understanding and developing context specific, geographically appropriate systems to manage the nutrient, energy, and water nexus. http://usf-reclaim.org/

Kappe Lecture:
Maximizing Process Intensification and Resource Recovery:
from Practice to Theory (and back to Practice)

Sudhir N. Murthy, PhD, PE, BCEE

Innovations Chief, DC Water


1500 MLD plant capacity
Largest AWTP in the world

Intensification factor and resource savings are calculated compared to conventional treatment (nitrification/denitrification, mesophilic digestion) or the current Blue Plains operation (carbon, mainstream)

Intensification factor	Resource savings
2-4	50% hauling cost Electricity production

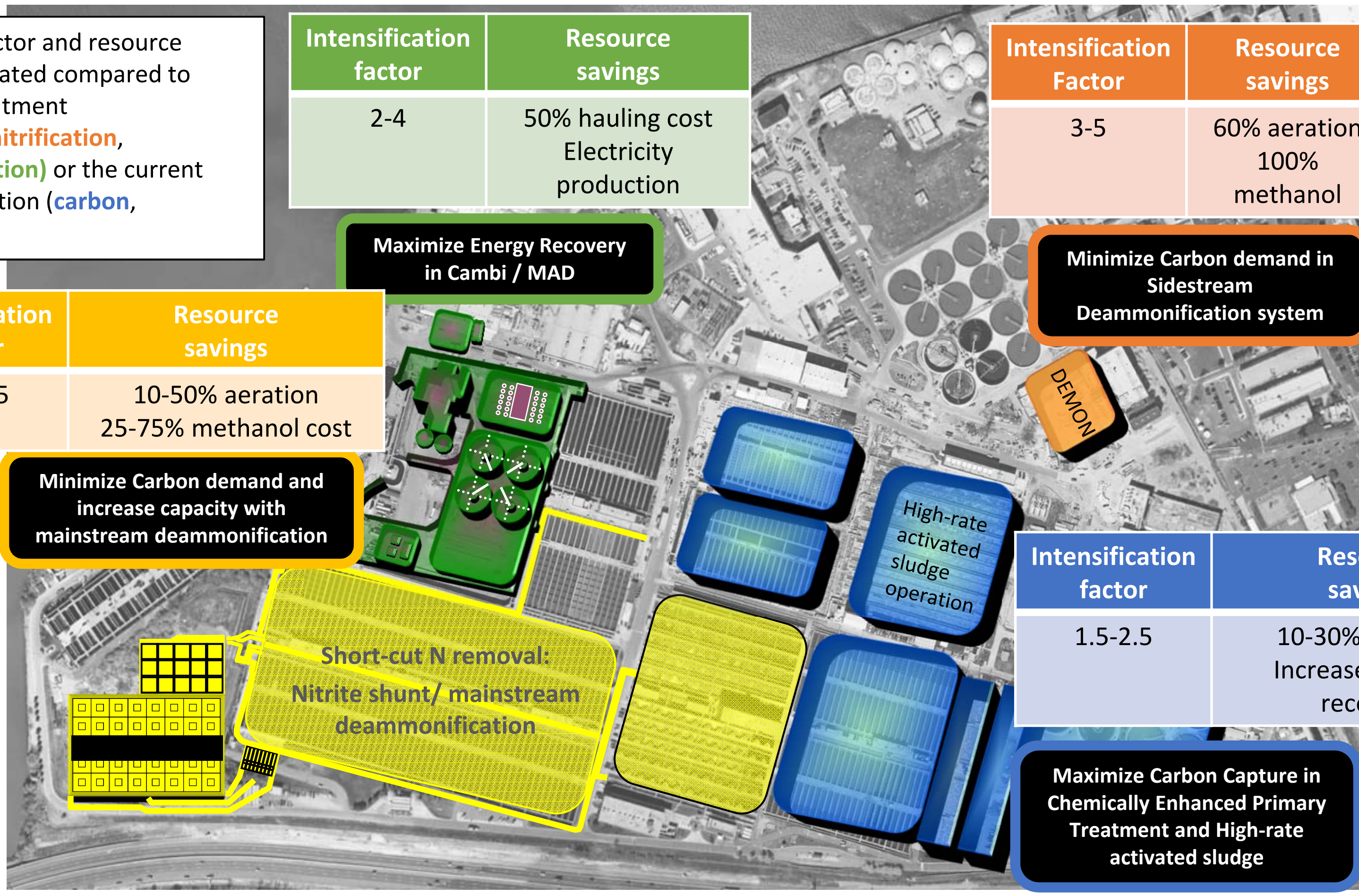
Maximize Energy Recovery in Cambi / MAD

Intensification Factor	Resource savings
3-5	60% aeration 100% methanol

Minimize Carbon demand in Sidestream Deammonification system

Intensification factor	Resource savings
1.5-2.5	10-50% aeration 25-75% methanol cost

Minimize Carbon demand and increase capacity with mainstream deammonification



Intensification factor	Resource savings
1.5-2.5	10-30% aeration Increased energy recovery

Maximize Carbon Capture in Chemically Enhanced Primary Treatment and High-rate activated sludge

Challenges Blue Plains Washington, D.C.

DO more

- Growth
- More Stringent Regulations – Now and in the Future
  - Eliminate CSOs
  - Nutrients (TN<3 & TP<0.18),
  - Class A Biosolids

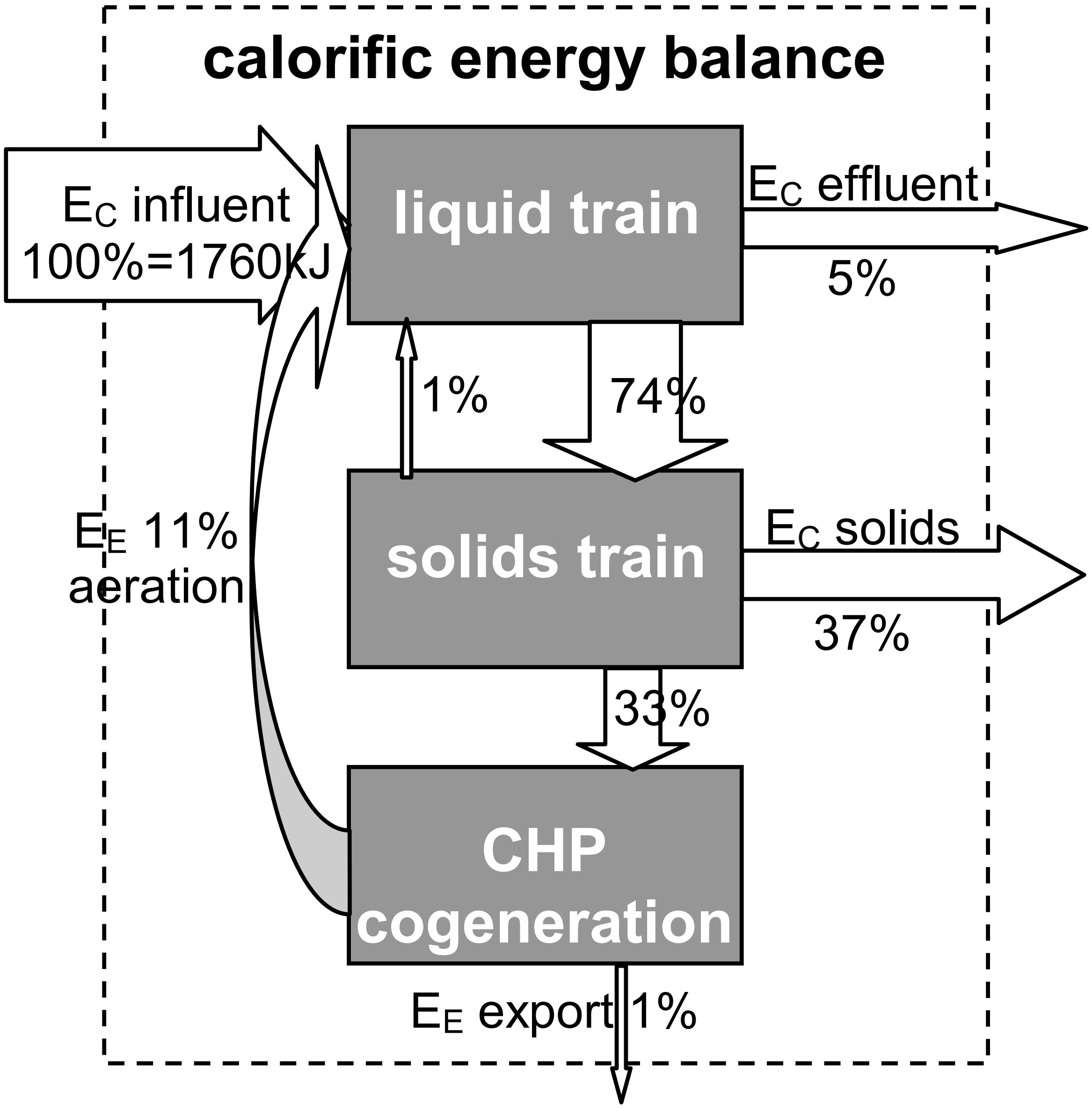
IN less

- Space constraints
- Aging infrastructure

WITH less

- Sustainability Vision
  - Energy Neutrality
  - Resource Recovery – Energy, Biosolids, Nutrients, Water
- Cost – long term rate impacts

Carbon Redirection



Source:
Bernhard Wett

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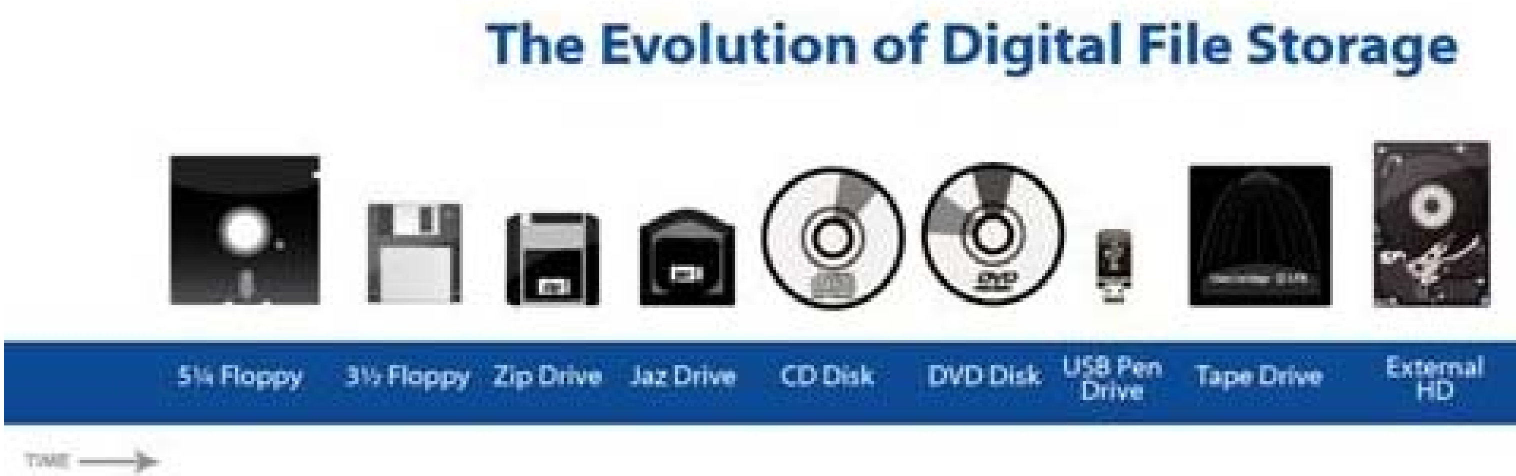
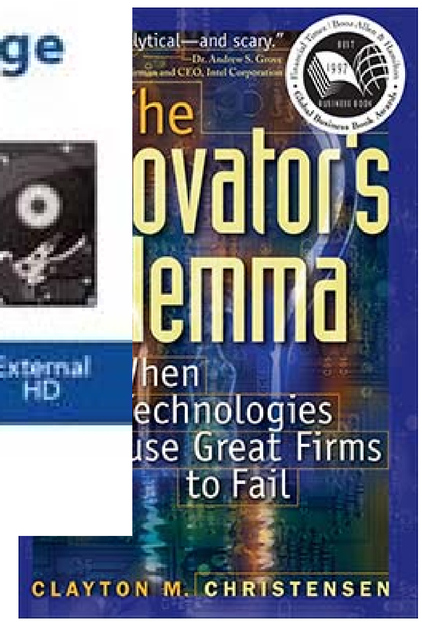
Innovation Life cycle

Clayton M. Christensen
Harvard Business School





biology.ualberta.ca
filetwin.com

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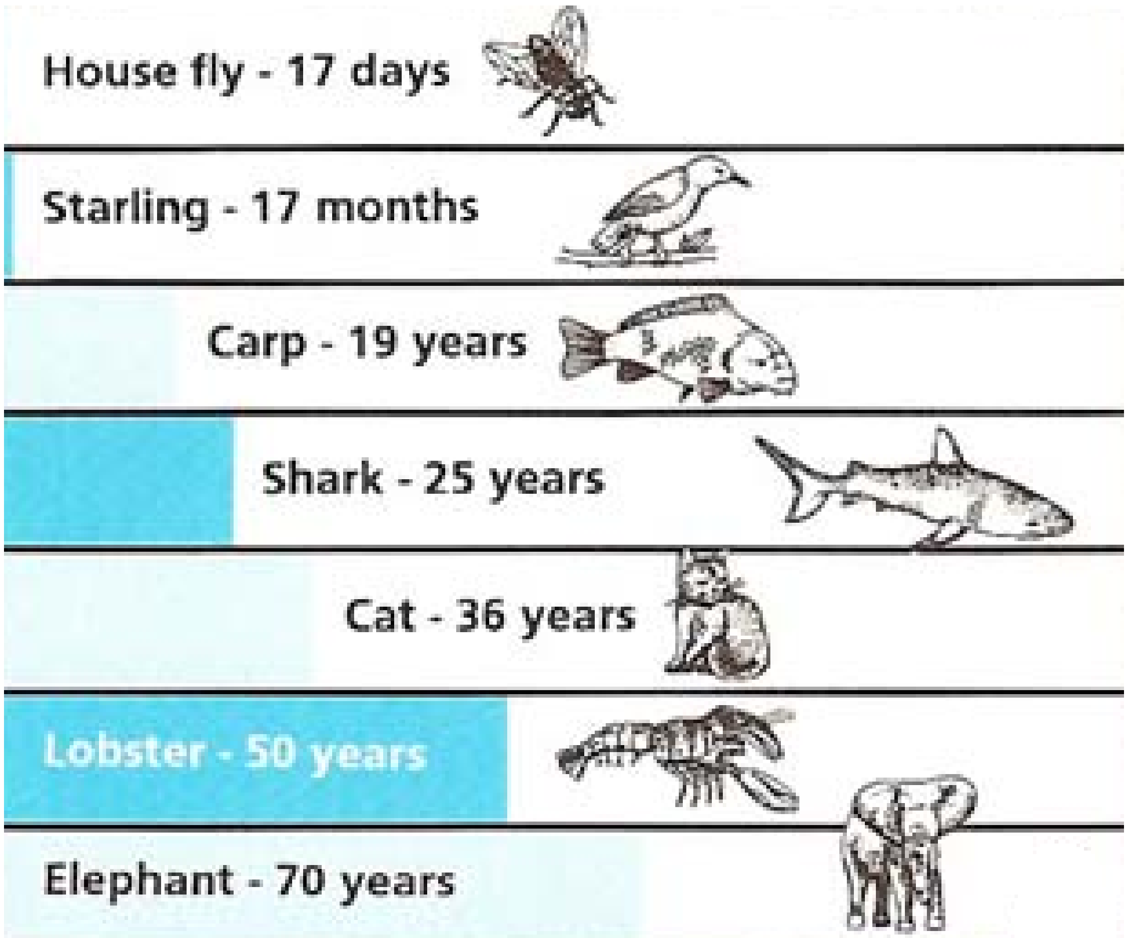
The Fly and The Elephant

water is life



http://www.uniondocs.org

http://www.daviddarling.info

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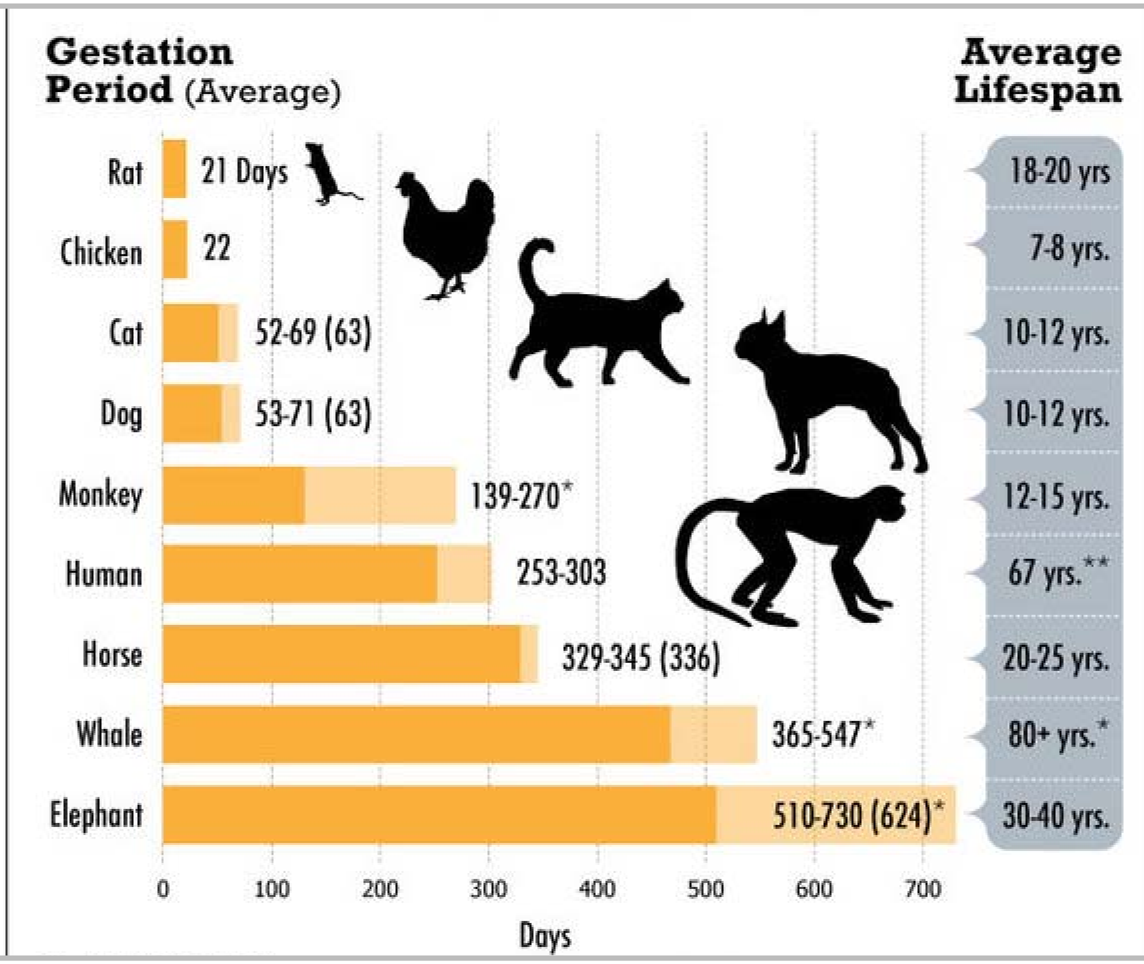
Innovation Lifecycle

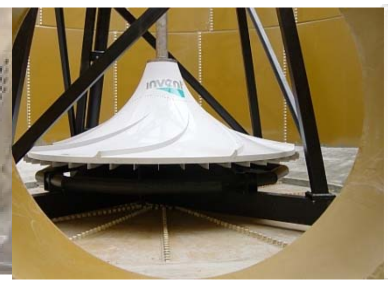


Source: R. Toro, LiveScience.com

The Hare, The Horse and The Elephant







Increasing Maximum Life

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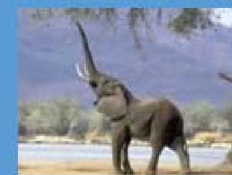
The Innovation Portfolio

Hares (lifecycle of 5 years) 	Horses (lifecycle of 20 years) 	Elephants (lifecycle of >50 years) 
Devices (sensors, tablets, industrial PCs, edge devices)	**Mechanical Technology** (mixers, aerators, scrapers, meters)	**Centralized Infrastructure** (systems and processes within water reclamation plants, drinking water plants, pump stations, buried infrastructure)
Analytics (controls, algorithms, machine learning)	**Hydraulic/Selection Technology** (pumps, screens, filters, cyclones, diffusers)	**Distributed Systems** (asset management, watershed management, cloud systems)

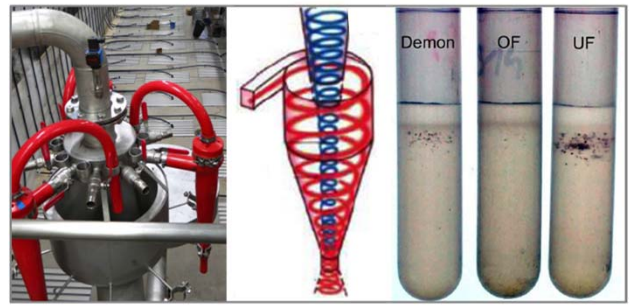
Open Innovation

- Utilities (Alex Renew, Fairfax County, **HRSD**, PWD, NYCDEP, **Thames Water**, **Sydney Water**, Singapore PUB, **Strass**, Salzburg)
- Universities (GWU, HU, UMd, Catholic U, VT, **Bucknell U**, UCI, Columbia U, UK, U. Innsbruck, **Ghent U.**, U. Queensland, U. Cape Town)
- Within Manufacturing/Services (WWW, HKF, Ovivo, Cambi, Cisco, Qualcomm, Meiden, WWW India)
- Consultants (Most Major US Consultants, ARA Consult, Dynamita)

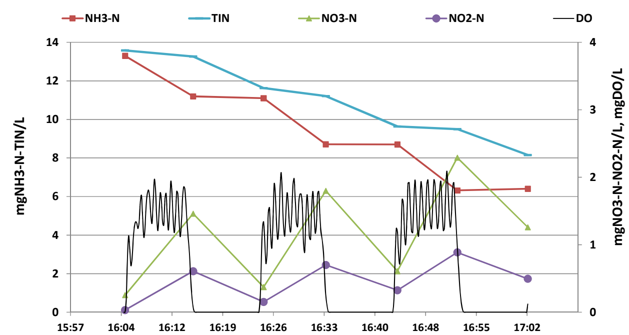
Theme

Underlying theme for ***Intensification*** and managing ***Resource*** used:

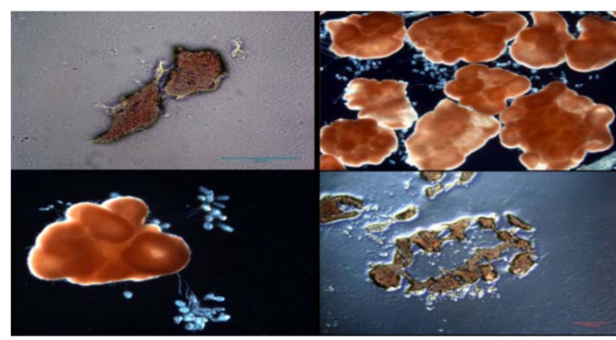
- Improve the 'physical factors' that limit process performance



- Sensors and process control can leverage further improvements



- Biological selection is key to managing yield and inventory



Physical Factors

- Viscosity
- Flocculation
- Stokes Law (Gravitational Force)
- Compressibility
- Diffusion

* Shear plays an underlying role in many of these concepts

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Physical Factor

- Viscosity

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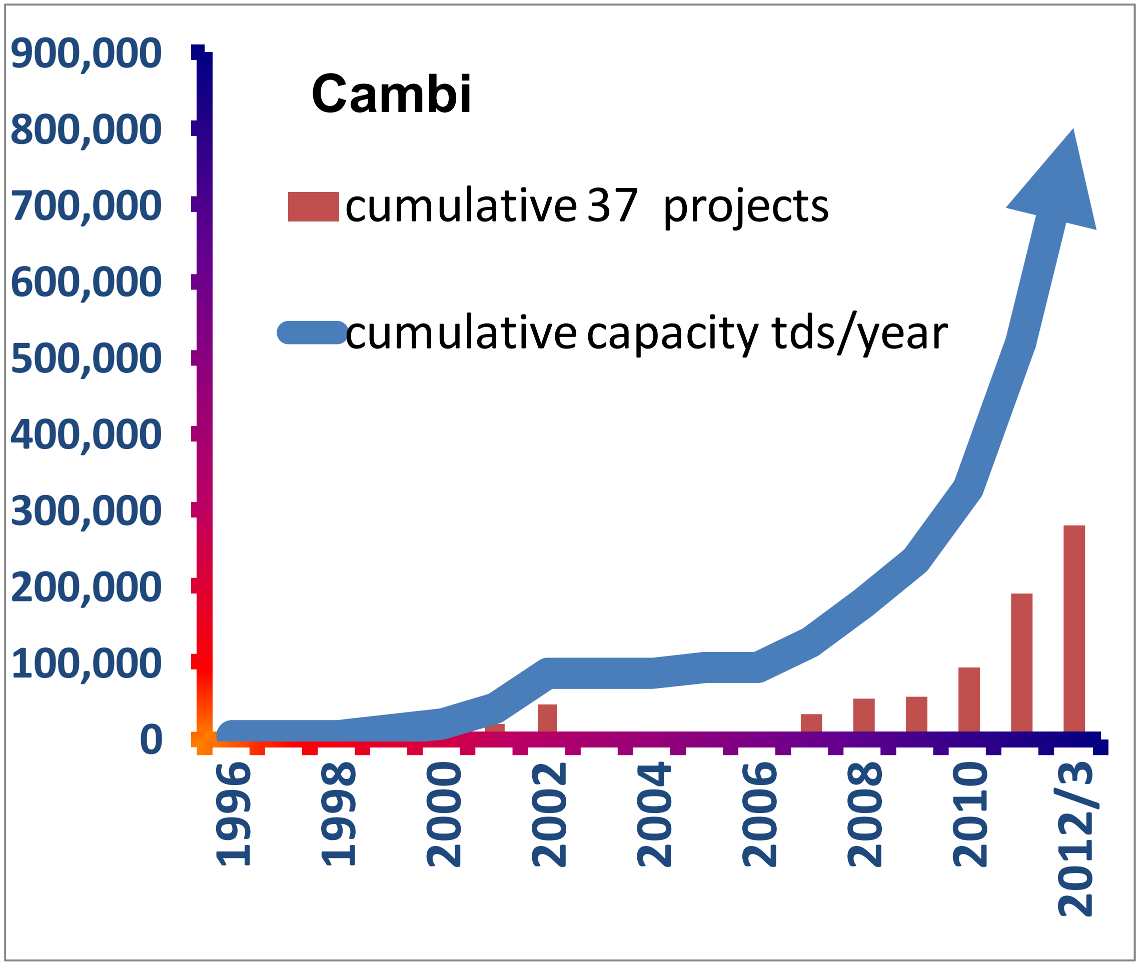
Water Technology



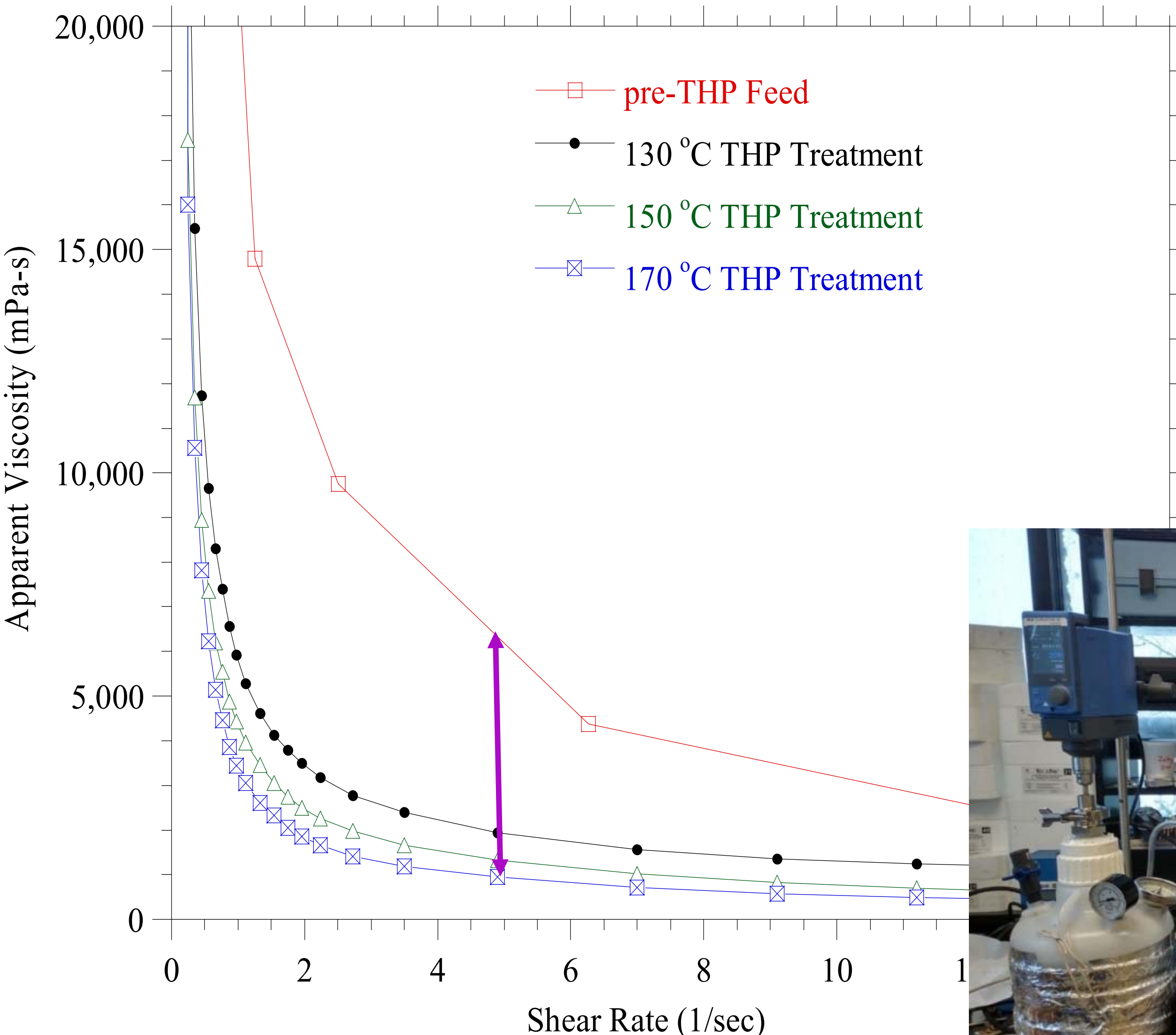
Haug, R.T., Stuckey, D.C., Gossett, I.M., McCarty, P.I. (1978)

Effect of thermal pretreatment on digestibility and dewaterability of organic sludges,

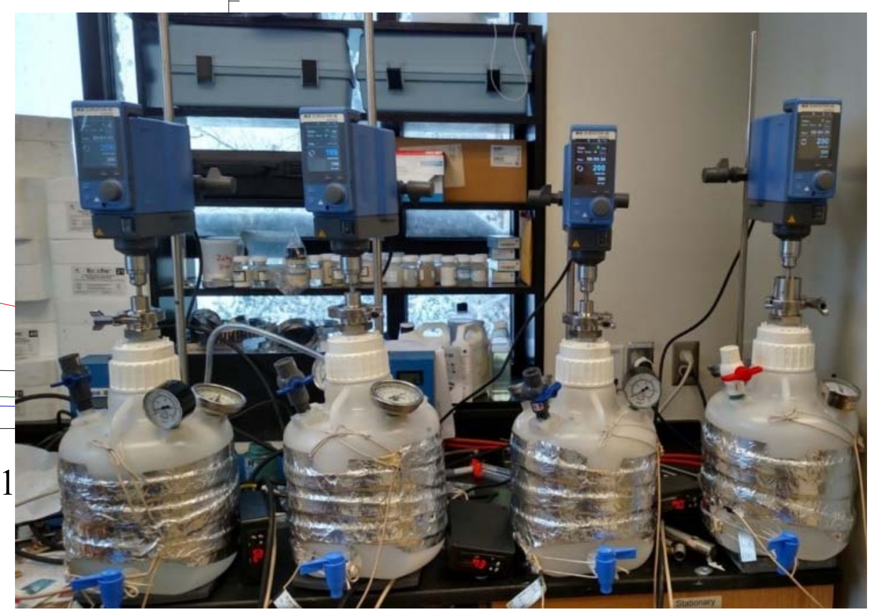
J. Water Poll. Control Fed., 50, 73.

Source: Cambi

Viscosity



pre-THP Feed
130 °C THP Treatment
150 °C THP Treatment
170 °C THP Treatment
Apparent Viscosity (mPa-s)
20,000
15,000
10,000
5,000
0
0
2
4
6
8
10
Shear Rate (1/sec)



BLOOM

GOOD SOIL,
BETTER EARTH.

Improving Capacity

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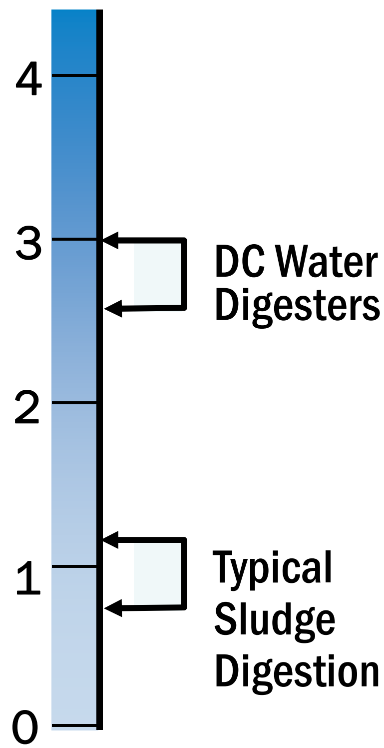
Ft^3 biogas/day

Ft^3 of tankage



Feeding ~10% Solids

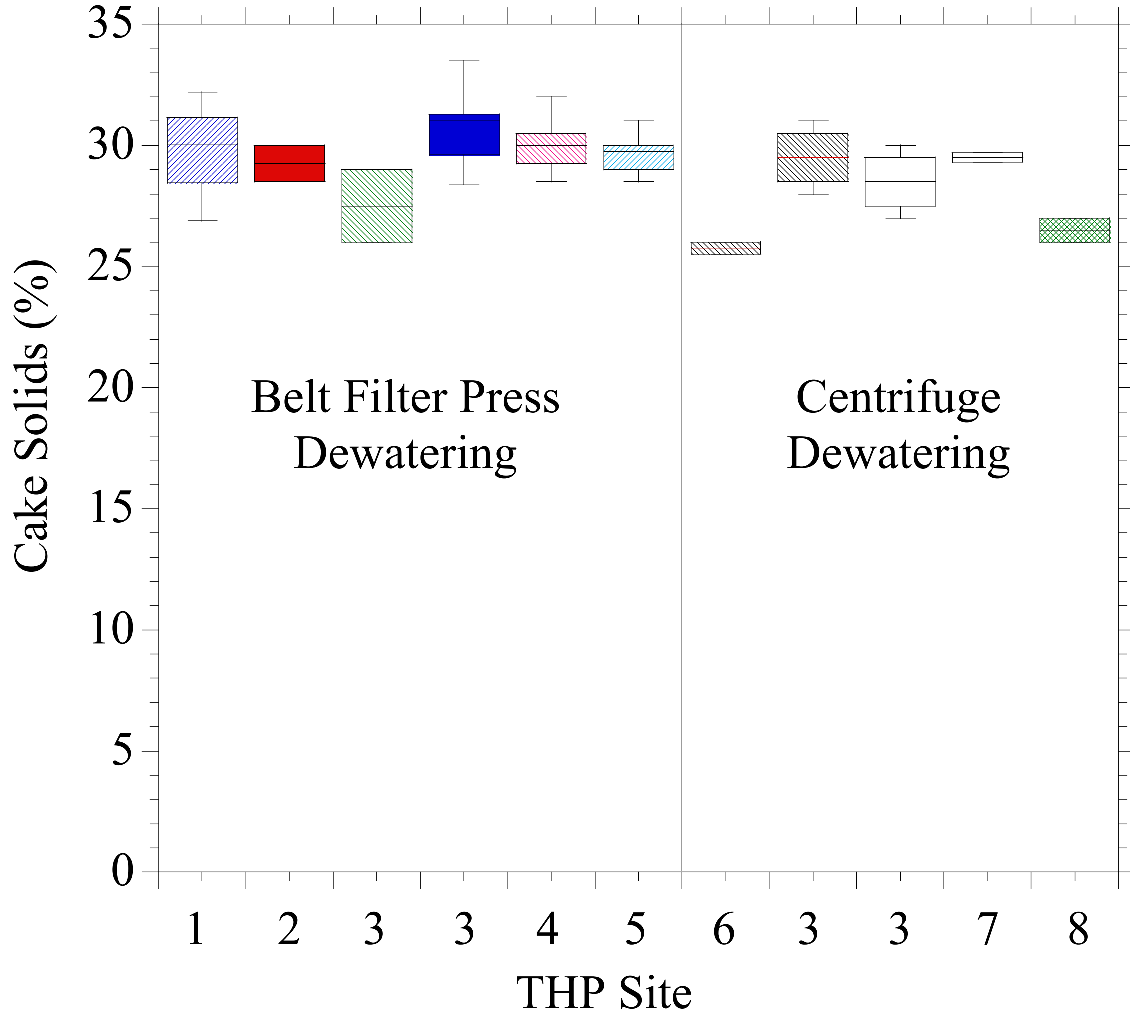
- VS loading at 0.4$^+$ lb VS/ft^3/day
- Only 15 MG of Digesters, rather than 40+MG required for typical MAD
- At $5/gal = $125+ million savings and much less space required

Source:
Perry Schafer

Physical Factor for Discussion

- Flocculation

Dewatering at TH Plants



Dewatering Intensification

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Site	Dewatering Equipment	Solids Loading Rate (kg/hr-m)	Polymer Dose (kg/mt)	Cake Solids	Filtrate Solids - TSS (mg/L)
Aberdeen	2.2 m, Ashbrook Klampress	246	11-12	28-32	4700
Denmark Naestved	1973 -2 m, Bellmer Winklepress	330	6-8	29-30	2330
Bran Sands	3 m, Andritz Belt press Powerpress S11	290-320	10	26-29	2000-8000
HIAS	2 m, Stantec BFP	210	4-5.5	24-26	3000

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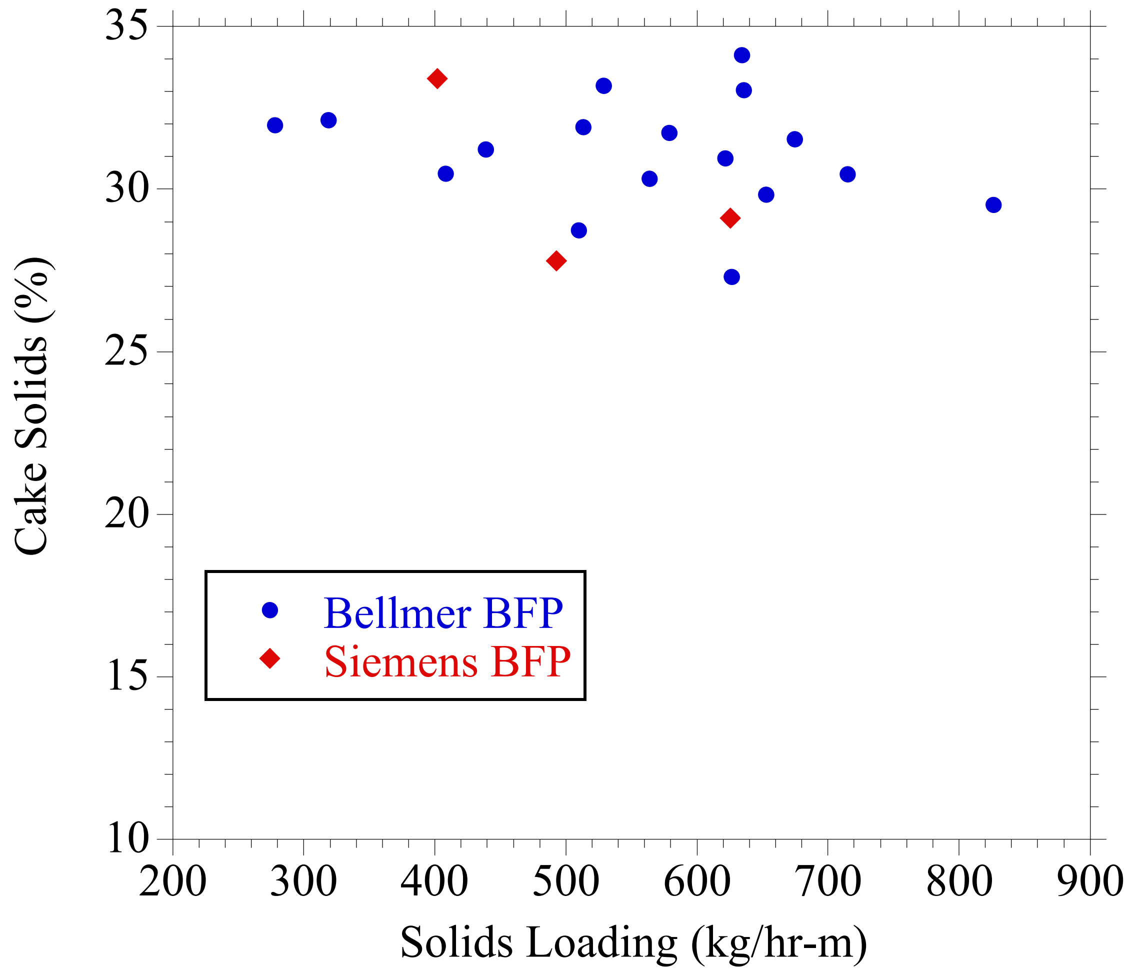
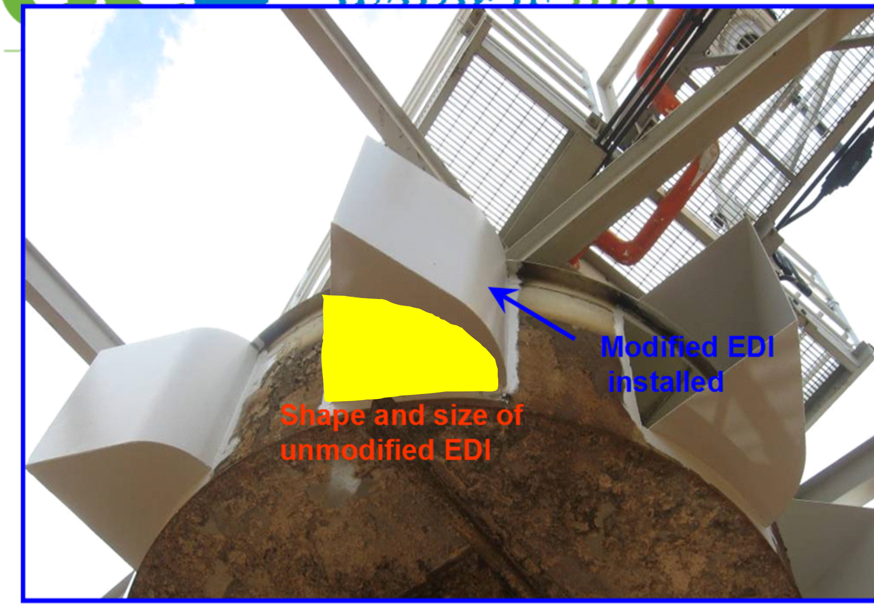
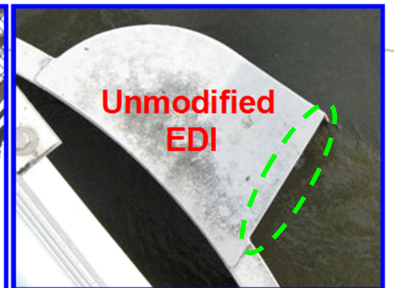
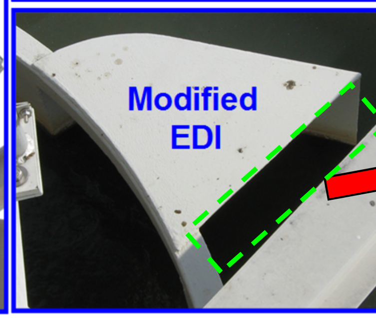
Dewatering Intensification

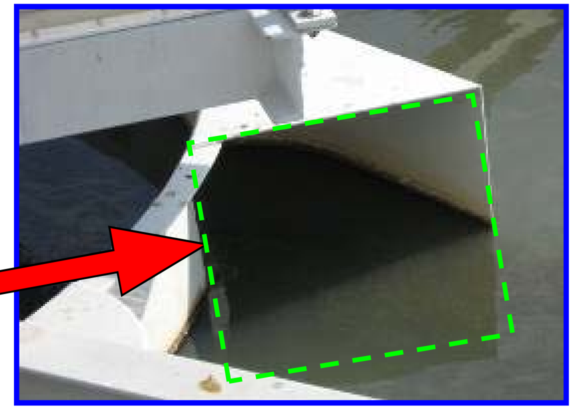


Stress Test with Modified EDI



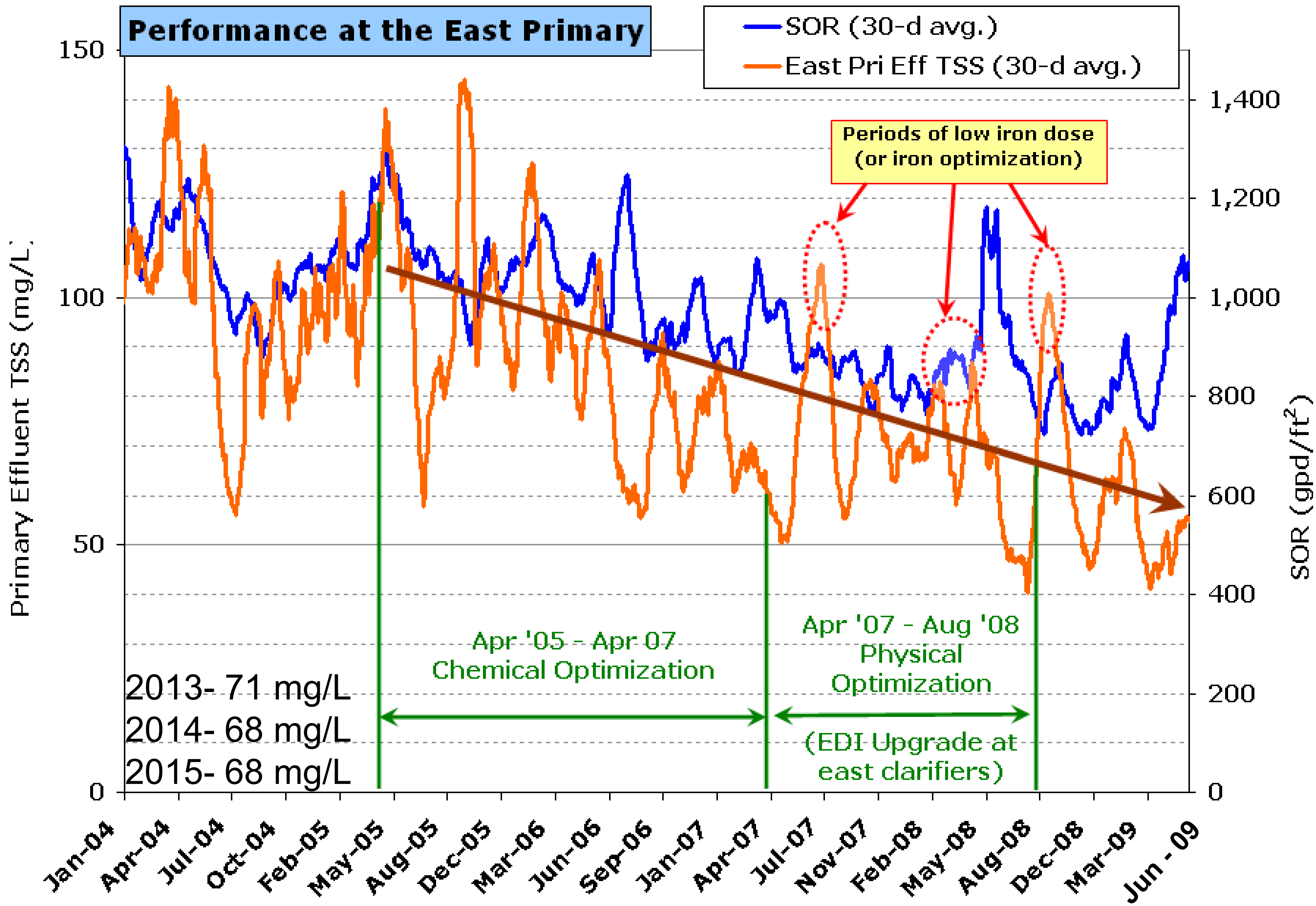






Date	Fe^{3+} (mg/L)	Polymer (mg/L)	SOR Mod. EDI (gpd/ft^2)	SOR Unmod. EDI (gpd/ft^2)	Influent TSS (mg/L)	Effluent TSS	
						Mod. EDI (mg/L)	Unmod. EDI (mg/L)
6/14/05	4.0	0.23	1,550	1,550	248	41	59
9/20/05	7.0	0.16	1,770	1,770	253	58	135
10/18/05	6.0	0	1,785	1,770	224	71	137
9/27/05	6.5	0.31	2,000	1,925	211	48	139
9/20/05	7.0	0.16	2,025	1,950	253	92	141
9/6/05	6.5	0.23	2,125	1,750	205	47	98
10/4/05	5.8	0.32	2,125	1,825	212	104	128
9/15/05	6.1	0.14	2,210	2,210	216	115	159
6/1/05	6.0	0.18	2,360	2,360	NS	88	166

Plant Data: Results of Optimization



Physical Factor

- Sedimentation (Gravitational)

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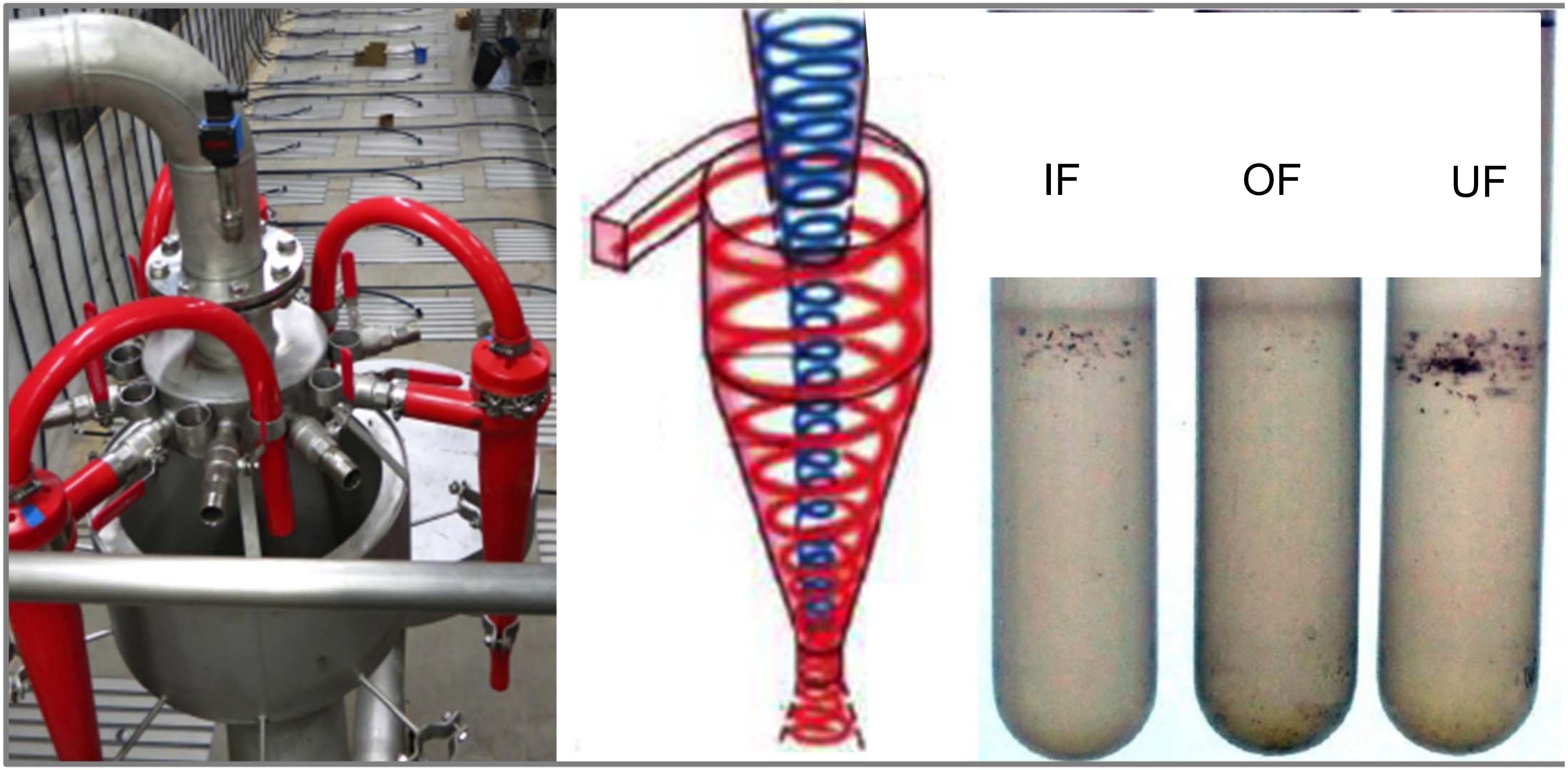
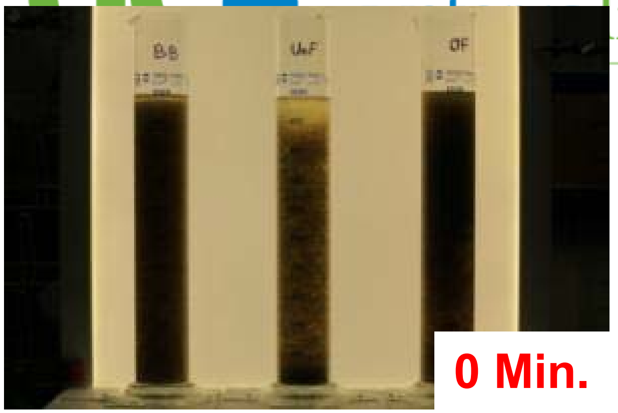
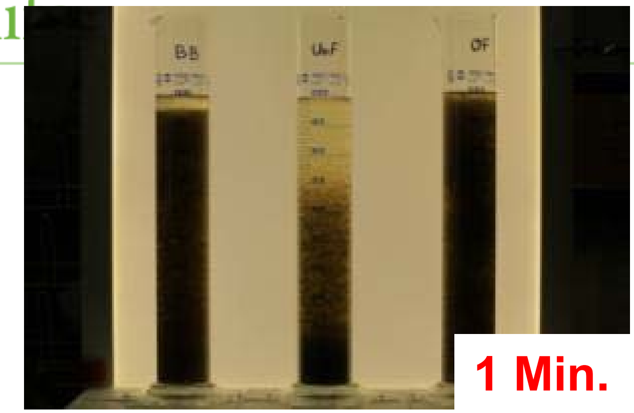


Density difference between flocculant and granular sludge fraction

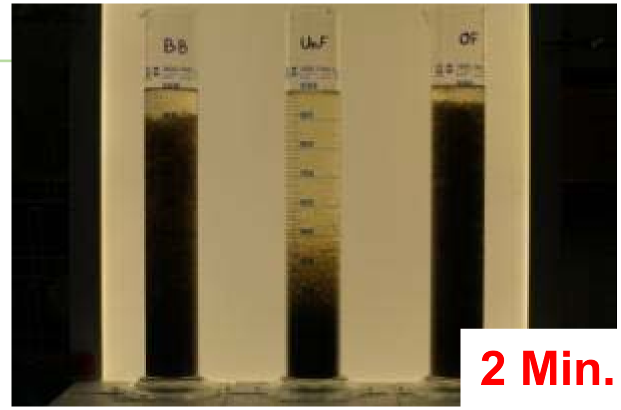
Settling velocity test



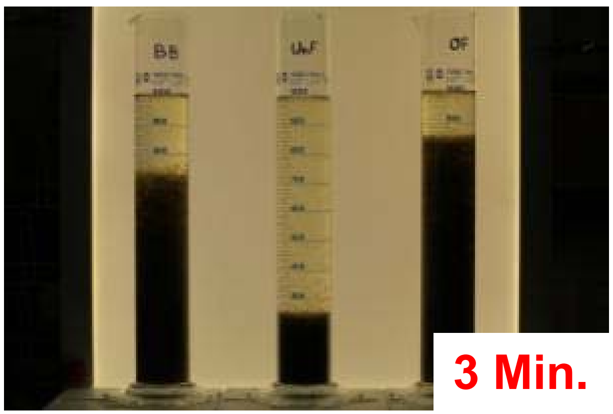
0 Min.



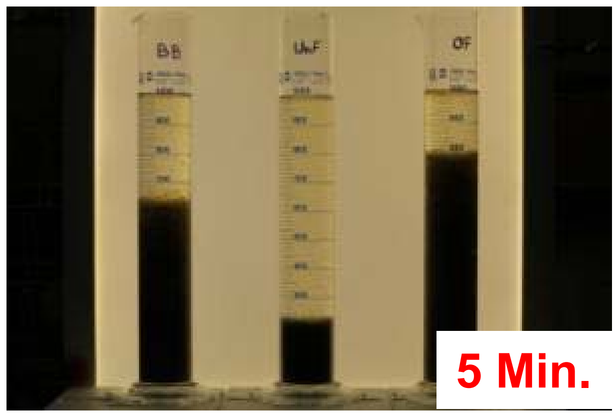
1 Min.



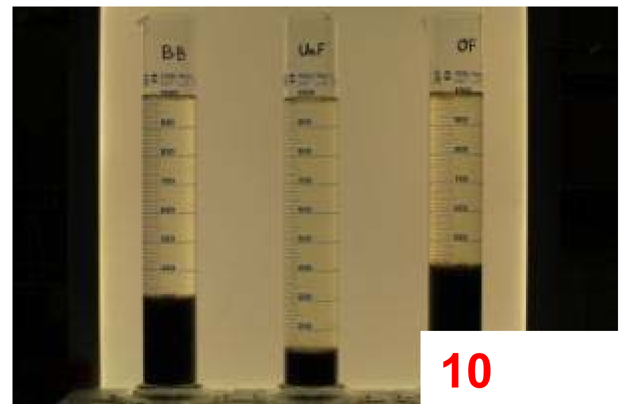
2 Min.



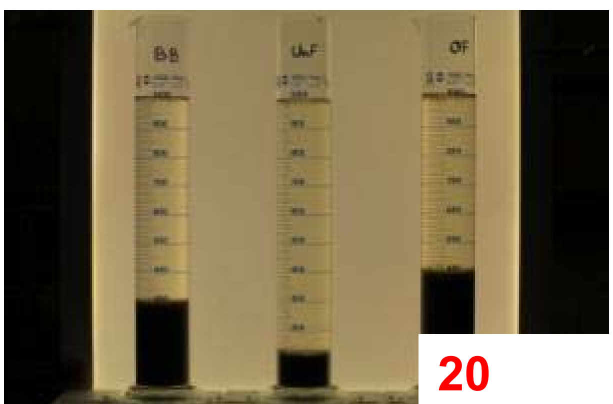
3 Min.



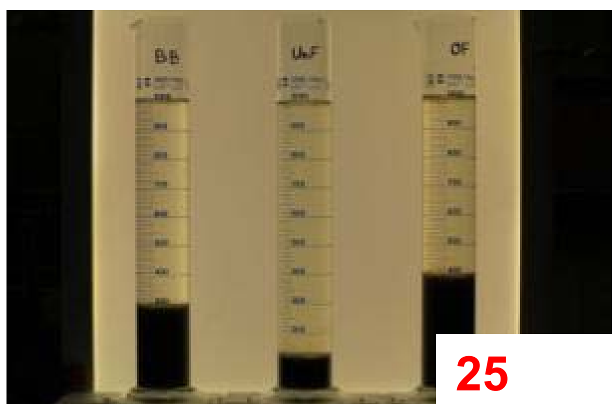
5 Min.



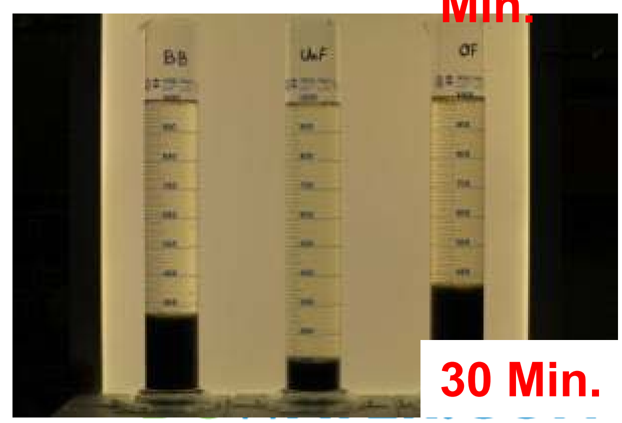
10 Min.



20 Min.



25 Min.



30 Min.

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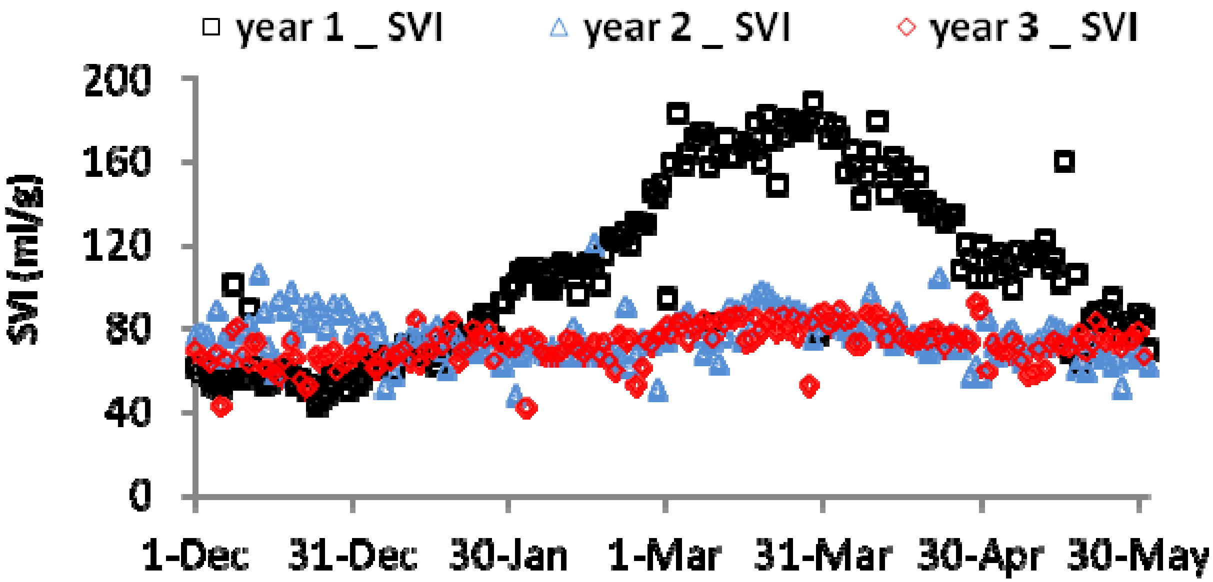
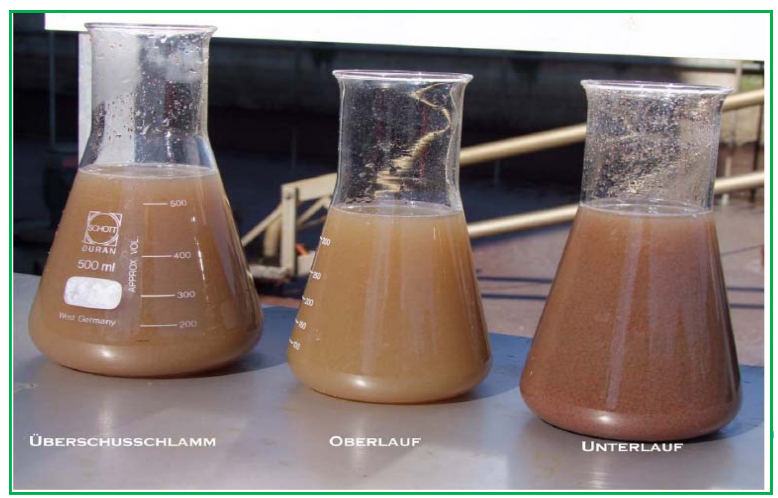
inDENSE
process intensification by densified biomass



Main feature:
Selective retention of particles with improved settling characteristics

Main outcomes:
- Improved and stable settling behavior
- Increased capacity
- Biological phosphorous removal



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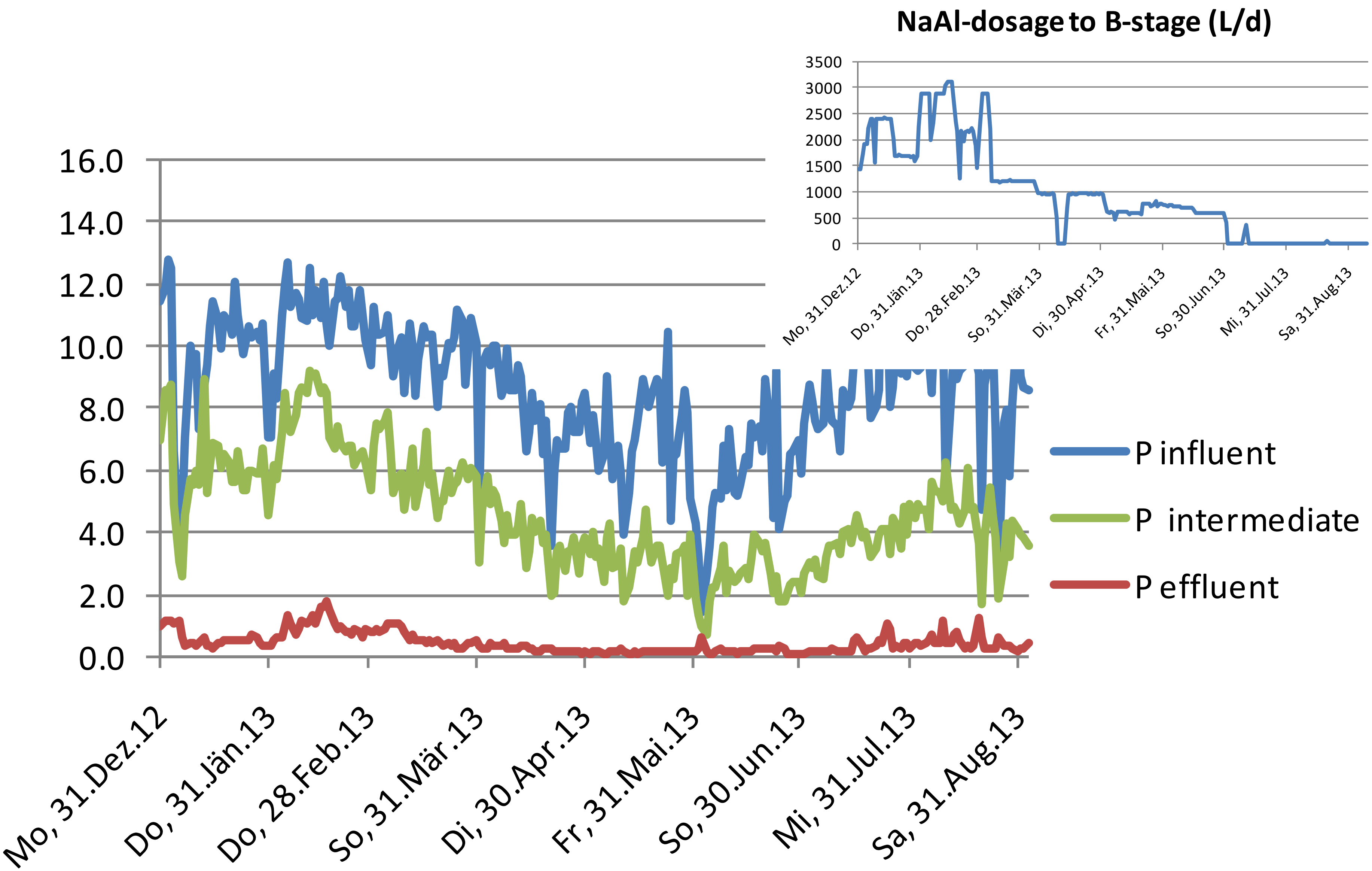
inDENSE
process intensification by densified biomass

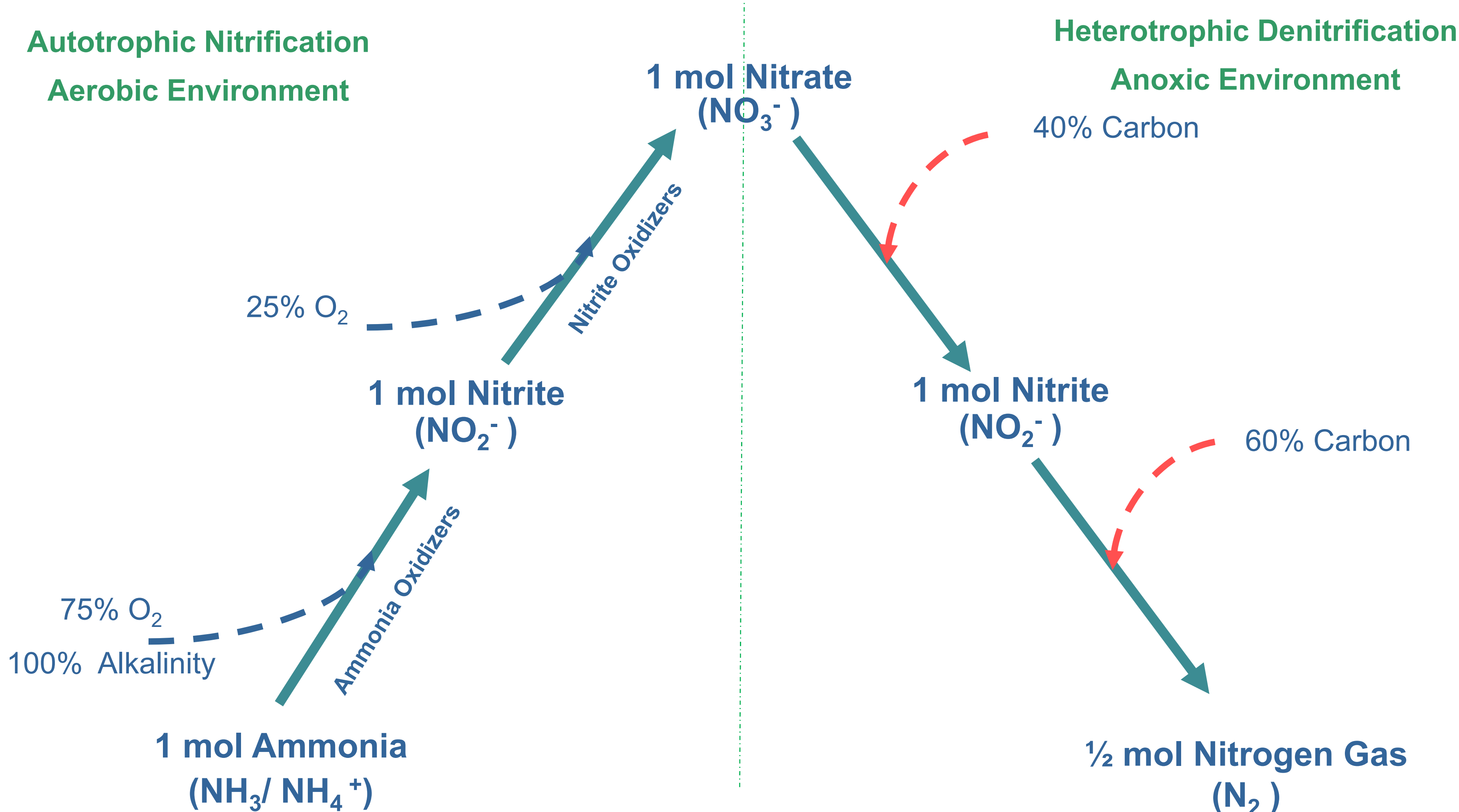


Physical Factor

- Compressibility

Fundamentals of Nitrification - Denitrification

water is life



Oxygen demand 4.57 g / g NH^+_4-N oxidized
Carbon demand 4.77 g COD / g NO^-_3-N reduced

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Fundamentals of Nitritation - Denitritation

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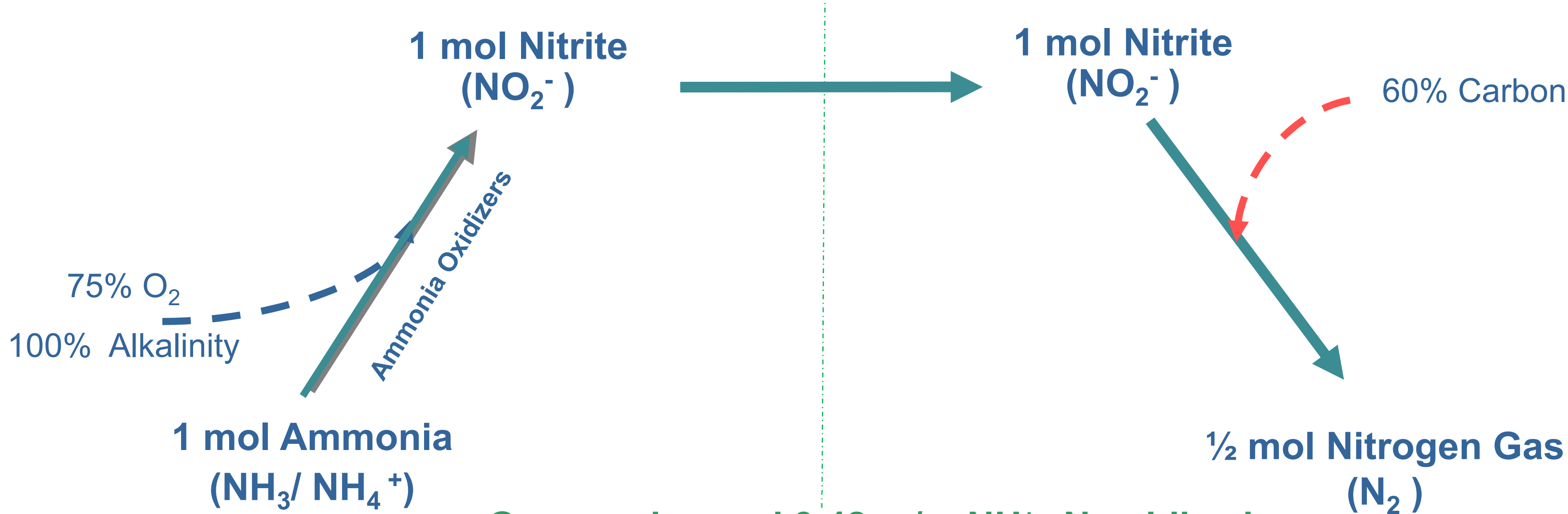
Autotrophic Nitritation
Aerobic Environment

Heterotrophic Denitrification
Anoxic Environment

- **25% reduction in Oxygen**
- **40 % reduction in Carbon demand**
- **40% reduction in Biomass production**



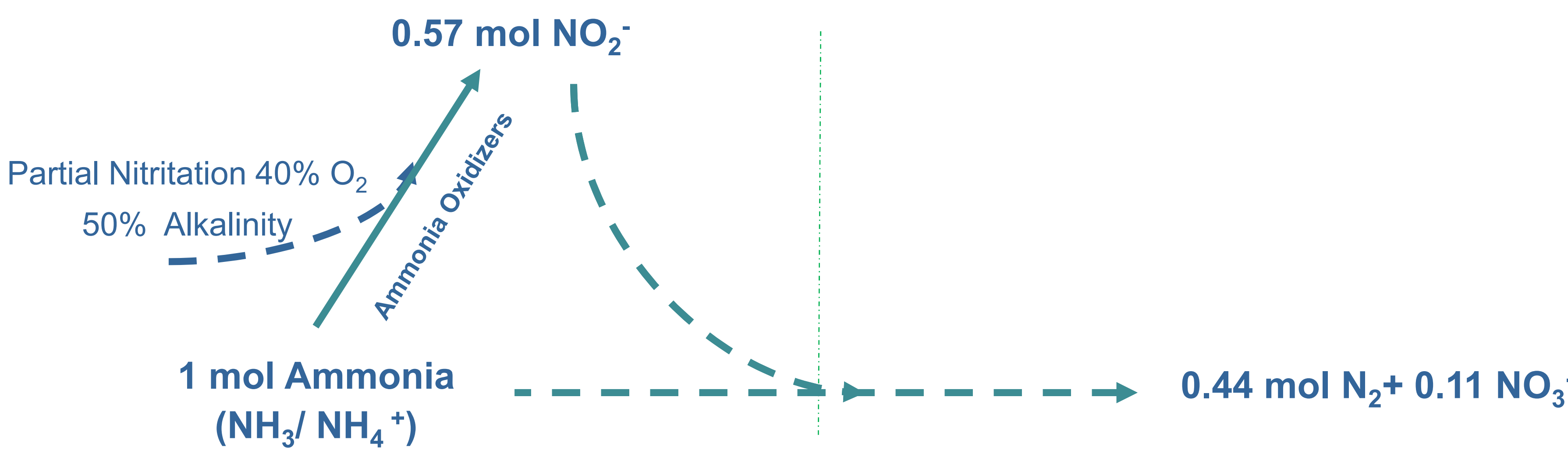
Oxygen demand 3.42 g / g NH^+_4-N oxidized
Carbon demand 2.86 g COD / g NO^-_3-N reduced

N-shortcut for enhanced energy balance

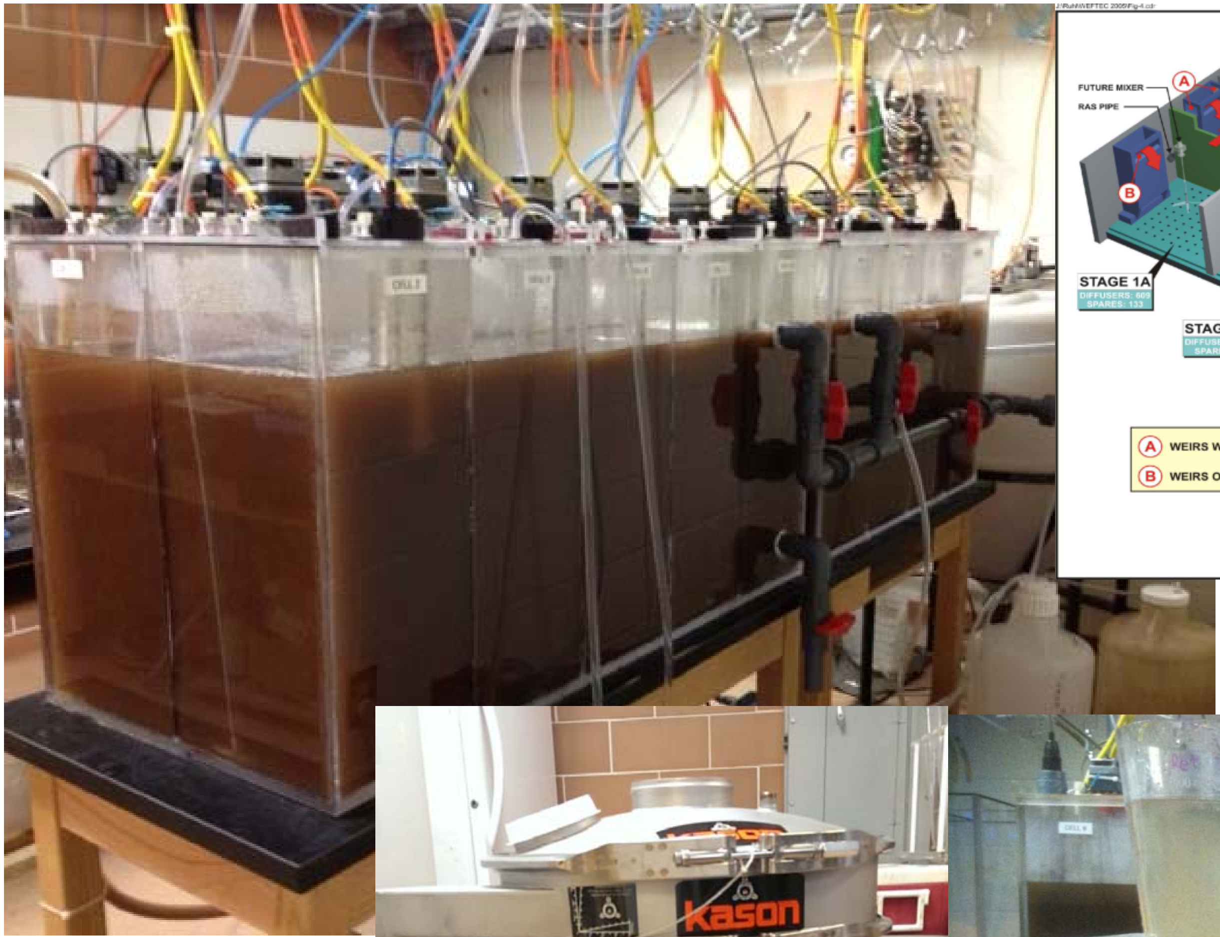
Partial Nitritation
Aerobic Environment

ANAMMOX Deammonification
Anaerobic Ammonium Oxidation Autotrophic Nitrite Reduction
(New Planctomycete, Strous et. al. 1999)

- **> 60% reduction in Oxygen**
- **Eliminate demand for supplemental carbon**
- **50% of the alkalinity demand**



Oxygen demand 1.9 g / g NH^+_4-N oxidized



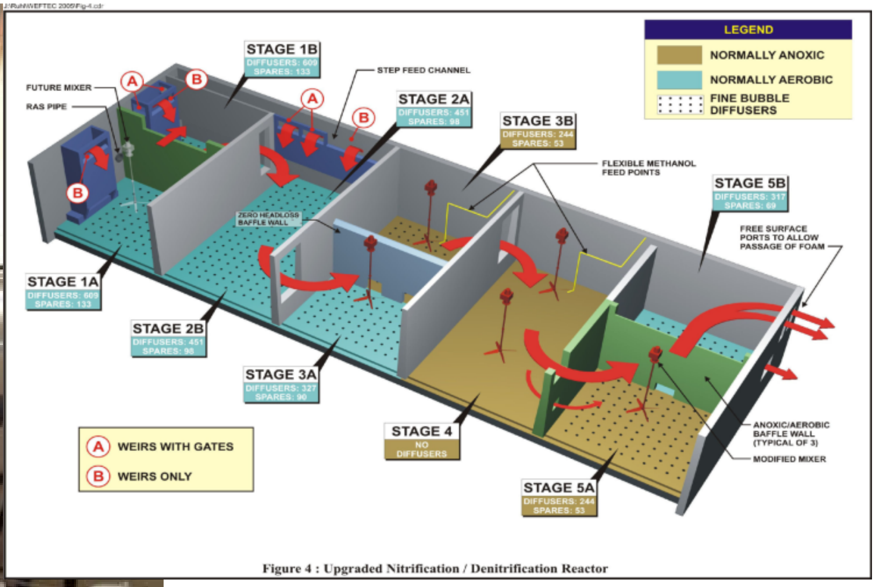
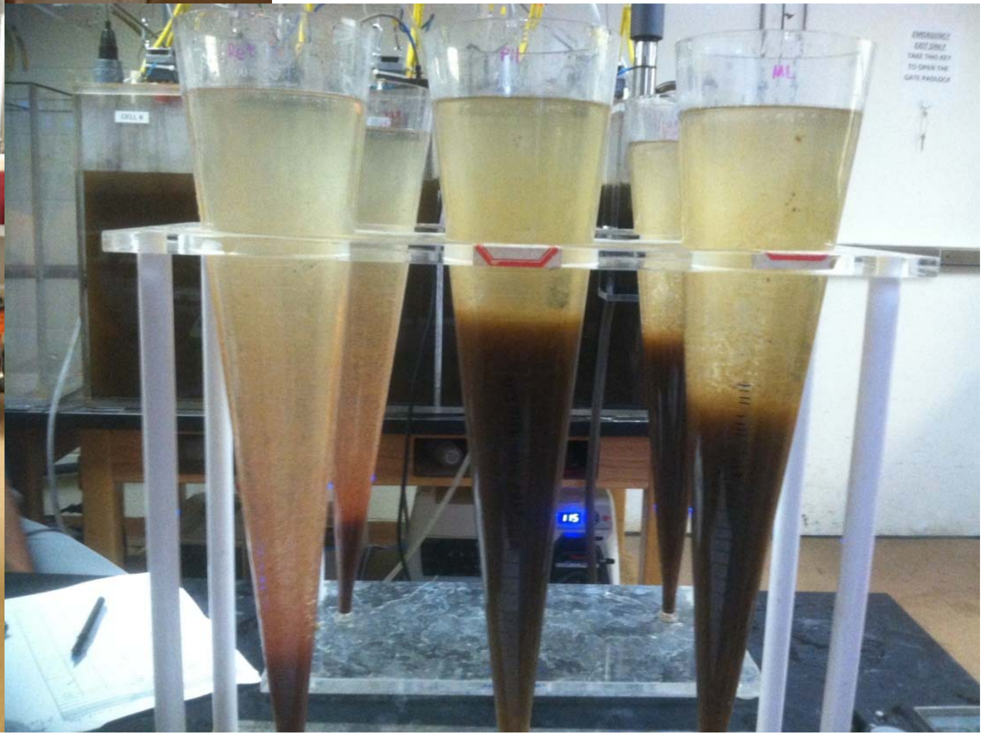


Figure 4 : Upgraded Nitrification / Denitrification Reactor



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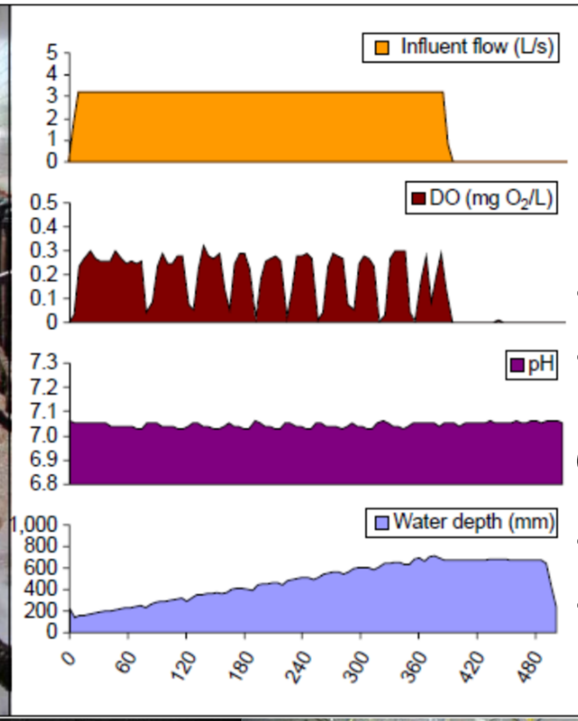
conDEA
continuous deammonification



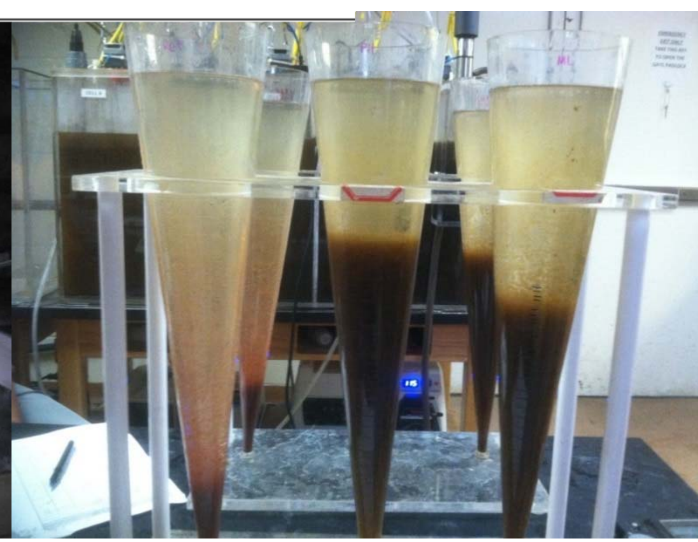
Sidestream Continuous Deammonification

Features

- pH based aeration control
- Screens for anammox retention

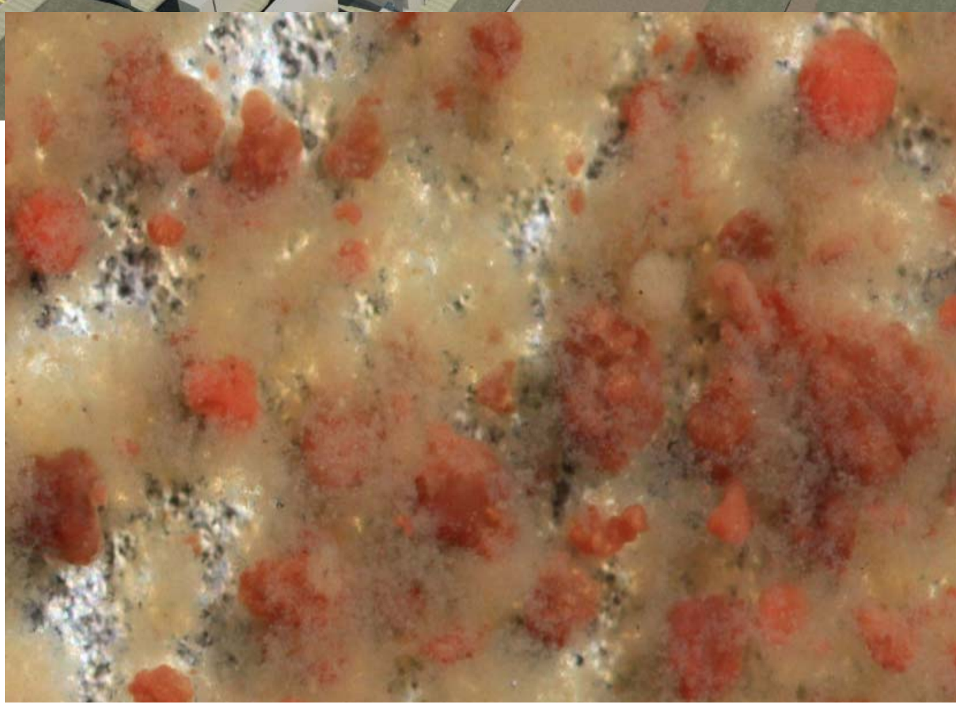
Outcome

- Anammox Selection
- Granulation



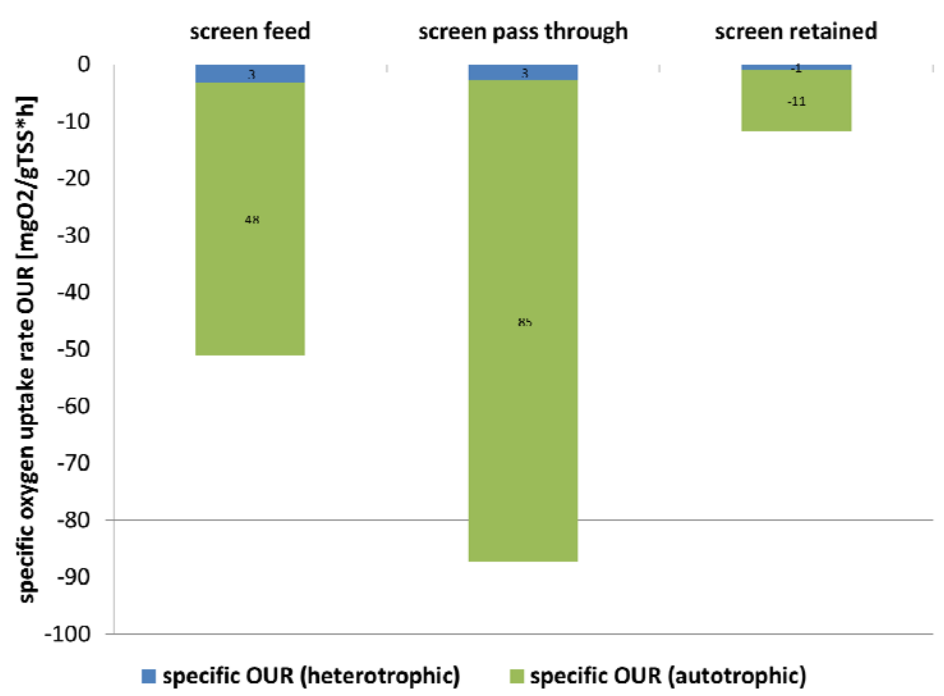
Implementation at Strass WWTP (Austria) for centrate treatment (13 others in Europe)

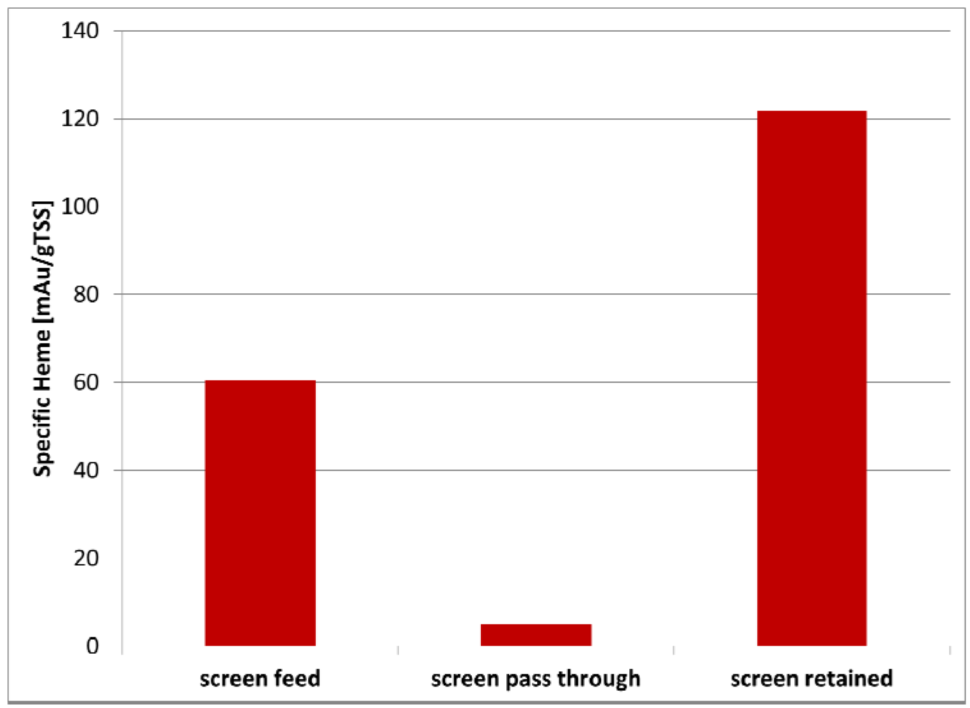
WATER.COM



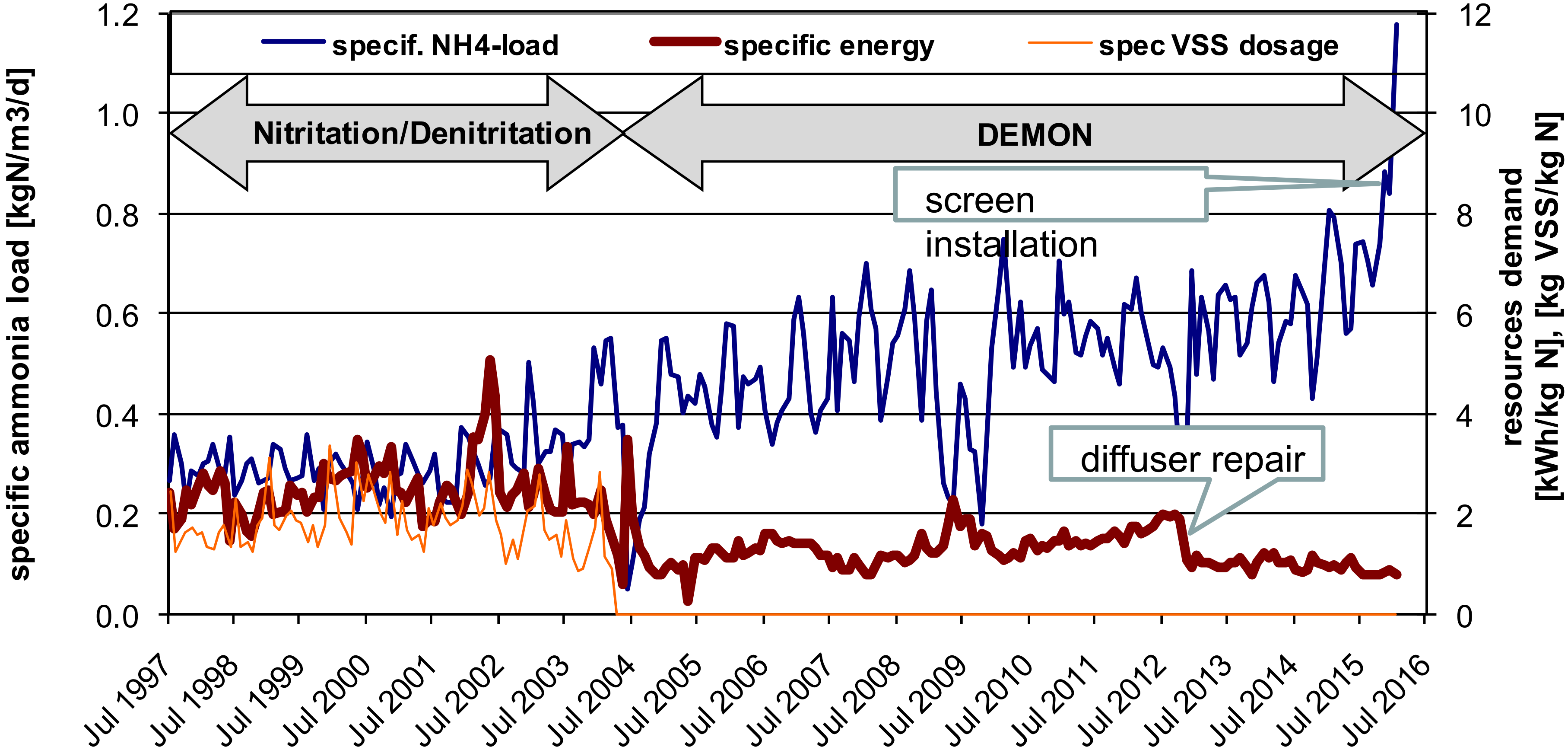
Continuous Deammonification

Screen selector:
Particle size distribution

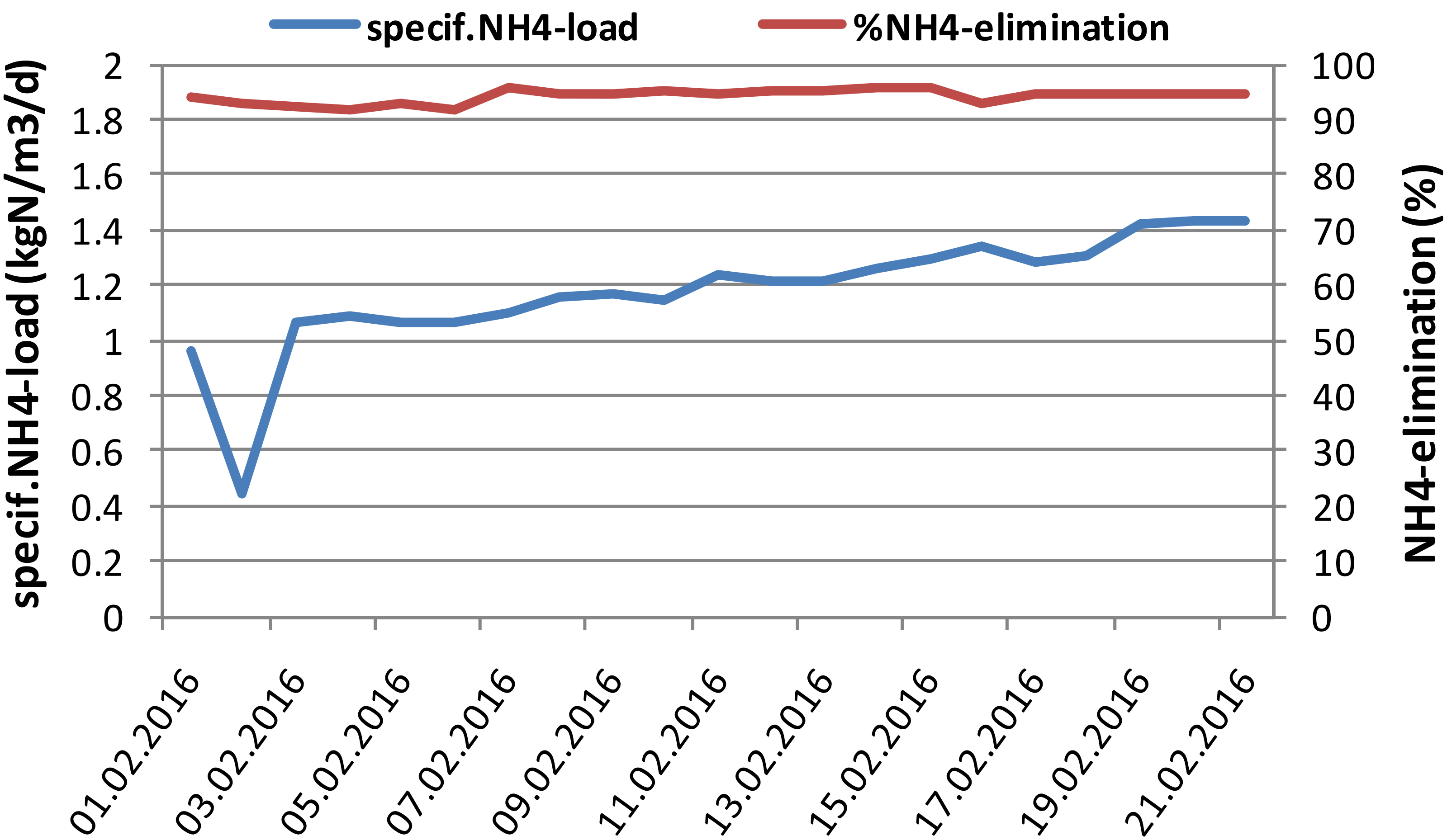




resource requirements of sidestream deammonification Strass



Continuous Deammonification

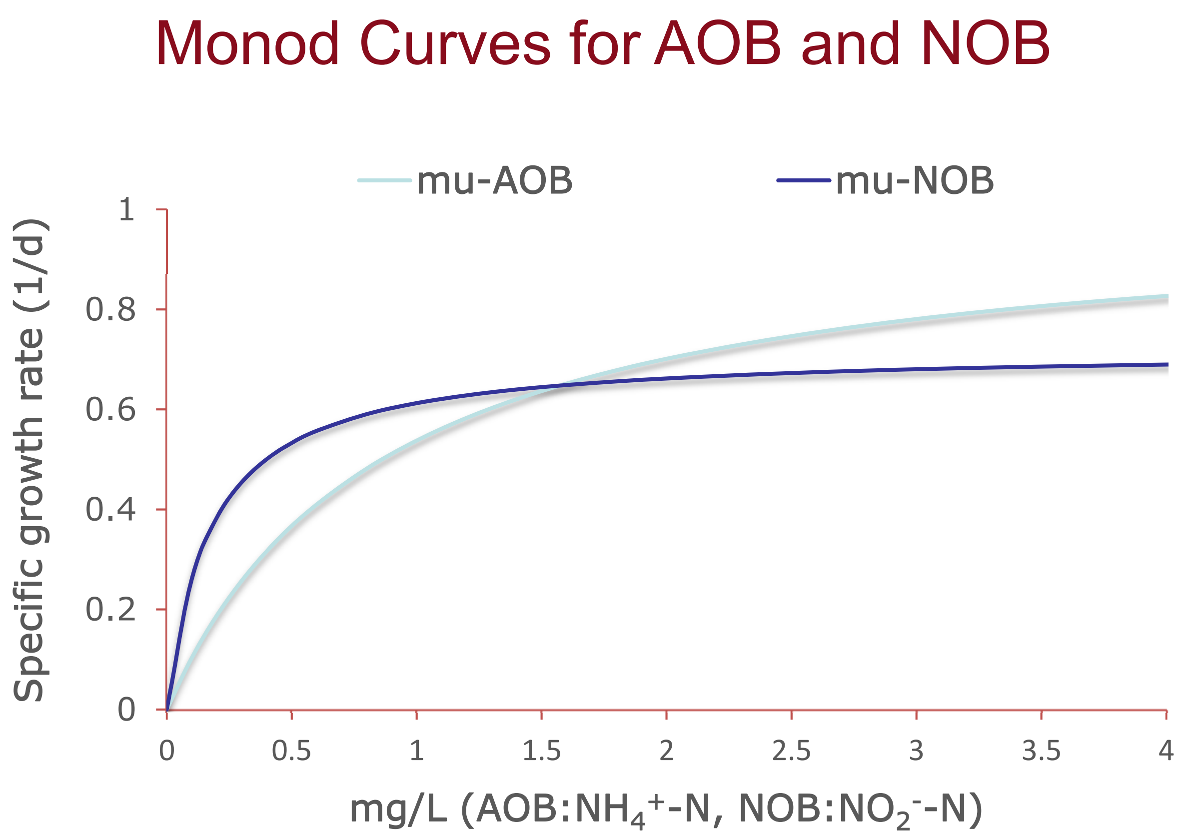


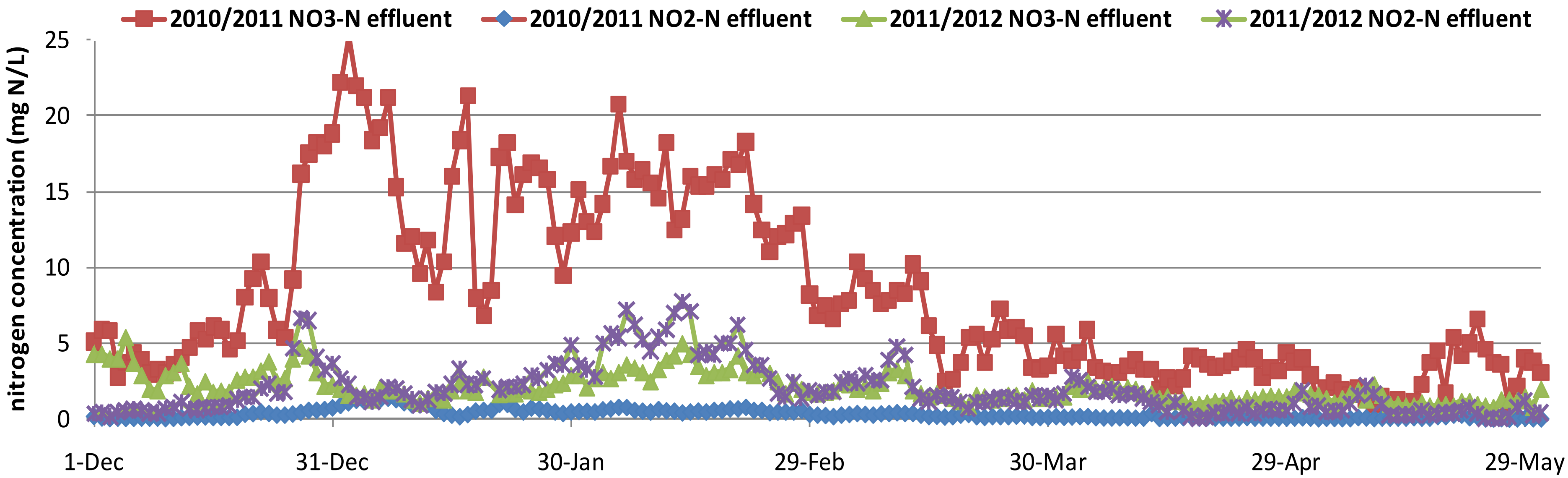
Physical Factor

- Diffusion

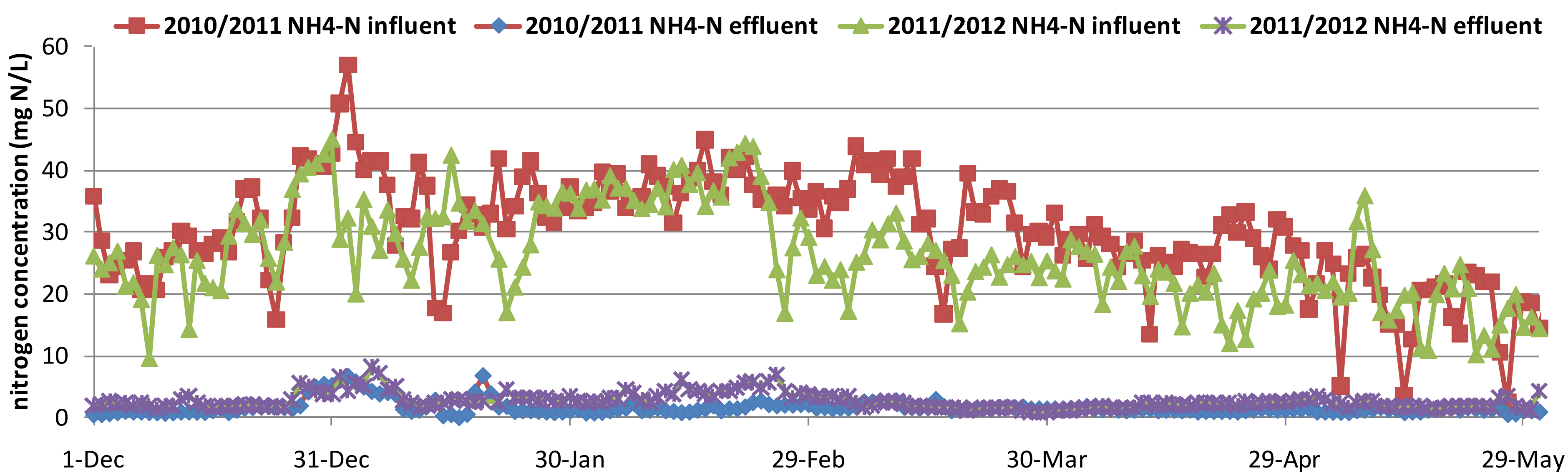
Ammonia

- Ammonia levels and temperature are too low for free NH3 inhibition
- Residual ammonia allows AOB to grow closer to their maximum growth rate
- Minimize NO2-N to outselect NOB related reactions





Comparison of operational data of the full-scale pilot Strass indicating advanced NOB-repression (typically high nitrate level at Christmas peak-load; similar temperature conditions of ca. 10°C , load conditions and ammonia effluent concentrations of about 2-5 mgN/L)



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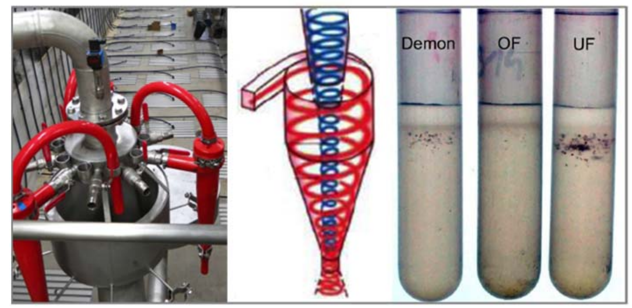
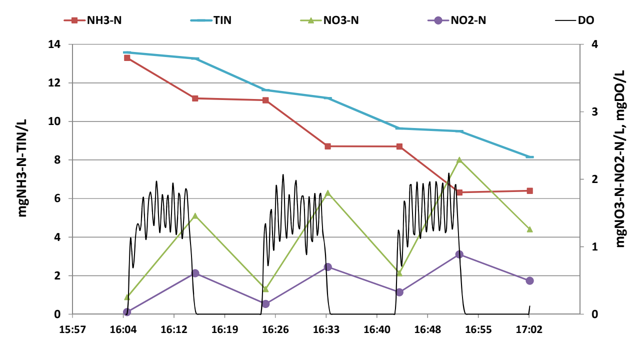
Summary

Underlying theme for ***Intensification*** and managing ***Resource*** used:

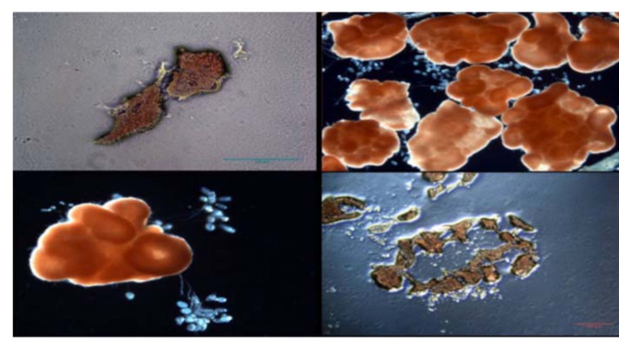
– Improve physical forces that limit process performance



– Sensors and process control can leverage further improvements



– Biological selection is key to managing yield and inventory



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Operationalizing Innovation as a Business Process at DC Water

<u>Commercializing Products and Services.</u>

- Products include intellectual property
- Services include the delivery of short-term or sustained expertise associated with a product
  - Products and services are bundled to maximize efficiency for the customer and revenue potential for DC Water.

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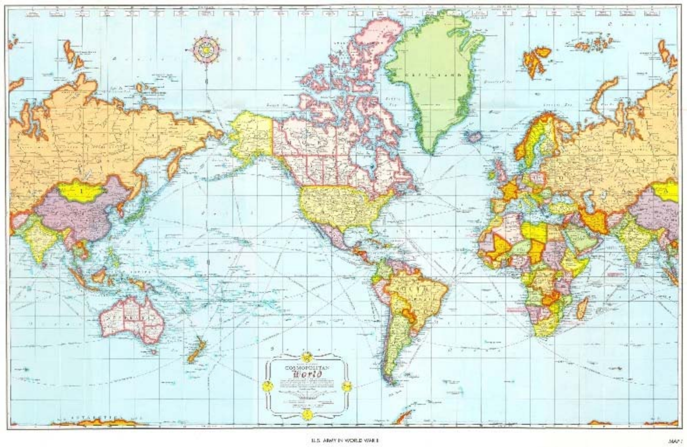
Operationalizing Innovation as a Business Process at DC Water

- Develop MOUs
- Joint Development Agreements
- Joint Commercialization Agreements
- Franchise approach for products and services (concept design, design review, commissioning and startup, ESCOs)
  - North America
  - Europe
  - China
  - India



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Open Innovation Team