WRF 4973 Nutrient Optimization

WRF 4973 - Emerging Technologies for Nutrient Optimization

March 31, 2021

Guidelines for Optimizing Nutrient Removal Plant Performance

WRF 4973 Nutrient Optimization

Starting Shortly

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Guidelines for Optimizing Nutrient Removal Plant Performance

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Housekeeping

- Submit questions through the question box at any time. We will do a Q&A at the end of the webcast.
- Slides and a recording of the webcast will be available at www.waterrf.org.
- Survey at the end of the webcast.

Certificate of Completion (for CEU/PDH)

- WRF cannot give out the certifications, but we provide a certificate of completion
- Instructions
  - Email WRF (MSuazo@waterrf.org) to obtain a Certificate of Completion
  - Contact your state/province licensing agency to verify that CEUs/PDHs will be awarded for the webcast and any other materials are required. Certification contacts are listed on the Association of Boards of Certification Website (Search for **ABCCERT Certification Contacts**)
    - www.abccert.org/certification_contacts
- This information will be COPIED INTO THE CHAT of this webinar

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WRF 4973 Nutrient Optimization

Overview of WRF 4973 - Guidelines for Optimizing Nutrient Removal Plant Performance

JB Neethling, HDR Inc.

Project Overview

The goal of WRF project 4973 is to provide guidance for optimizing WRRF operation while reducing nutrient discharge into the environment.

Nutrient Optimization	**Comment/Goal**
Gain "some" nutrient reduction from BOD process	Achieve incremental nutrient load limits
Increase nutrient removal efficiency at a NutRem process	Meet lower limits, increase reliability, increase capacity
Reduce operating cost for nutrient removal	Lower energy, chemical, materials, operator cost
Nutrient reduction by other means	Sidestream treatment, reuse, source control, etc.

WRF 4973 Webinar Series

Search: WRF 4973 webinar

Applied Fundamentals for Nitrogen and Phosphorus Removal Optimization	3/17/21
Emerging Technologies for Nutrient Optimization	**3/31/21**
Beyond Liquid Treatment: Reduce Nutrient Discharge Loads by Other Means	4/14/21
Sidestream Management to Optimize WRRF Nutrient Removal	4/28/21
Instrumentation and Control for Nutrient Optimization – Part 1: Sensors	5/12/21
Instrumentation and Control for Nutrient Optimization – Part 2: Controls	5/19/21
Strategies to reduce O&M Cost in Nutrient Removal WRRFS	5/26/21
Nutrient Reduction from Secondary (BOD removal WRRFs)	6/23/21
Optimizing Nutrient Removal WRRFs	7/7/21
Nutrient Reduction Approaches for Small Systems	7/21/21
Optimize Nutrient Removal WRRF Operations	8/4/21
Tools to Evaluate Nutrient Optimization in WRRFs	8/18/21
Nutrient Discharge Permitting and WRRF Optimization	9/1/21





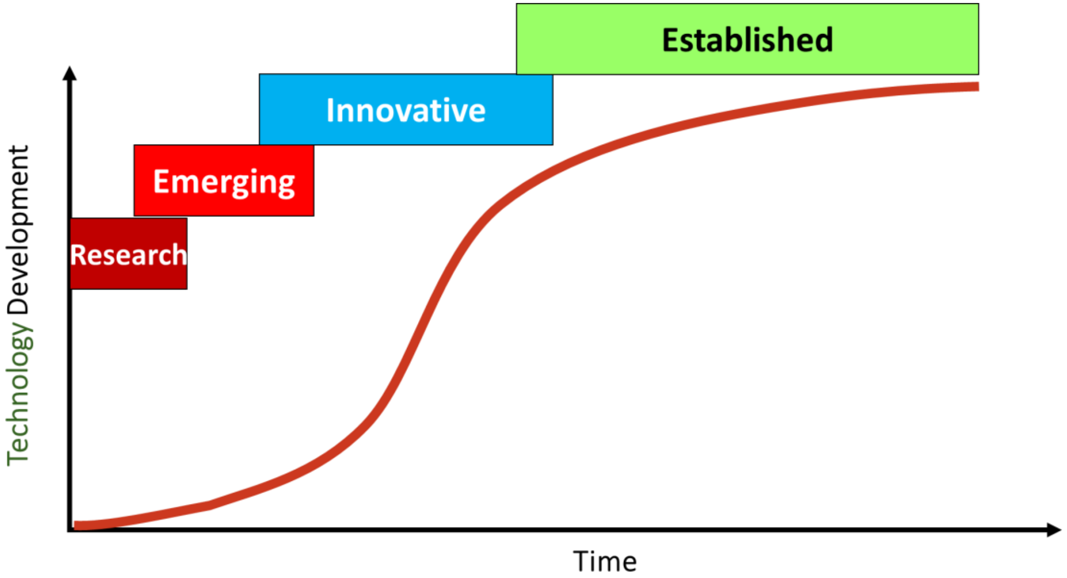
Emerging Technologies for Nutrient Optimization

Emerging Technologies for Nutrient Optimization

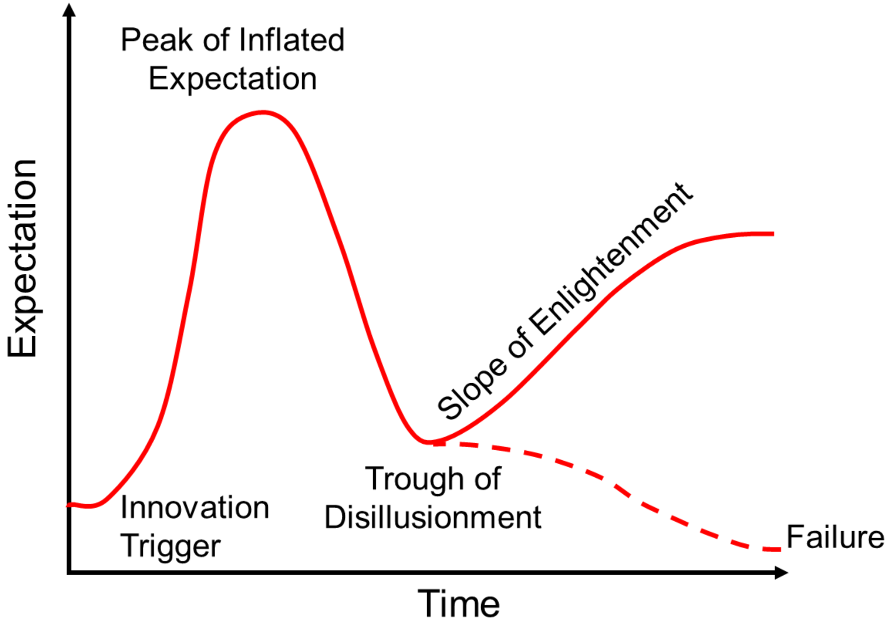
TDL Stage		TDL Definition
1	**Bench Research & Development**	These technologies are in the early development stage and/or have been tested at the bench scale or proof of concept scale in a laboratory environment. (TRL 3-5)
2	**Small-Scale Pilot**	These technologies have been successfully tested at a sufficient scale to establish the basis of the first generation of full-scale facilities in a relevant environment. (TRL 6-7)
3	**Full-Scale Pilot** (Demonstration)	These technologies have been successfully demonstrated at 1 or more facilities at final commercial design stage in an operational water environment. (TRL 7-8)
4	**Pioneer Stage** (Production & Implementation)	First-of-a-kind or initial commercial implementation: these technologies have been qualified through testing and implemented under full operational conditions and have some degree of initial use, but are not considered established in the water sector. (TRL 8-9) Adaptive Use- an established technology or process that has a new application or objective are eligible under this TDL
5	**Conventional***	These technologies are considered established and have been typically used at U.S. treatment facilities or have been available and widely implemented for more than five years. (TRL 9)

* This program is intended to showcase technologies at all levels except for those that are "Conventional". Applications for "Conventional" technologies are not currently accepted.

The TRL (Technology Readiness Level) conversion is provided for the convenience of those more familiar with the system used by the U.S. Government which uses a 1–9 scale.



S-Curve



Gartner Hype Cycle:

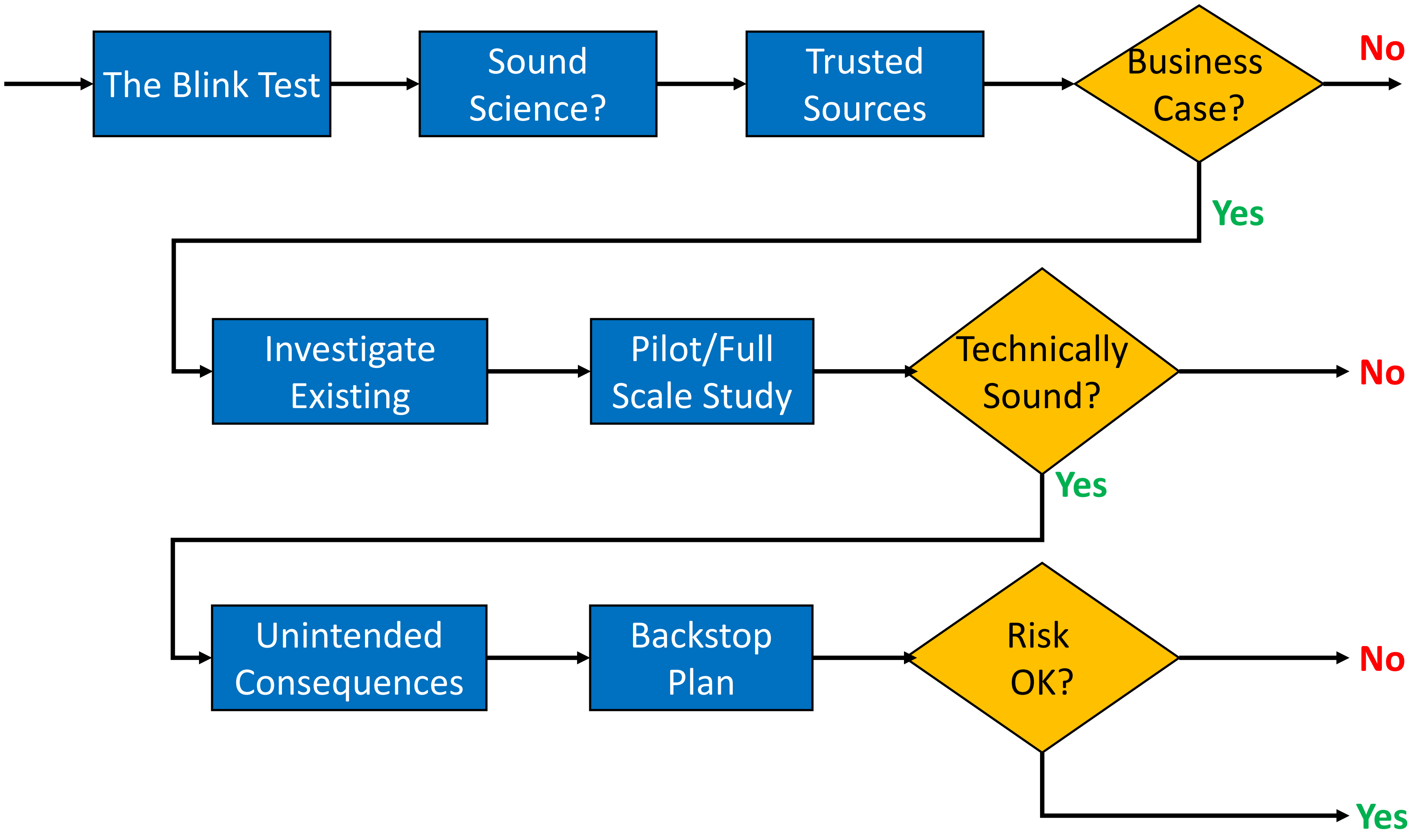
Putting New Technology into Practice - Implementation

Put into Practice/Implementation

First Reaction – Business Case

Investigate – Technical

Implement – Limit Risk



J.B. Neethling “Implementing New Technology In Rapidly Changing Environment” AEESP Lecture, WEFTEC 2014

First Reaction – Build the Case

- Use Malcolm Gladwell's "Blink" test!
  - If it sounds too good to be true, it probably is!
- Check the science
  - But remember it is evolving
- Check past experiences from trusted sources
- Is the business case favorable

Investigate the Technical Performance

- Investigate existing installations
  - Phone, in person, LIFT
  - Question the operators & owners
- Pilot test and/or Full-scale tests
  - Determine site specific conditions
  - Operations assessment
- Evaluate technology performance

Credit: HDR Inc. 2014

Implement – Limit the Risk

- Unintended consequences
- Develop Risk Mitigation Plan for Implementation
- Backstop option

Reduced Sludge Production Process
Operate as Aerobic Digester

Contact Clarifier – Filter
converted to Direct Filtration

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WRF 4973 Nutrient Optimization

Biomass Densification

Bryce Figdore, HDR INC.

Activated sludge densification approaches

Activated Sludge Densification to Improve Settling

Primarily through biological selection

- Aerobic Granular Sludge (AGS)
- Densified Activated Sludge (DAS)

Primarily through physical / chemical means

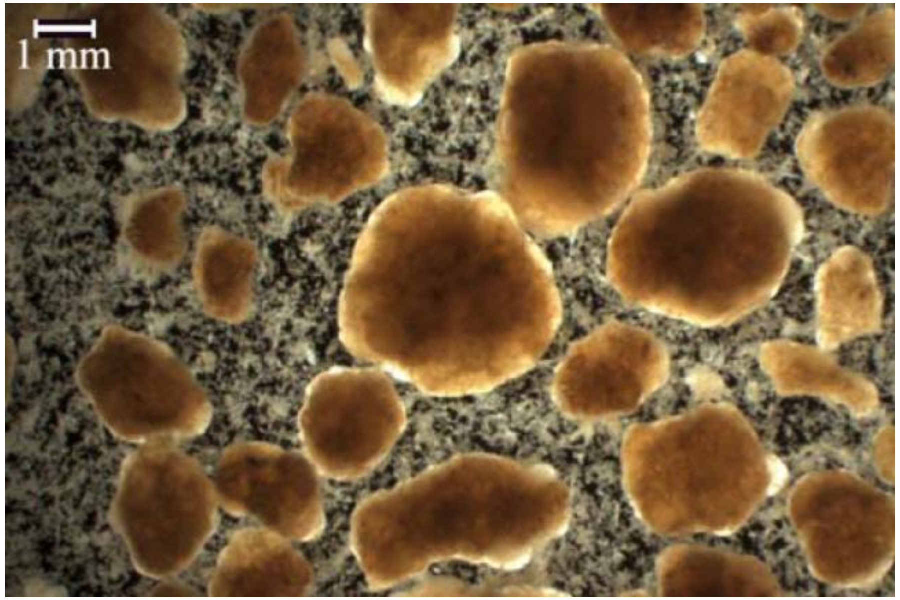
- BioMag® (add magnetite and polymer)
- PACT (add powdered activated carbon)
- BIOACTIFLO™
- WAS cyclones (inDENSE™)

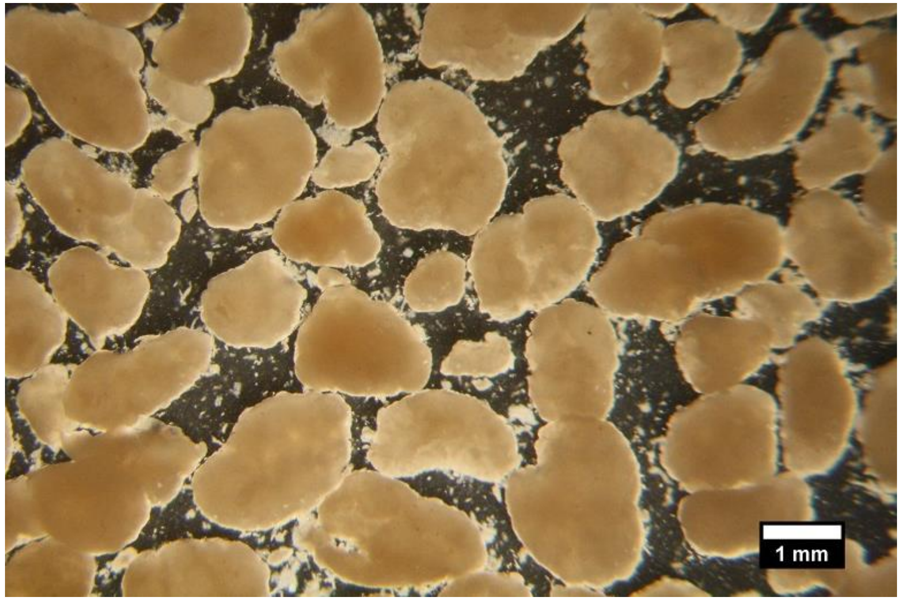
What are granules?

- Microbial biofilms
- Formed without carrier media
- Larger and faster-settling than flocs
  - Particle size >200 um
  - SVI_{30min} 30-50 mL/g
  - Discrete settling, complete in 5 minutes

Anaerobic granules

Anammox granules





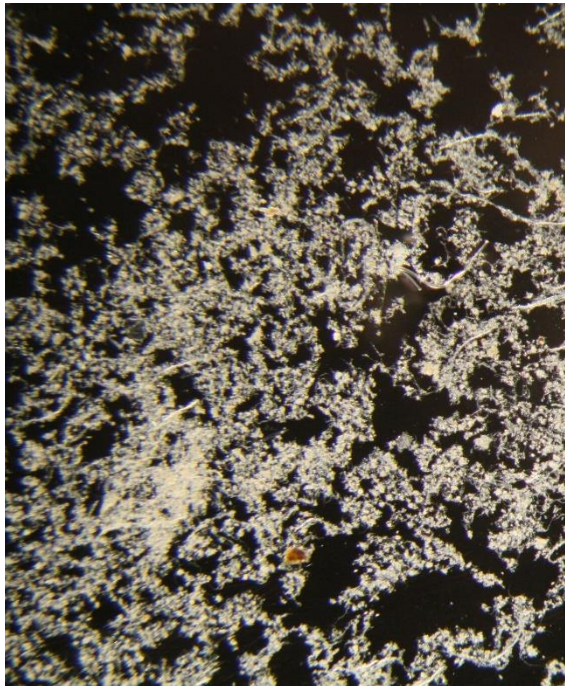
Aerobic Granular Sludge (AGS)

What is densified activated sludge (DAS)?

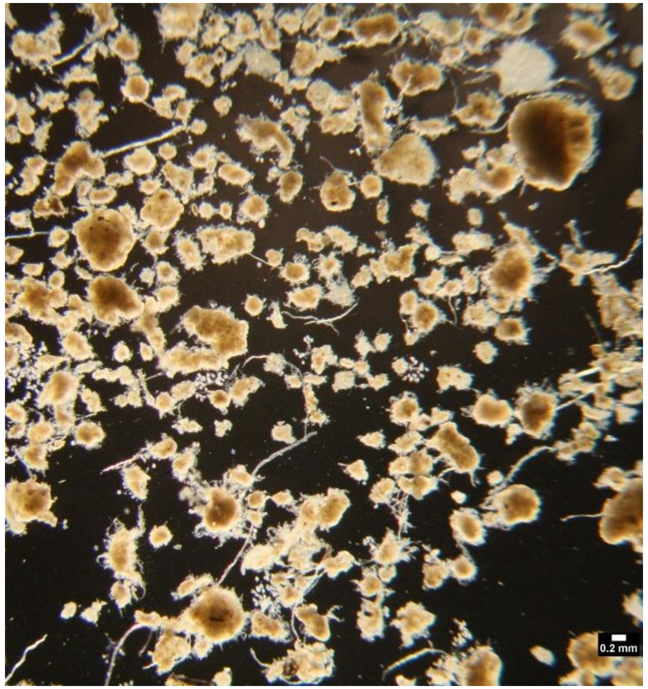
- Activated sludge possessing granule-like attributes but not fully granular
- SVI_{30min} 50 to 100 mL/g
- Smooth, dense floc morphology
- Particles generally smaller but may include fraction >200 um
- May provide similar benefits as AGS with less extensive retrofits in flow-through systems

Activated Sludge Densification Continuum

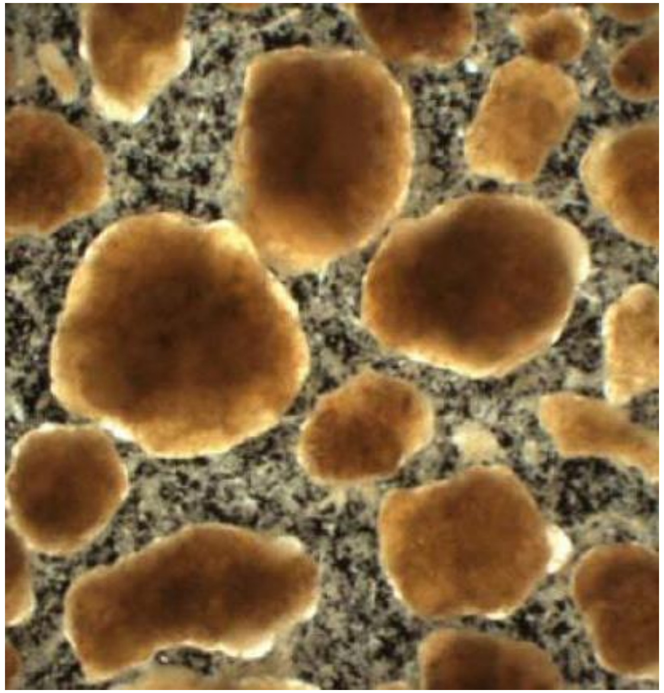
Increasing densification *Fully Granular*



Conventional Sludge: SVI >100
Few particles >200 um



Densified sludge:
SVI ~50 to 90
May contain some granules >200 um

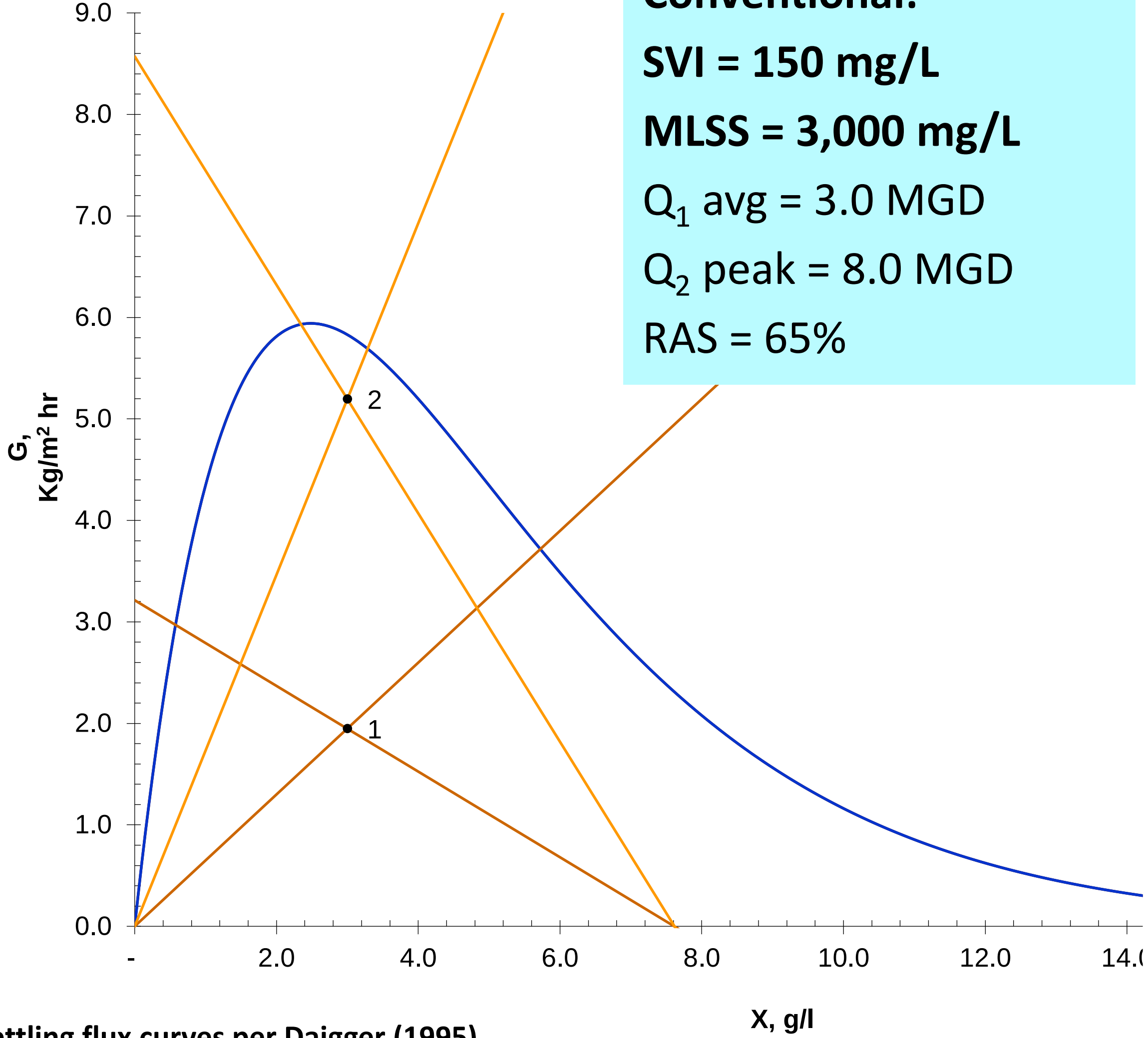


Granular sludge:
SVI <50
>80% MLSS mass >200 um

Optimization potential with granular/densified sludge

- Improved settling characteristics
- Increase design MLSS concentration
- Less tank volume – smaller footprint
- Increase capacity
- Biological nitrogen and phosphorus removal
- Simultaneous nitrification-denitrification potential

Densified sludge improved settling increases capacity



Conventional:

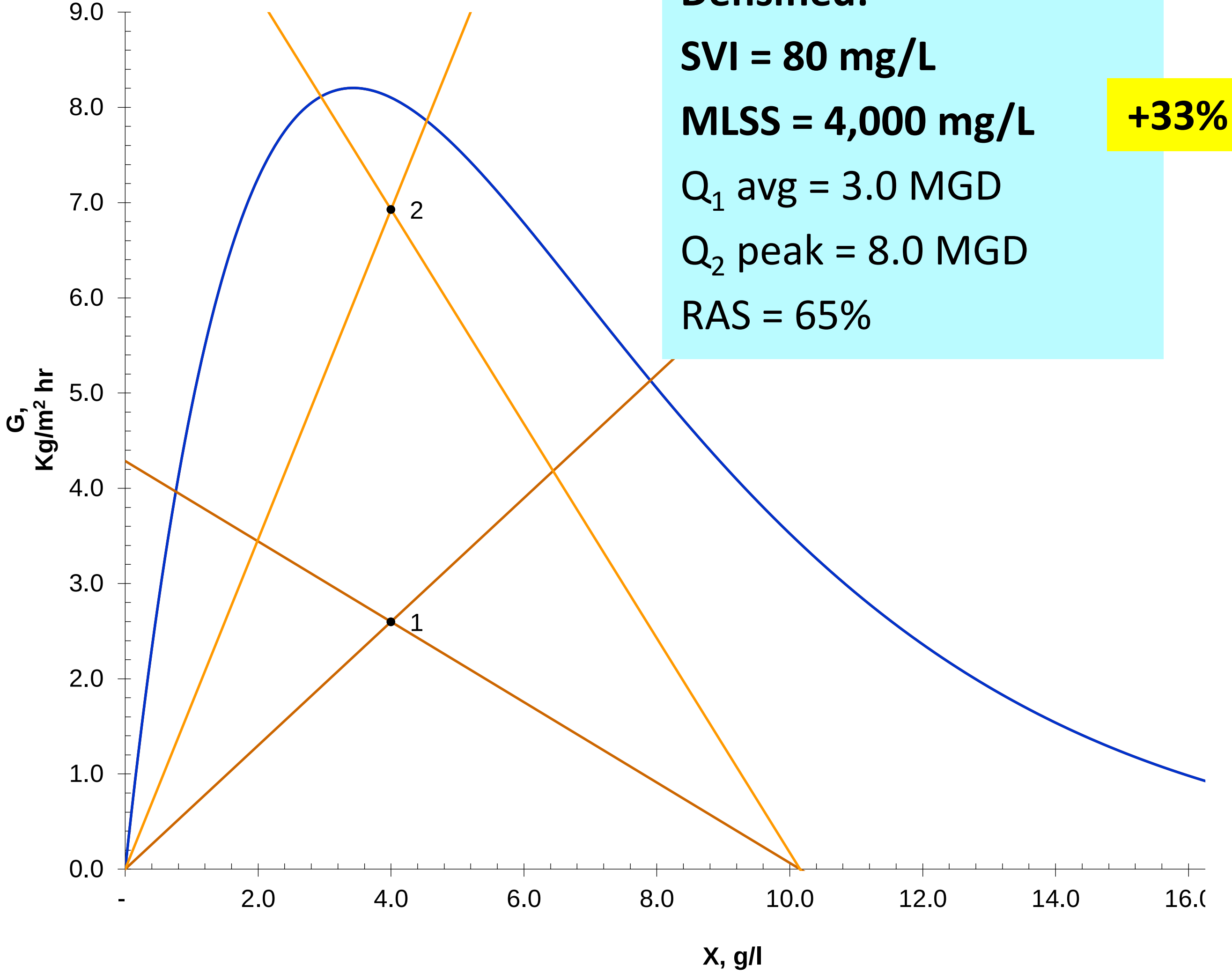
SVI = 150 mg/L

MLSS = 3,000 mg/L

Q_1 avg = 3.0 MGD

Q_2 peak = 8.0 MGD

RAS = 65%



Densified:

SVI = 80 mg/L

MLSS = 4,000 mg/L

Q_1 avg = 3.0 MGD

Q_2 peak = 8.0 MGD

RAS = 65%

+33%

Settling flux curves per Daigger (1995)

7850 ft² clarifier surface area

Selective Pressure Categories

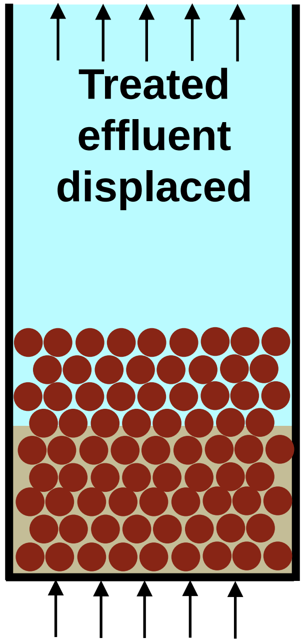
1. Biological – must have

2. Physical – bonus for larger particles

Feeding regime and reactor kinetics provide fundamental biological selection for AGS/DAS growth

1. High F/M anaerobic contacting → selects PAOs/GAOs for rbCOD uptake and drives diffusion to inner layer
2. Batch or plug-flow kinetics → feast-famine induces cell aggregation and EPS production

Nereda® SBRs



Slow upflow plug-flow anaerobic feeding through settled sludge bed

Well-Demonstrated

Continuous flow systems:

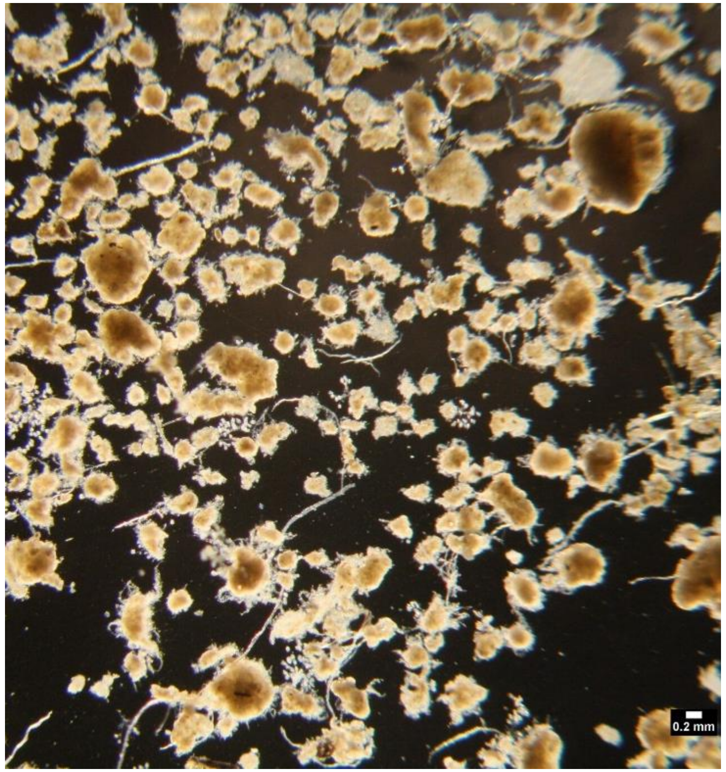
- Extension of granulation fundamentals
- "Fortuitous" densification observed; now better understood and applied with intent
- R&D ongoing

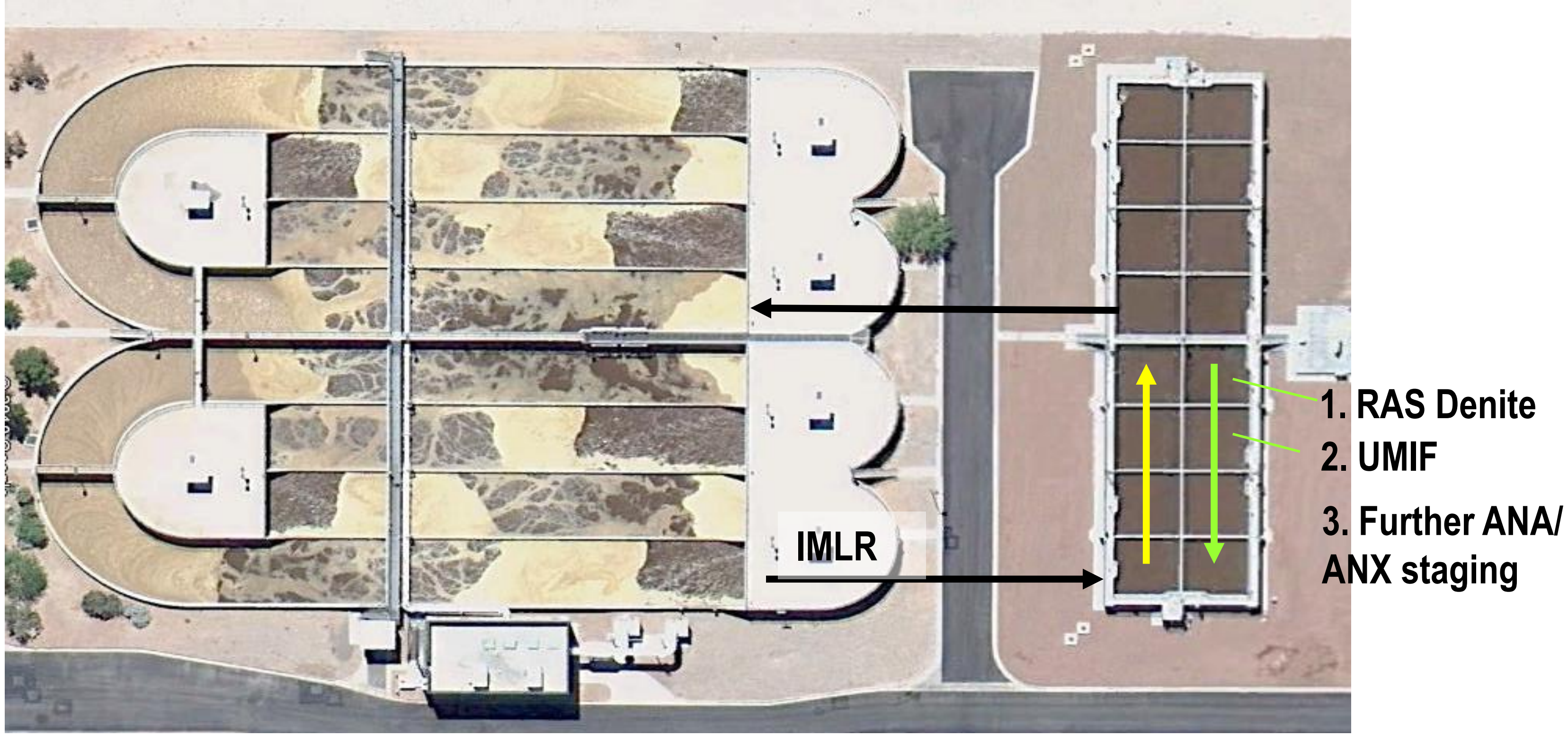
Continuous Flow DAS Biological Selection Toolbox

Approach	Relevance to Granulation / Densification Fundamentals
Staged anaerobic selectors	Promote high anaerobic F/M conditions
RAS / MLSS fermentation	Localized high anaerobic F/M conditions in fermenter sludge bed May be enhanced with primary sludge or VFA feeding
RAS denitrification	Protect anaerobic zone integrity
Plug flow reactors	Promotes feast-famine conditions But --- oxygen transfer limitations must be considered

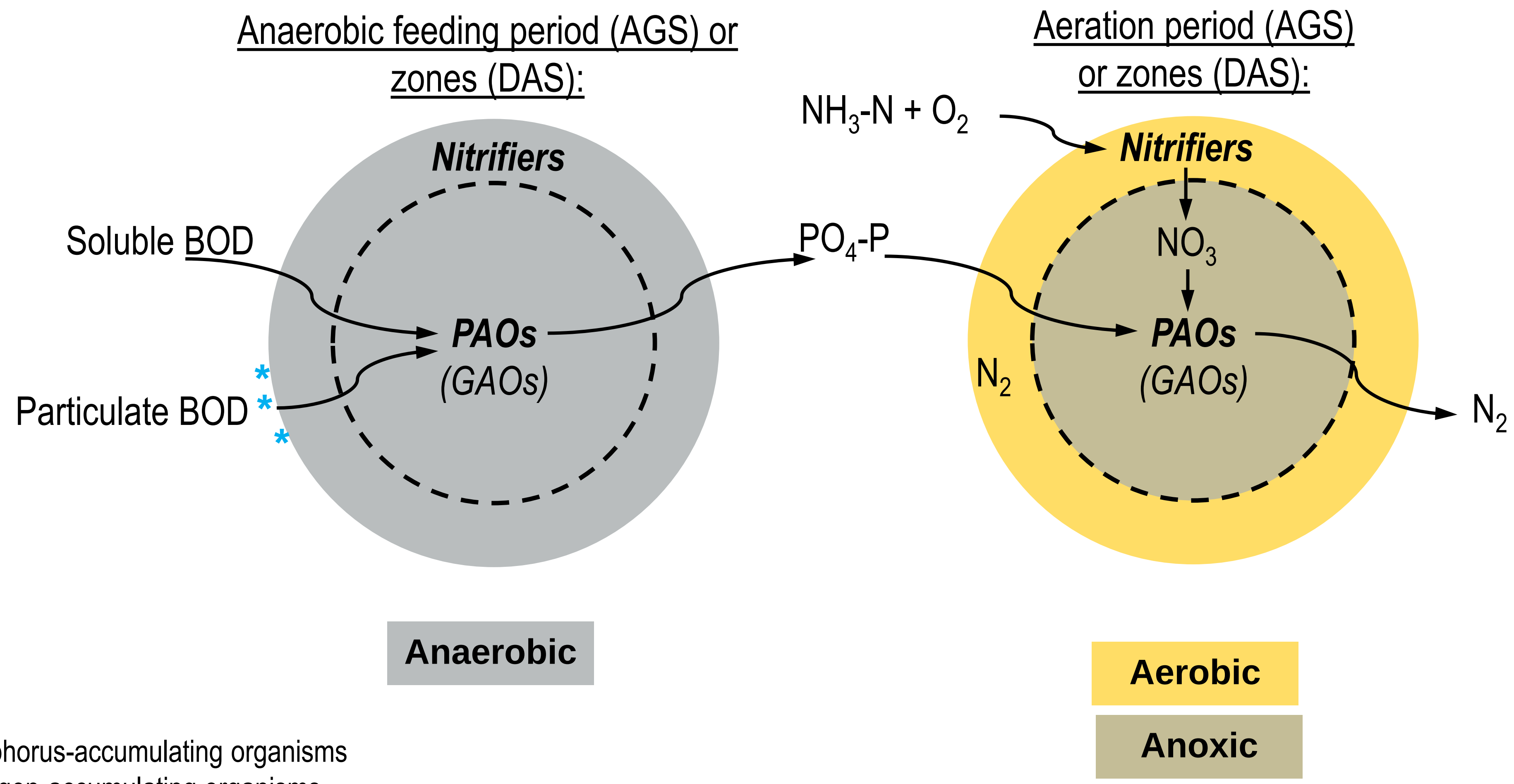
Selection pressure may not be as strong as bottom-fed SBRs

Example of biological selection factors at Henderson, NV with low-VFA influent from nitrate addition





Nutrient Removal goes hand-in-hand with biological selection for AGS/DAS



Simultaneous nitrification-denitrification (SND) with EBPR

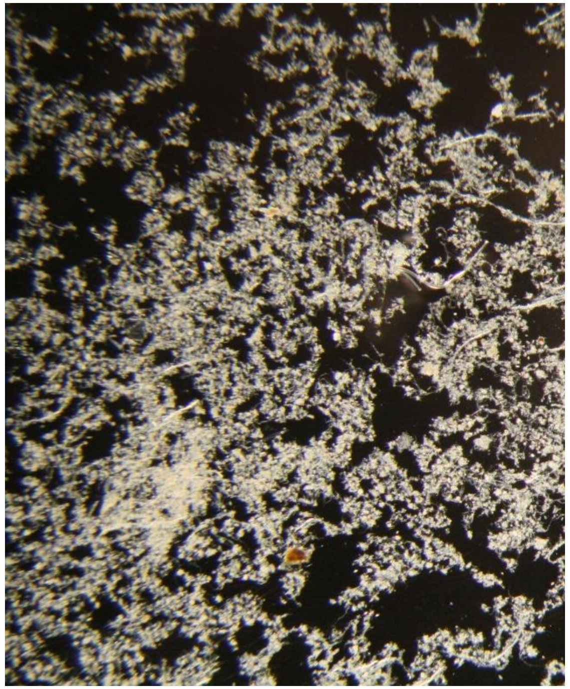
and/or

Storage-driven denitrification (may include anoxic zones)

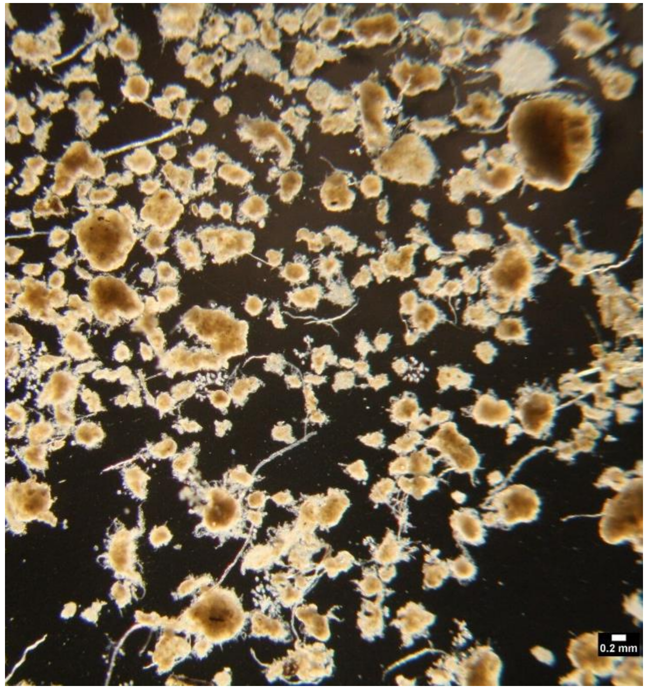
PAOs = phosphorus-accumulating organisms
GAOs = glycogen-accumulating organisms
EBPR = enhanced biological phosphorus removal

Biological selection alone is sufficient for DAS

Increasing densification *Fully Granular*



Conventional Sludge

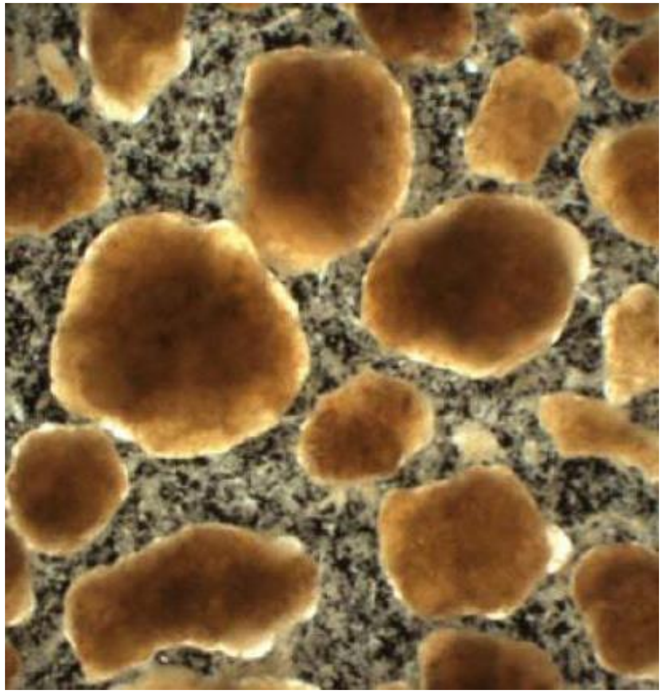


Densified sludge

Obtained without physical selection

Larger particles enriched with PAOs/GAOs

(Wei et al., 2019)



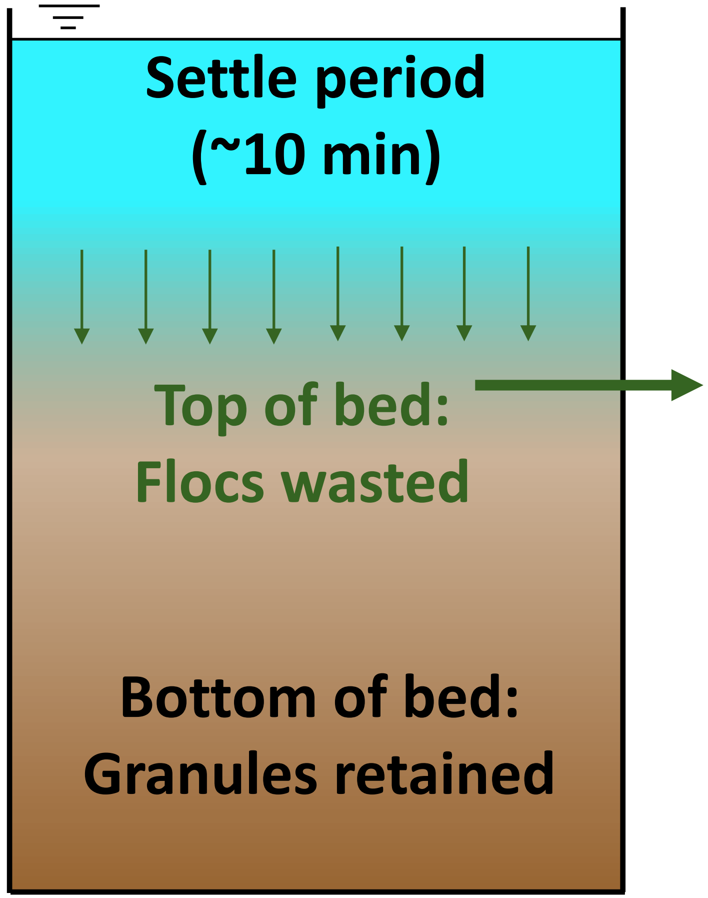
Granular sludge: SVI <50

Selective wasting provides fundamental <u>physical selection</u> for larger, faster settling granules over flocs

Nereda® SBRs (and lab SBRs):

- Short settling times in SBRs
- Slower-settling flocs and GAOs selectively wasted
- Largest granules on bottom of bed have **<u>preferential access to food</u>** during upflow feeding

Well-Demonstrated



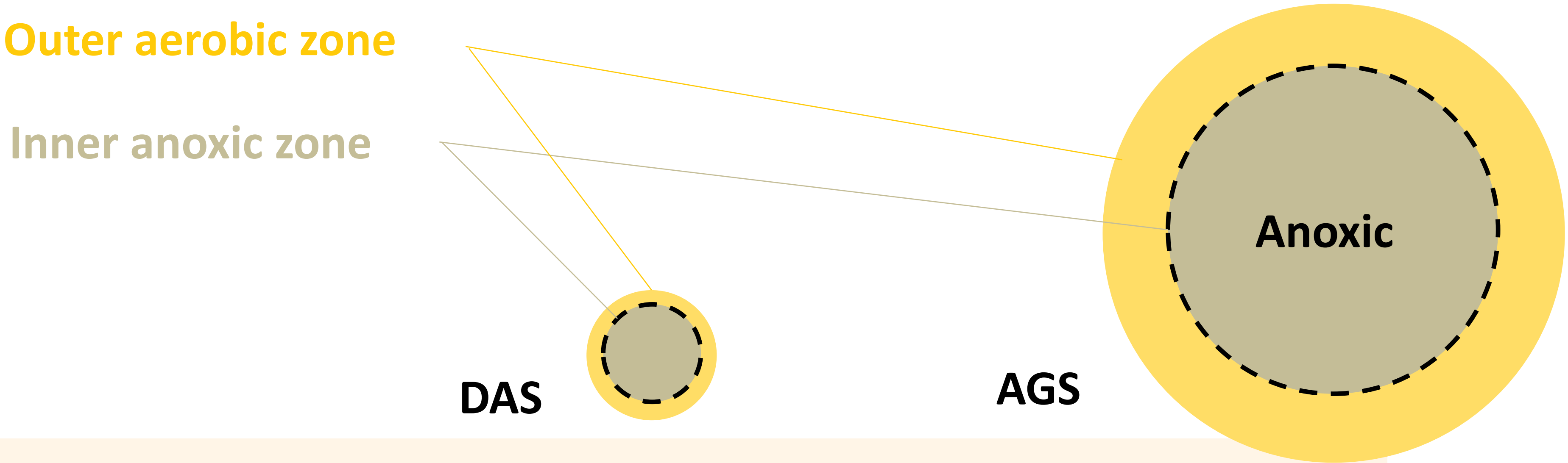
Continuous flow systems:

Ongoing development

Toolbox:

- **inDENSE WAS cyclones**
- **Sieves/Screens**
- **Gravimetric selectors**
- **Surface wasting**

AGS/DAS particle size affects operating conditions for SND and presents optimization potential



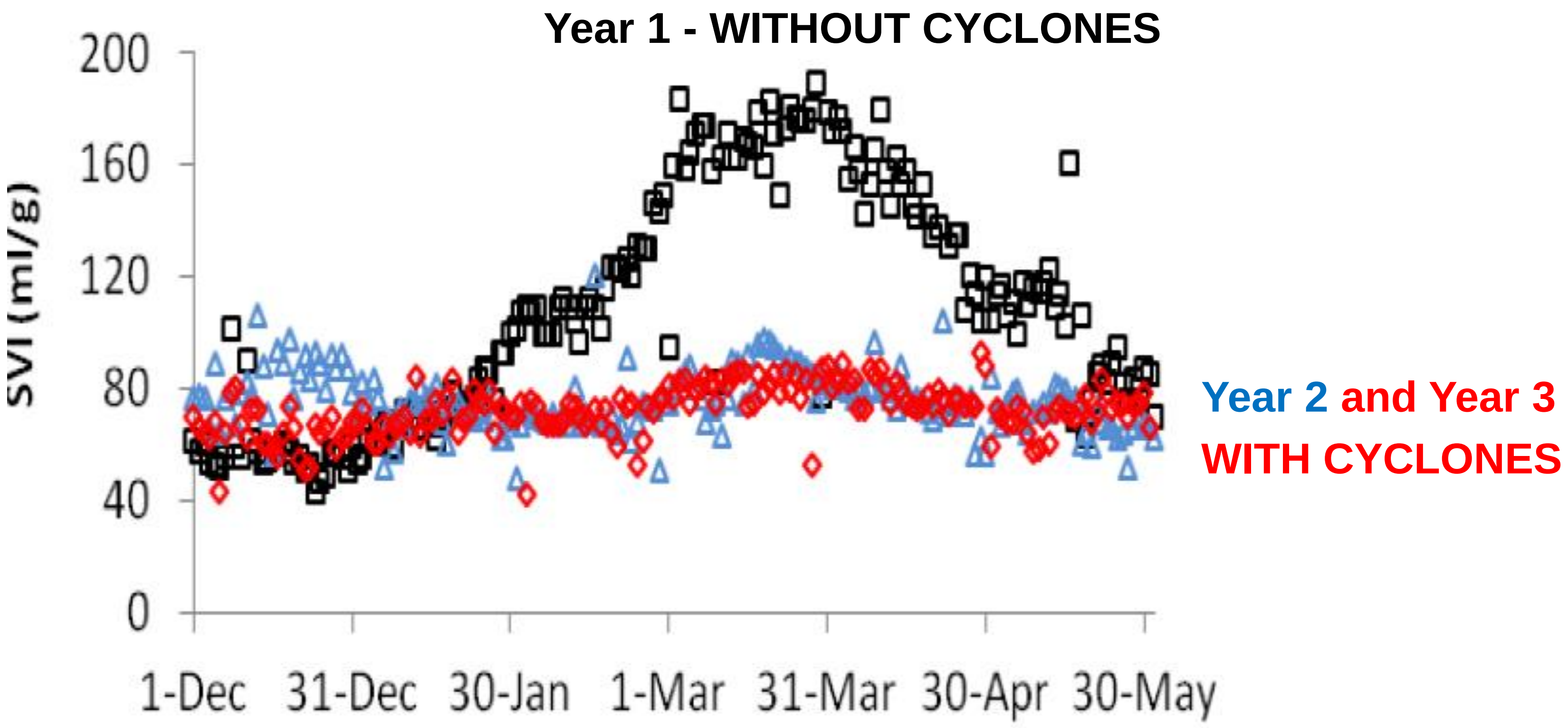
	DAS	AGS
Particle size:	Smaller	Larger
Specific surface area:	Higher	Lower
DO concentration for nitrification and SND:	Lower	Higher

inDENSE^{TM} WAS may help control SVI excursions regardless biological selection

<u>Overflow:</u>
Poorly-settling sludge (to waste)

Sludge feed

<u>Underflow:</u>
Well-settling sludge (returned)
Larger, denser particles
PAO-enriched sludge (more dense)
Granules (if present)



Data for Strass, Austria (A/B config) courtesy of World Water Works

Application "Broad Brush" Comments

Circumstance / Application	Comments
Greenfield application	More advantageous for AGS-SBRs • No pre-existing secondary clarifiers • Sizing often not affected by primary clarification
Retrofit application	More advantageous for DAS / less advantageous for AGS-SBRs • Particularly if BNR existing • Time horizon prove out DAS is a further advantage
N removal only to full BNR	"Add-on" RAS fermentation w/ carbon feed
Oxygen transfer limitations	Can become limiting
inDENSE	SVI control is a low-risk proposition Must be coupled with biological selection to achieve DAS

Takeaways

- Granular and densified sludge present BNR optimization opportunities.
- Granulation principles can be applied to achieve densified sludge in flow-through reactors.
- Biological selection is the cornerstone and sufficient to achieve densified sludge.

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WRF 4973 Nutrient Optimization

Next Generation Biofilms

Leon Downing, Black & Veatch

Oliver Schraa, inCTRL Solutions

Agenda/Presentation

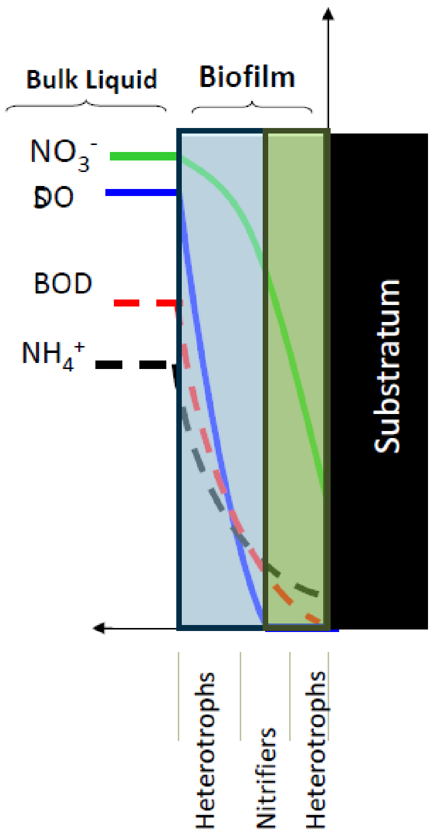
- Biofilm impacts for process optimization
- IFAS/MBBR optimization
- MABR for intensification
- Mobile biofilm concepts

Biofilms for process optimization

Leon Downing, Black & Veatch

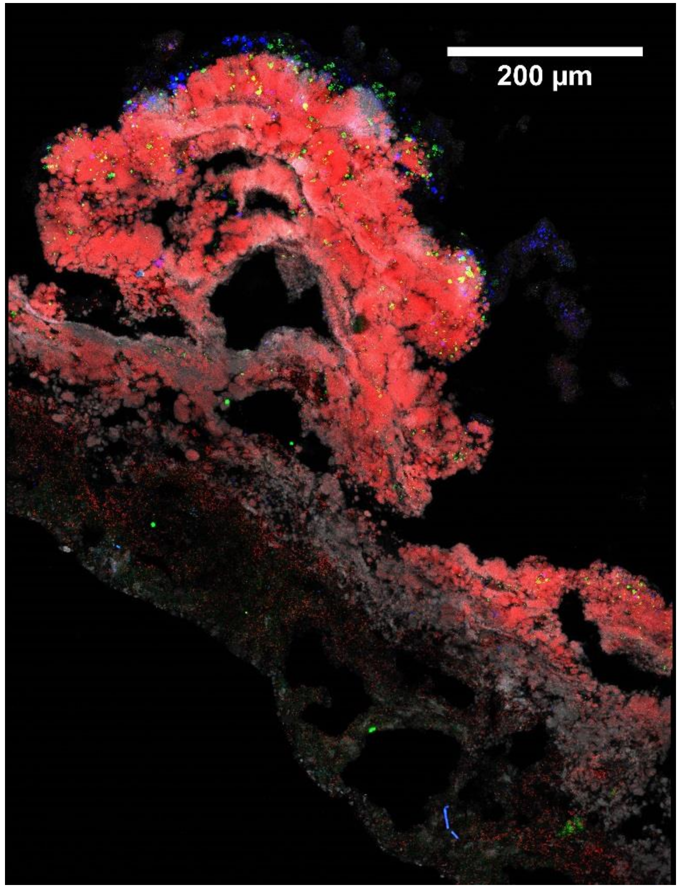
Key differences from suspended growth (e.g. activated sludge)

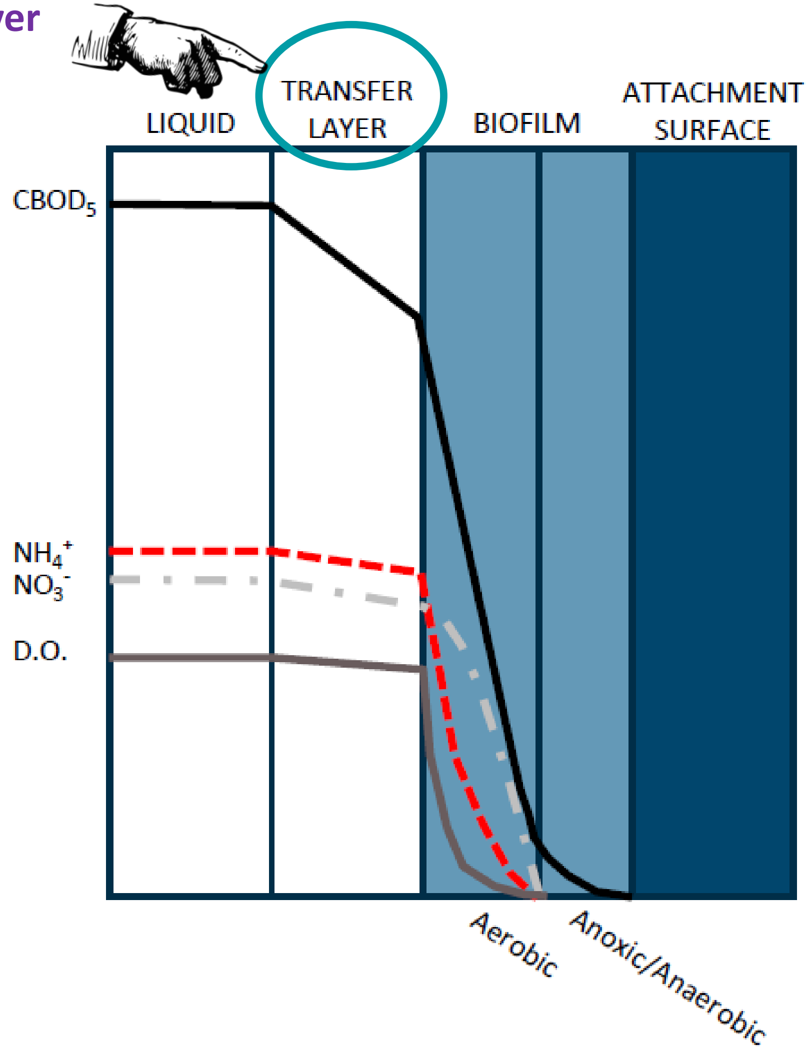
- Mass transfer limitation
- Zone specific ecology
- Settleability of solids
- Biomass control and quantification



How does stuff get into a biofilm?

Smaller mass transfer boundary layer (MTBL): more transfer into biofilm





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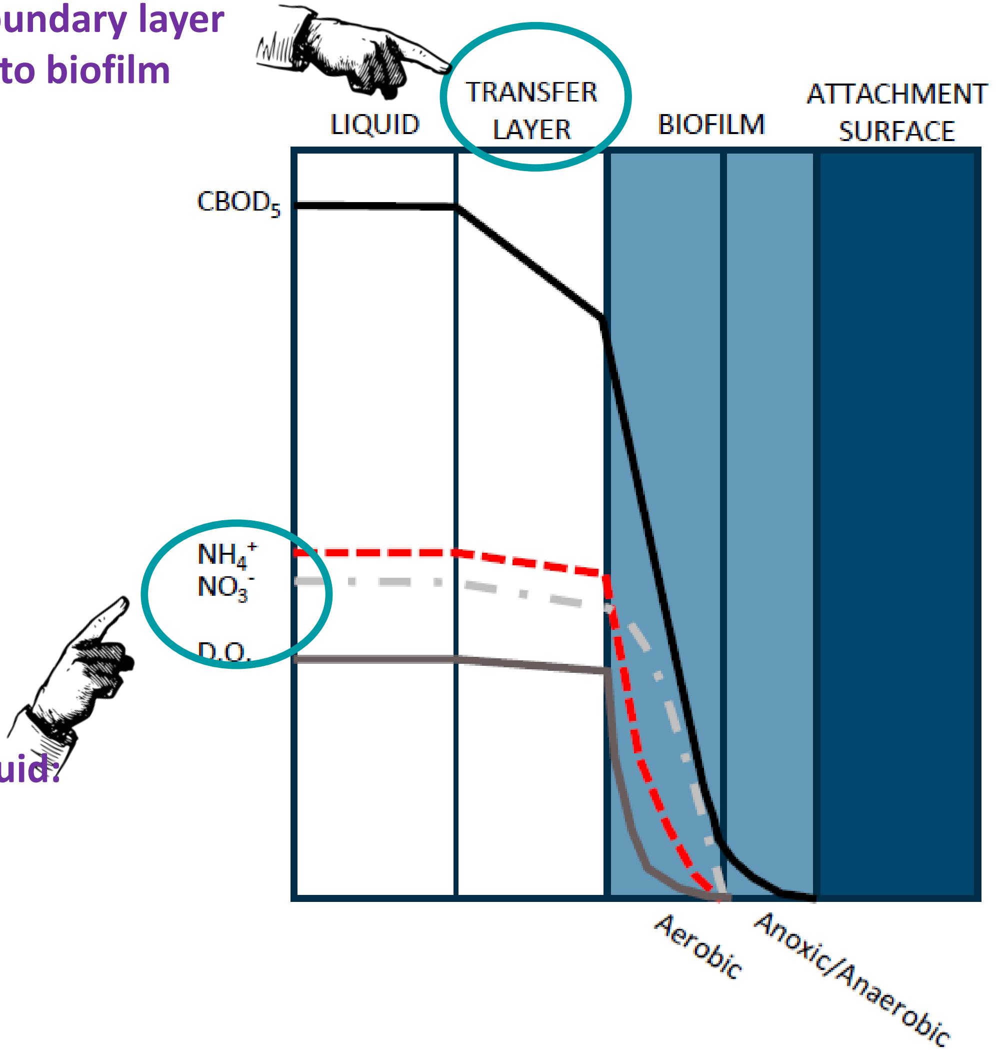
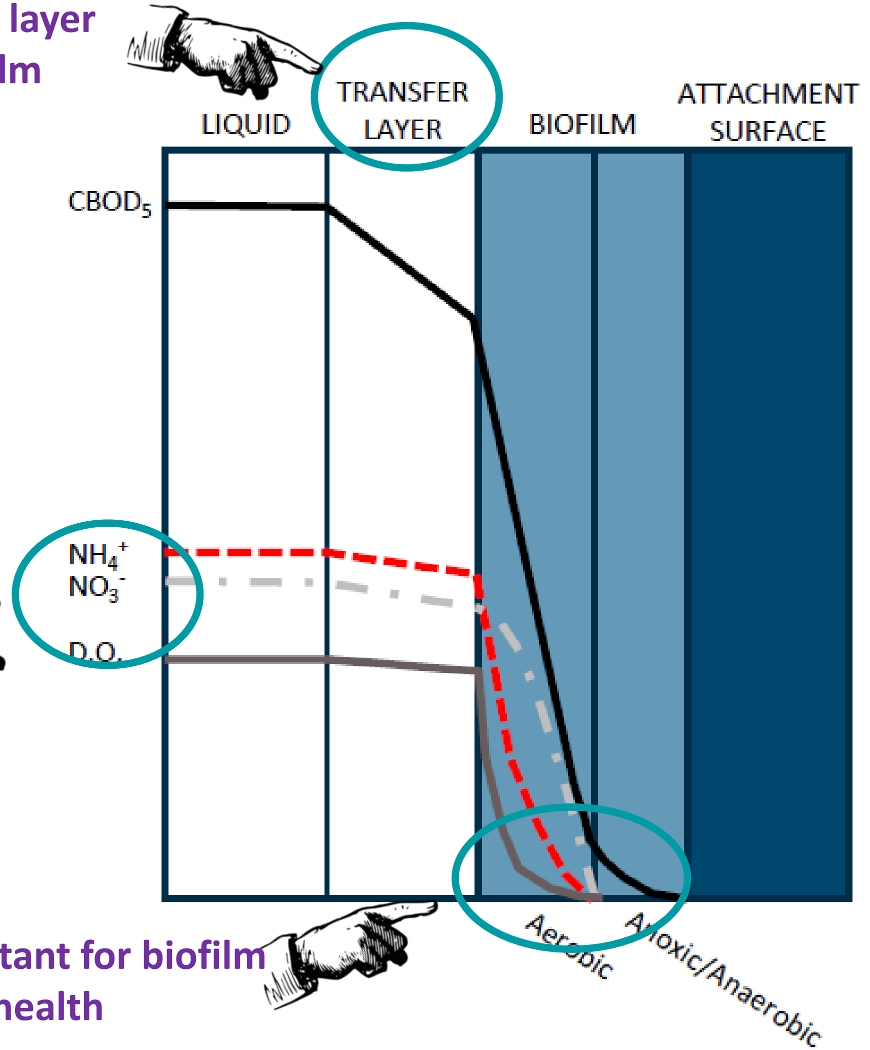


Higher concentration in bulk liquid: more transfer into biofilm

How does stuff get into a biofilm?

Smaller mass transfer boundary layer (MTBL): more transfer into biofilm

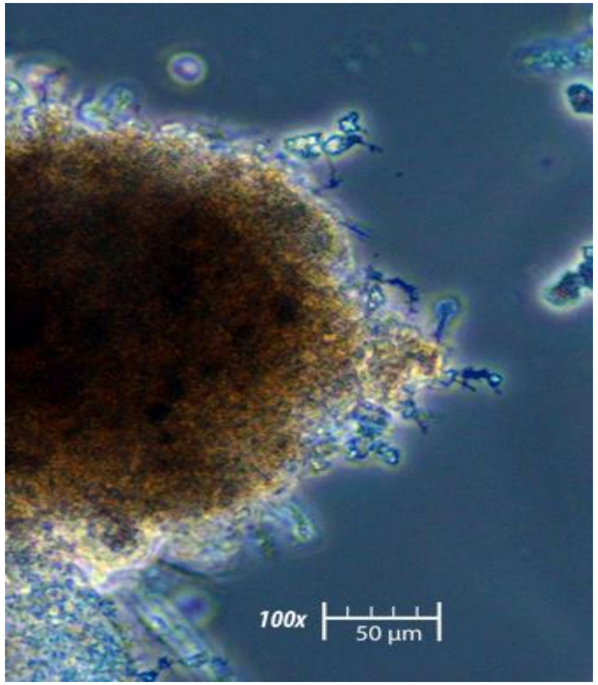


Higher concentration in bulk liquid: more transfer into biofilm

Thickness is important for biofilm performance *and* health

Mass transfer is the most critical consideration for biofilms

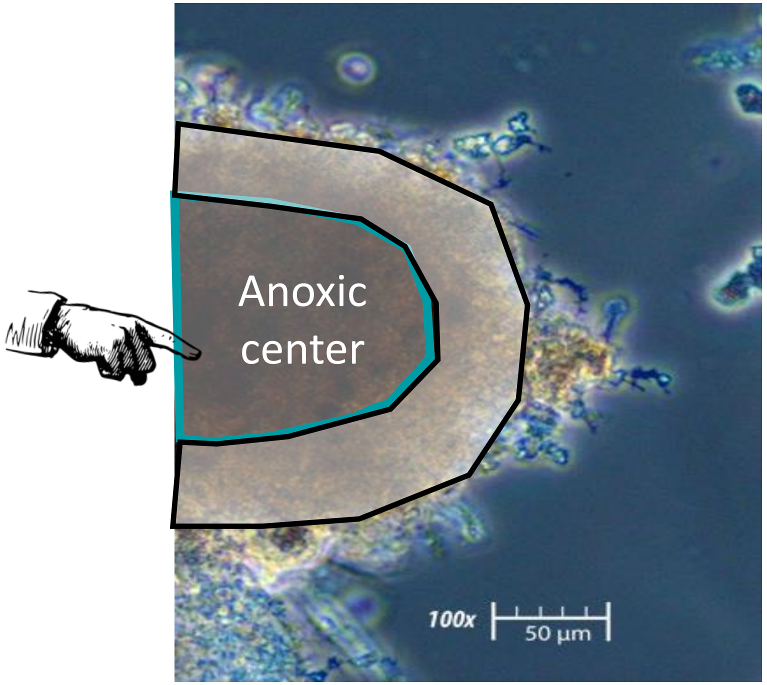
- Also important for activated sludge systems!



Mass transfer is the most critical consideration for biofilms

- Also important for activated sludge systems!

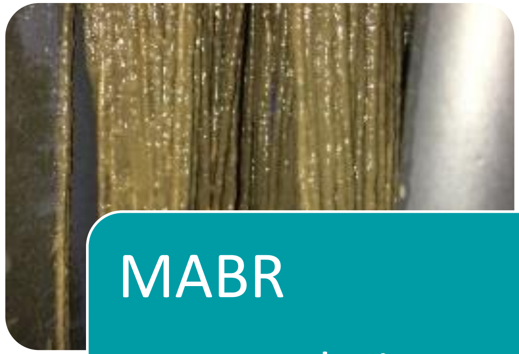
Mass transfer limitations in floc allows for the development of anoxic conditions in aerobic tanks, resulting in simultaneous nitrification and denitrification



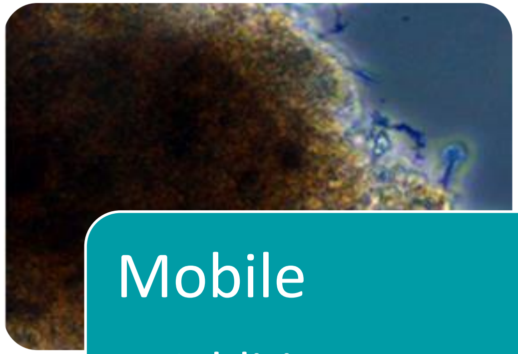
What are the benefits of biofilms for optimization?

- Oxygen gradients provide stratification of microbial processes
- “Fixed” biomass that is retained in the tank, regardless of HRT/SRT
- Intensification of process tanks

IFAS
- Nitrification enhancement
- Hybrid application



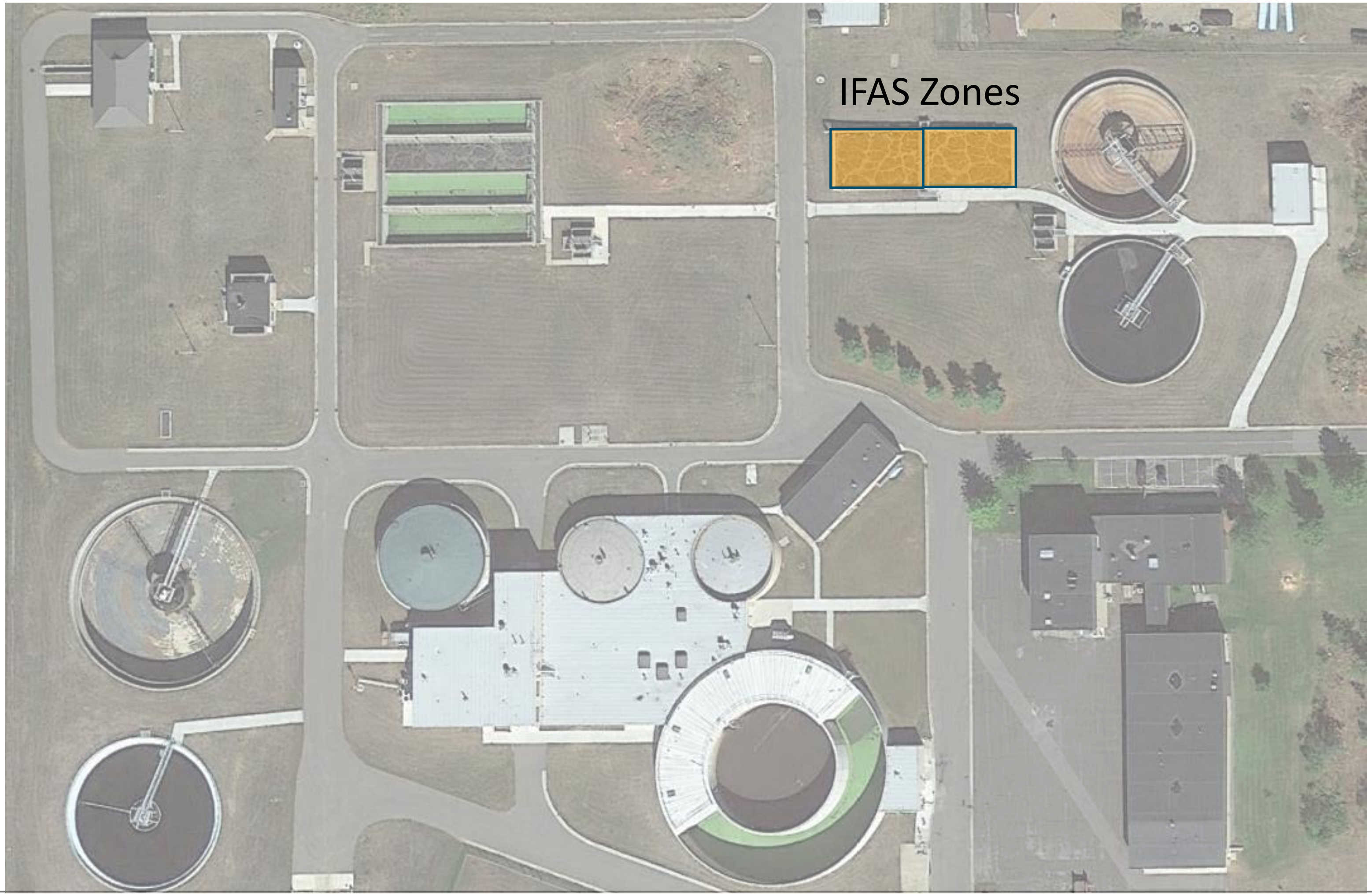
MABR
- BNR solution
- Process intensification



Mobile
- Addition to activated sludge
- No fixed media

IFAS Optimization

Integrated fixed film activated sludge (IFAS) is a balance of biofilm and suspended growth activity



Different technologies are available for incorporation of media into aeration basins

Floating Media

Fixed Media

Biofilm optimization is tied closely to organic loading and DO setpoints and mixing

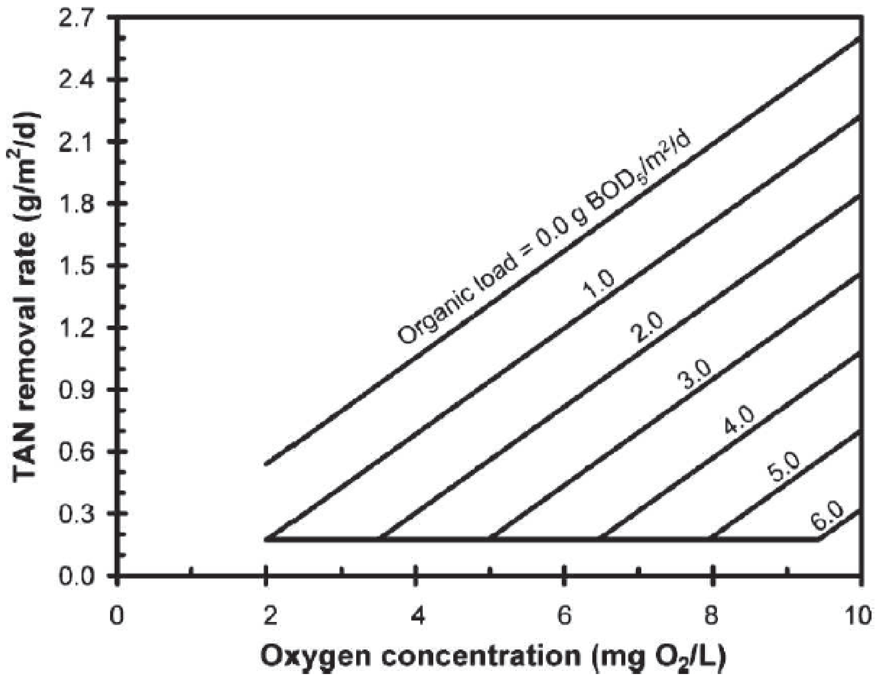


Figure 5—Effect of organic load and bulk-liquid dissolved oxygen concentration on ammonium (or total NH_3-N, TAN) flux (Rusten et al., 2006). Reprinted with permission from IWA publishing.

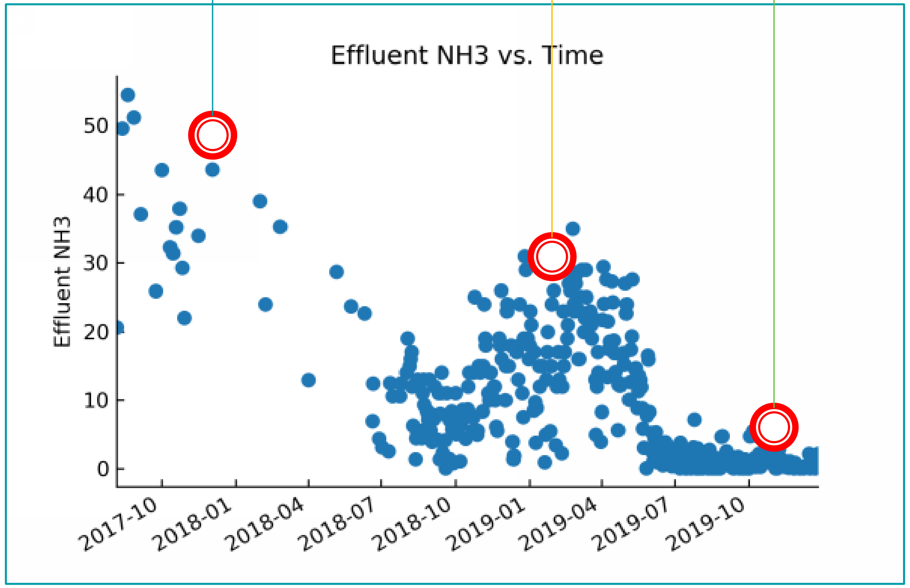
McQuarrie and Boltz (2010)

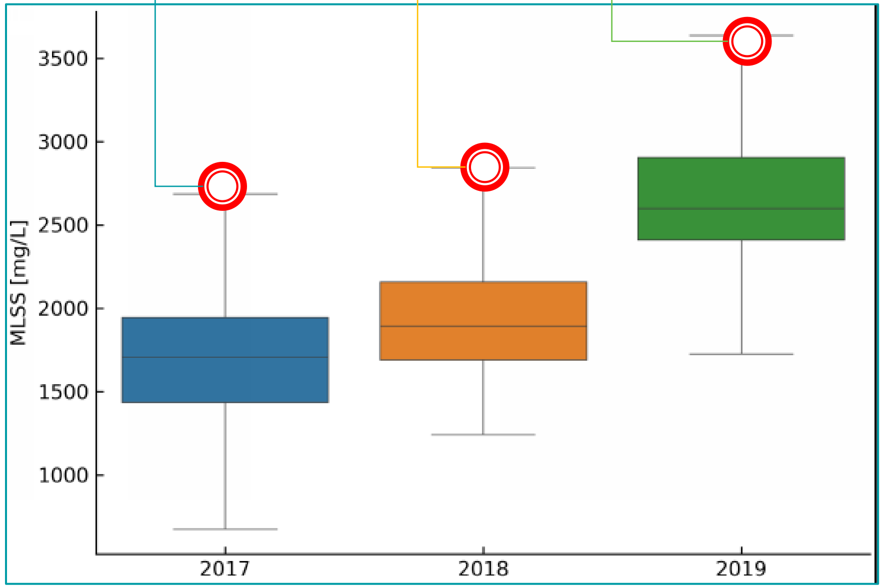
Biofilm impacts nitrification safety factor for operation

Bulk liquid SRT = 1 to 2 days
Safety factor = 0

Bulk liquid SRT = 3 to 5 days
Safety factor = 1.5

Bulk liquid SRT = 6 to 8 days
Safety factor = 1.8



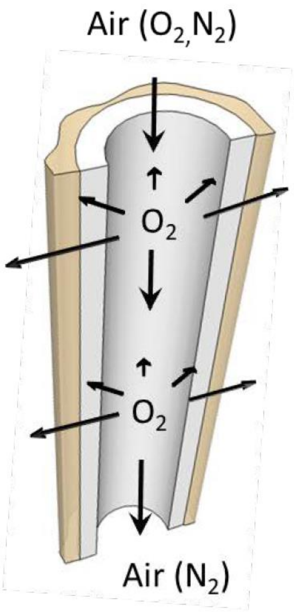


Membrane aerated biofilm reactors (MABR) for intensification

Oliver Schraa, inCTRL Solutions

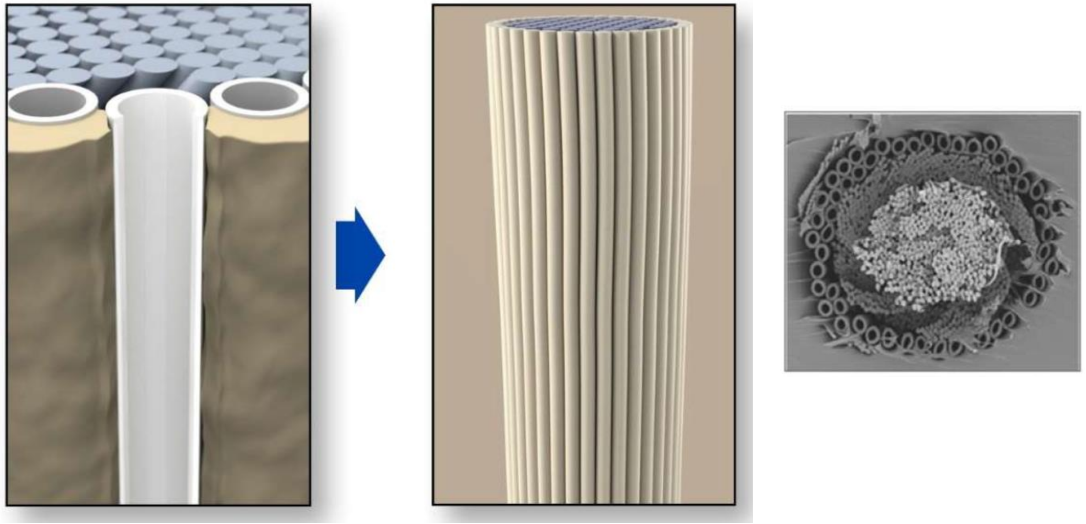
Membrane Aerated Biofilm Reactors (MABR)

- Basis of Technology:
  - Oxygen permeable, polymeric membranes used for oxygen transfer and biofilm support



Shaw *et al*. (2020)

MABR: Available Membranes

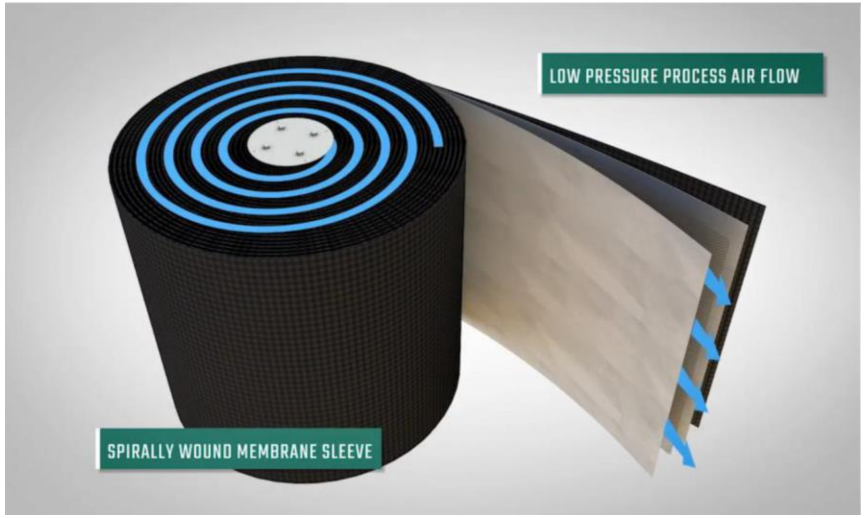


Suez: Hollow fibers around a cord

Peters (2019), Peters *et al*. (2017)

OxyMem: Hollow fibers

Syron and Heffernan (2017)



Fluence: Spiral Wound Sheets with Spacers

Nathan *et al*. (2020)

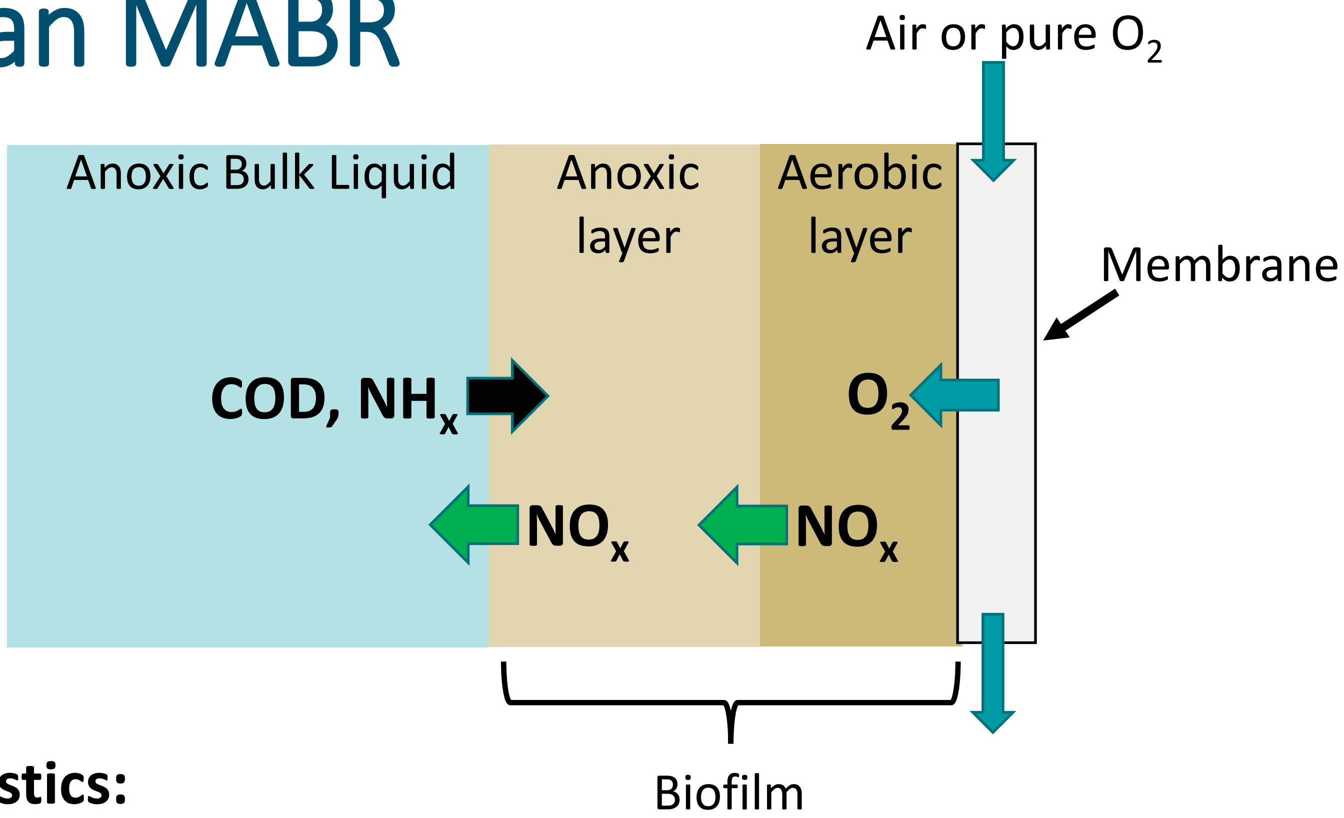
MABR: Aeration Efficiency

- Bubble-free aeration with high O_2 transfer efficiency
- 3 to 4 times more efficient than fine bubble aeration
- Lower discharge pressure for blowers

Aerator Type	Standard Aeration Efficiency (kg O_2/kWh)[1,2]	Aeration Efficiency (kg O_2/kWh)[1,3]
Surface Aeration	0.9 to 2.1	0.4 to 1.5
Coarse-Bubble	0.6 to 1.5	0.3 to 0.9
Turbines or jets	1.2 to 1.8	0.4 to 0.8
Fine-Bubble	3.6 to 4.8	0.7 to 2.6
MABR	Up to 14	Greater than 6

[1]Stenstrom and Rosso (2010), [2]Heffernan *et al*. (2019), [3]Peters (2019)

Biofilm in an MABR



Characteristics:

- Counter-diffusion
- Nitrification occurs in the inner layers; Denitrification occurs in the outer layers
- Performance drops as biofilm becomes too thick; biofilm management is important

MABR: Nitrogen Removal

- Supports total nitrogen removal
  - Nitrification in the inner part of biofilm
  - Denitrification in the outer part of biofilm and in bulk liquid
- All nitrate produced in biofilm so internal recycle not needed
  - Less pumping requirements

Mixing and Biofilm Management

- Biofilm thickness management is critical as benefits of MABR reduced if biofilm becomes too thick
- Suez and OxyMem use waste air (from membranes) for mixing and scouring
- Fluence uses cyclic application of diffused air for mixing and scouring

MABR: Ideal for Upgrading Existing Plants

- Drop-in membranes allow intensification of existing plants

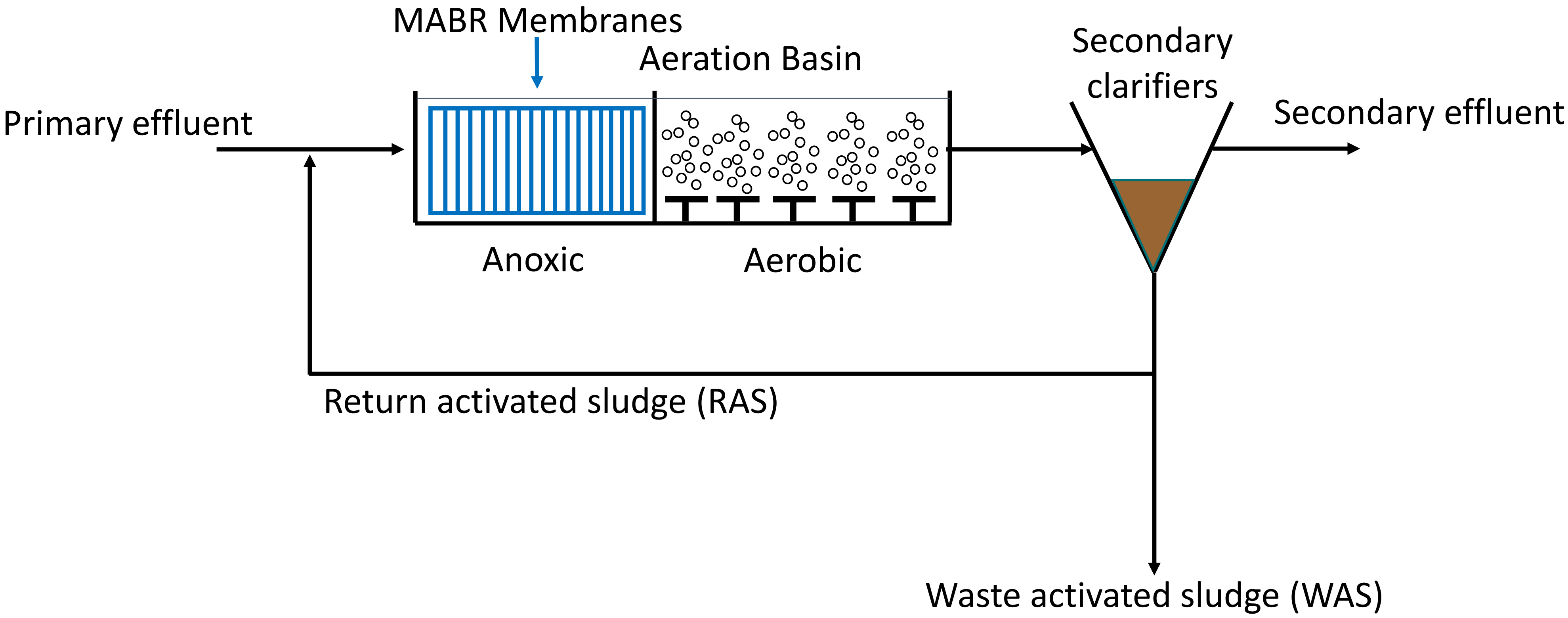
Constantine *et al*. (2020)

Manzano (2020)

Nathan *et al*. (2020)

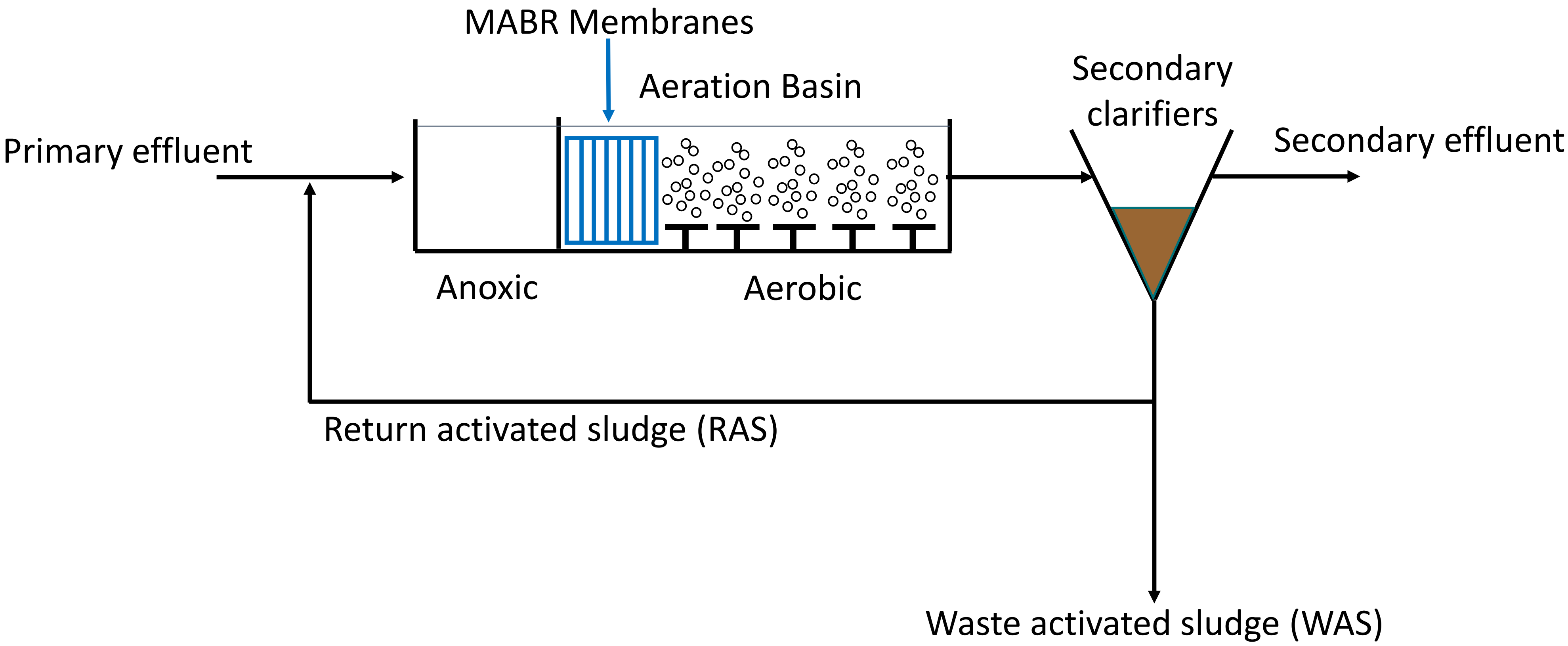
MABR: Placement of Membranes

- Typical Membrane Placement in Anoxic Zone:



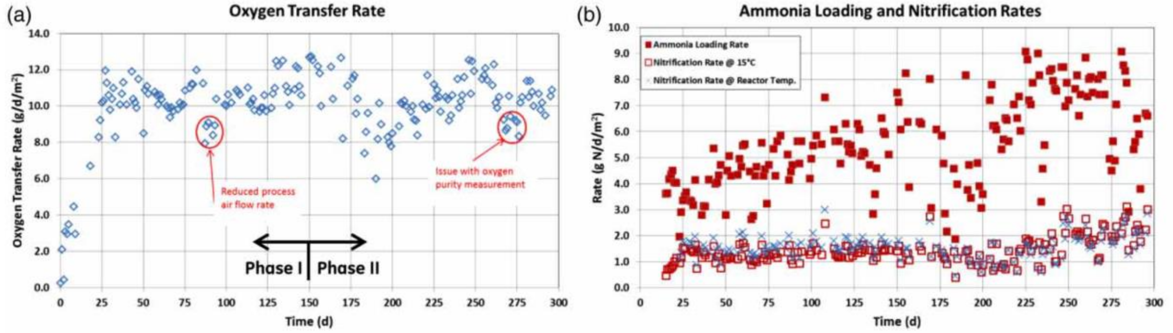
MABR: Placement of Membranes

- Typical Membrane Placement in Aerobic Zone:



Full-Scale Results

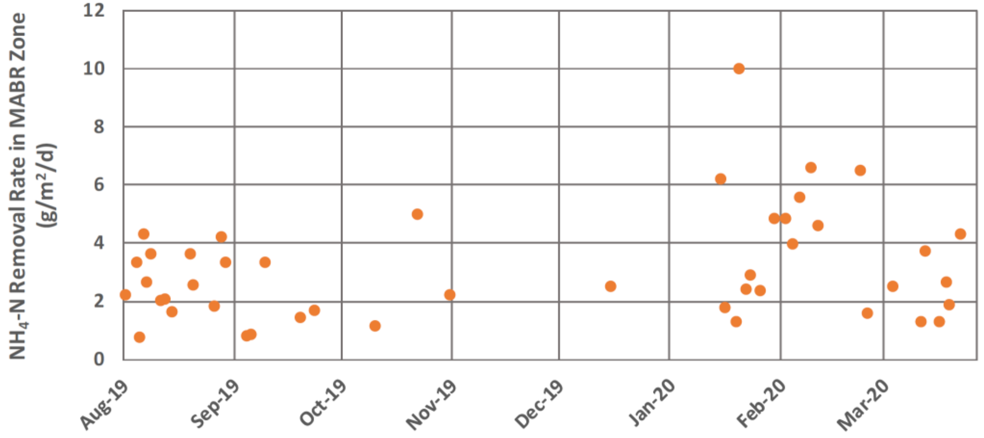
Suez: O'Brien Water Reclamation Plant (OWRP), Chicago MWRD



Peters *et al*. (2017)

- OTR varied between 10 and 12 g/m²/d
- Nitrification rate ranged between 1 and 3 g N/m²/d

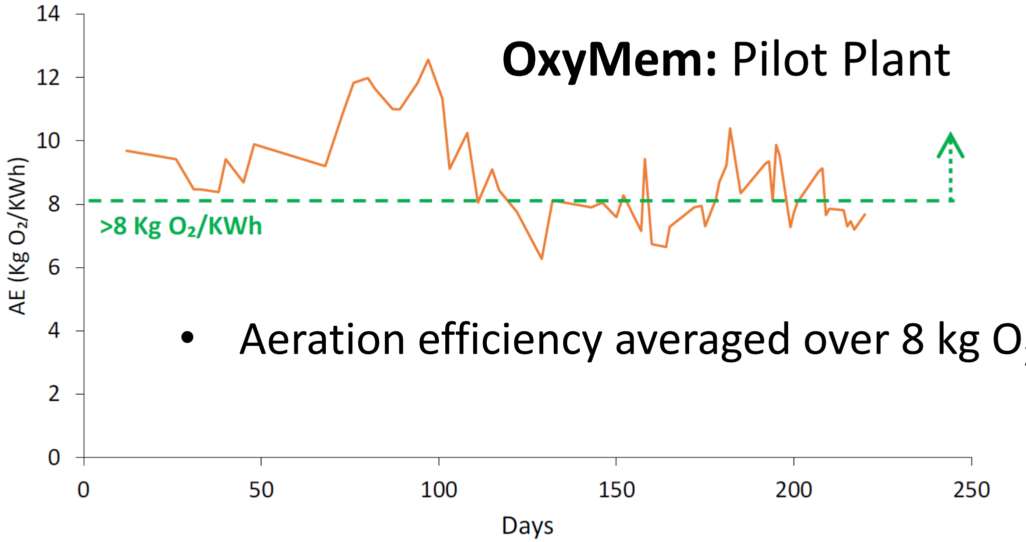
Fluence: Mayan Zvi Wastewater Treatment Plant, Israel



Nitrification rate ranged from 1.3 to 5.5 g/m²/day, with the average being 3.1 g/m²/d.

Nathan *et al*. (2020)

OxyMem: Pilot Plant



- Aeration efficiency averaged over 8 kg O_2/kWh

Koch *et al*. (2019)

MABR: Key Optimization Considerations

- Very high O_2 transfer efficiency leads to low operating cost
- With drop-in membranes can add or enhance nitrogen and phosphorus removal
- Can achieve nitrogen removal at low suspended growth SRT
- Internal recycle usually not required which reduces pumping costs

Scenarios Where the MABR Has the Most Impact

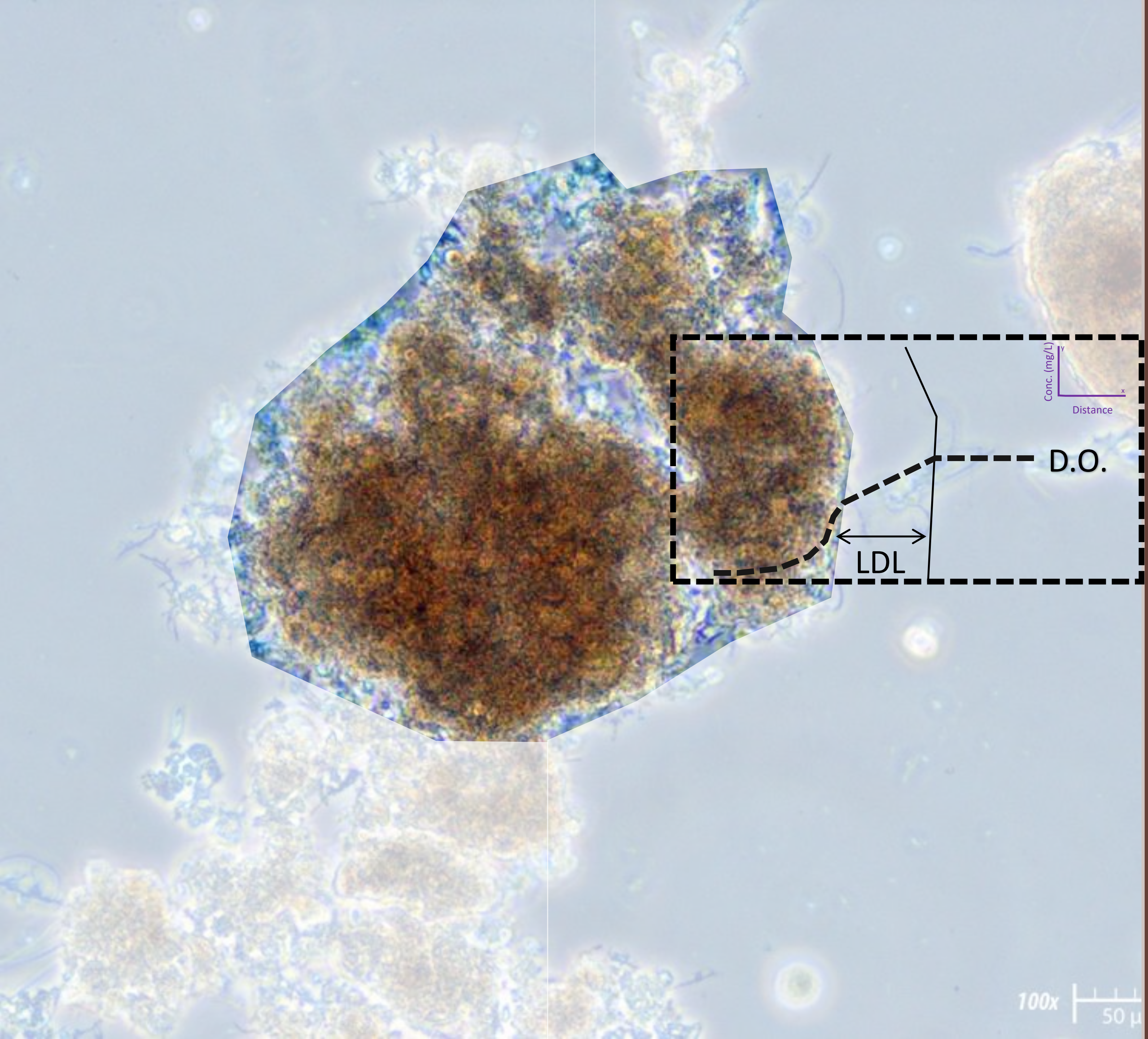
- The MABR has the greatest impact at water resource recovery facilities that would like to achieve one or more of the following goals:
  - Reduce aeration energy costs or move towards energy neutrality
  - Add nitrification capacity within an existing footprint
  - Add total nitrogen removal capacity within an existing footprint
  - Meet more stringent effluent nitrogen and phosphorus limits within an existing footprint

MABR: Other Considerations

- Fine screening of influent required (1 to 3 mm) and may affect plant hydraulics
- Retrofits of existing aeration basins may require replacement of reactor internals in area occupied by MABR
- Separate blower may be required for MABR
- Biofilm thickness management with air scouring is required (included with membrane cassette/module)
- Membranes will need to be replaced periodically

Mobile biofilm systems

Leon Downing, Black & Veatch



Can we make biofilms mobile, and gain the benefits without the infrastructure?

This has been documented in granules, but the selection of granules can be difficult with existing infrastructure

Concentration gradients create different growth pressures in the granule

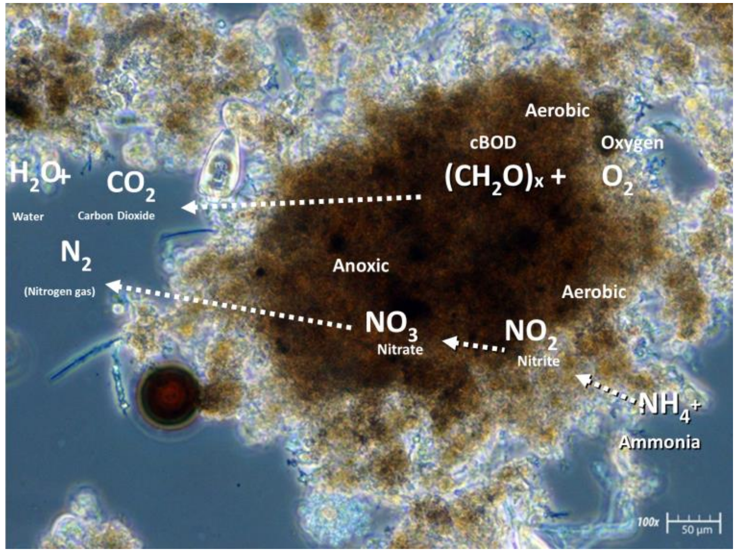
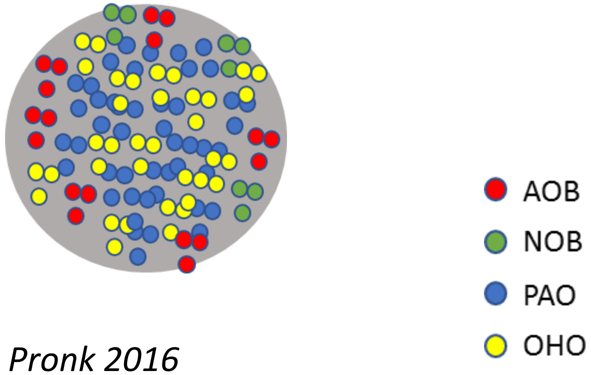


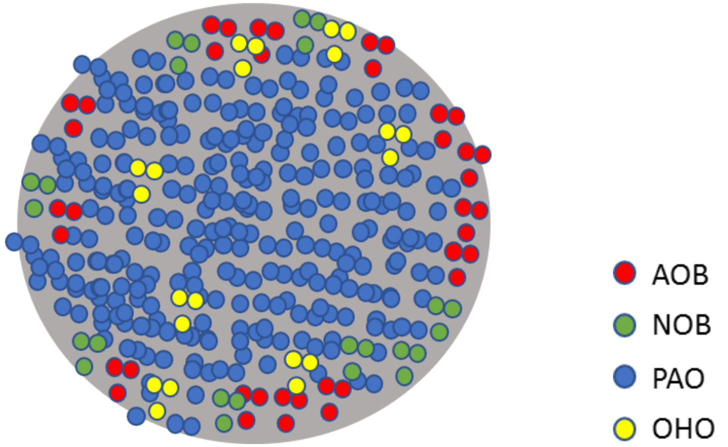
Image courtesy of Paul Klopping

Smaller granule: more heterogeneous



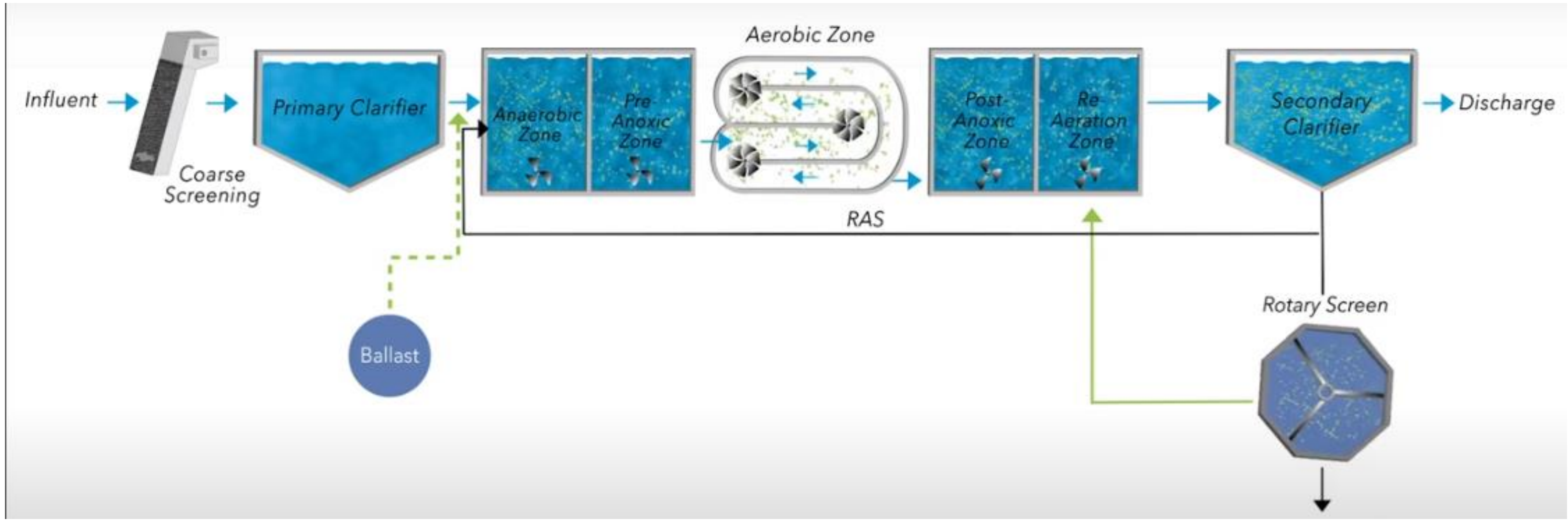
Adapted from Pronk 2016

Larger granule: more stratification



Adapted from Pronk 2016

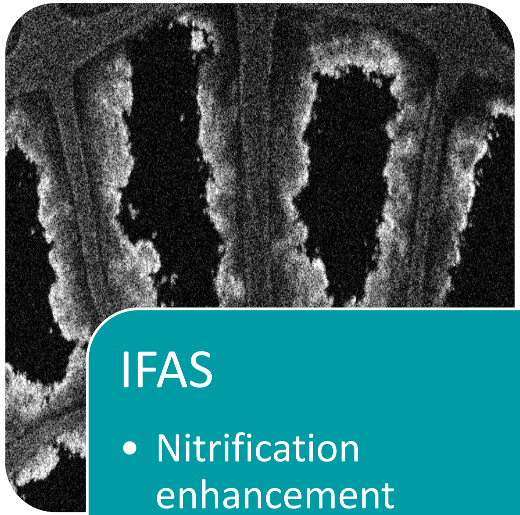
Addition of a "ballast" to support a biofilm that moves through the system



What are the advantages?

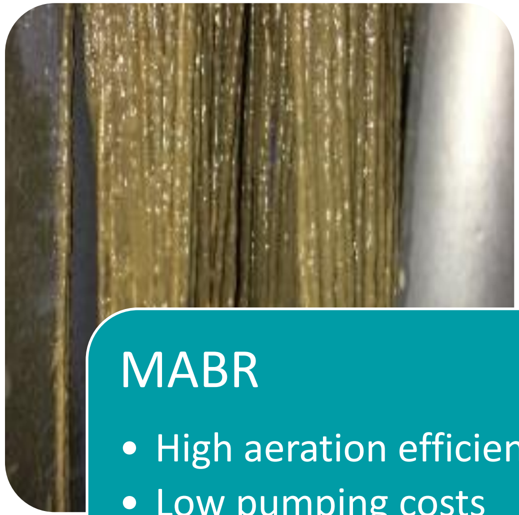
- “Relatively” low capital cost
- High retrofit potential
- Impacts
  - Increased settling rates
  - Higher biomass inventories
  - Mass transfer and biomass stratification

How are biofilms used for optimization?



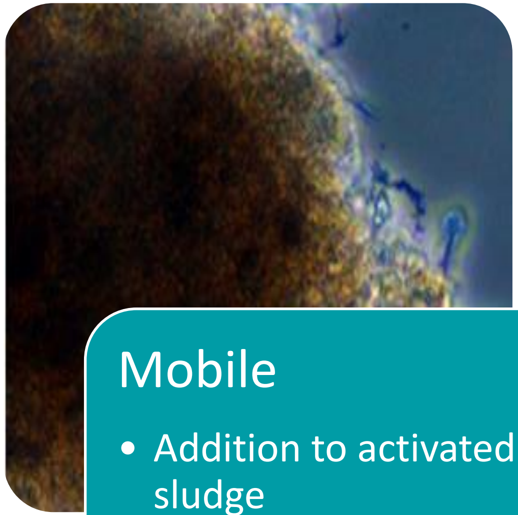
IFAS

- Nitrification enhancement
- Hybrid application



MABR

- High aeration efficiency
- Low pumping costs
- BNR solution
- Hybrid application



Mobile

- Addition to activated sludge
- No fixed media

"Live" Interaction Using Menti Meter

Go to:	menti.com
Enter Code:	9097 3512

Follow cues on your device screen

Remember to SUBMIT your answer

Some questions allow multiple entries

BREAK

Certificate of Completion (for CEU/PDH)

- WRF cannot give out the certifications, but we provide a certificate of completion
- Instructions
  - Email WRF (MSuazo@waterrf.org) to obtain a Certificate of Completion
  - Contact your state/province licensing agency to verify that CEUs/PDHs will be awarded for the webcast and any other materials are required. Certification contacts are listed on the Association of Boards of Certification Website (Search for **ABCCERT Certification Contacts**)
    - www.abccert.org/certification_contacts
- This information is COPIED INTO THE CHAT of this webinar

03:00

WRF 4973 Nutrient Optimization

Emerging Technologies – New Wave Bugs

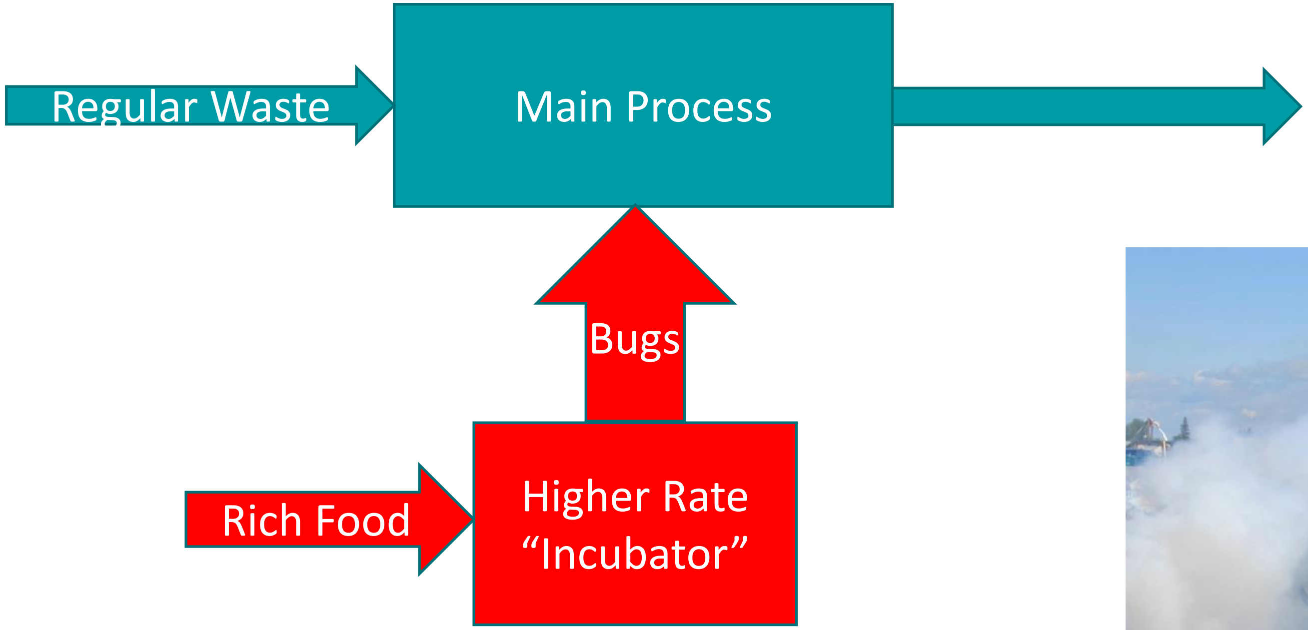
Andrew Shaw, Global Practice & Technology Leader

Black & Veatch

New Wave “bugs”

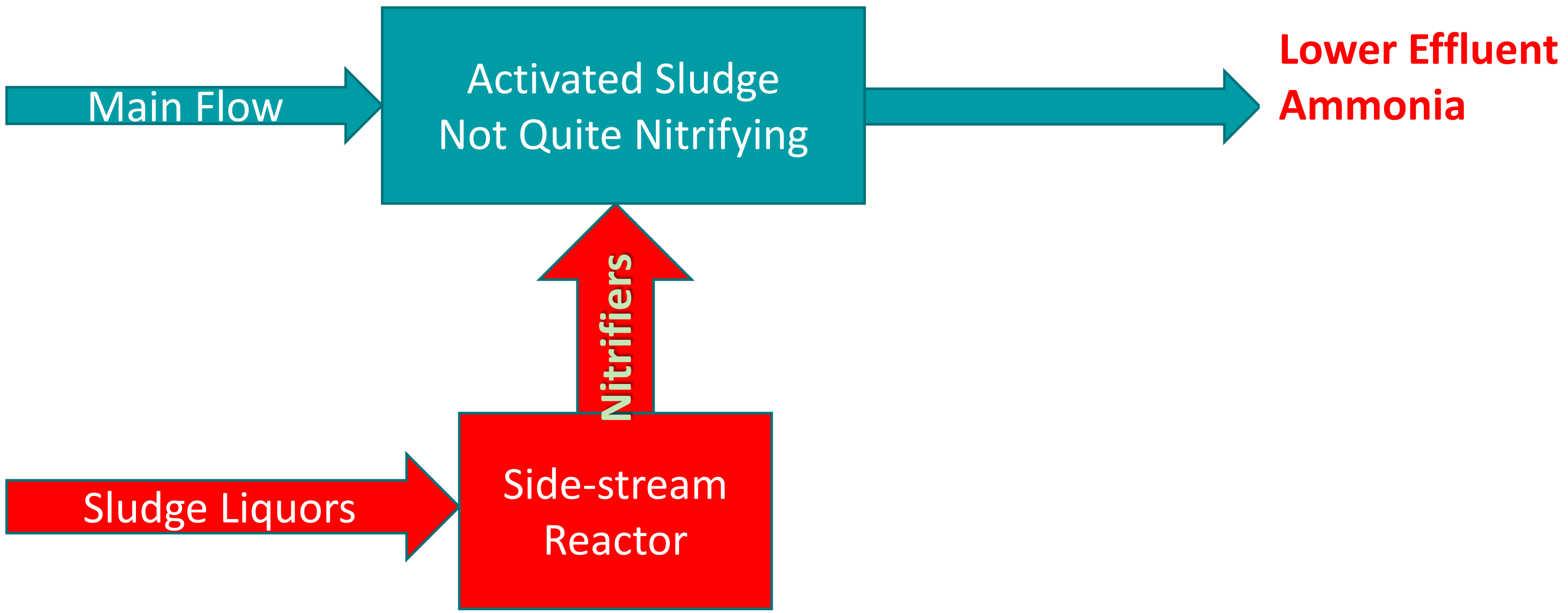
- Bioaugmentation
- Autotrophic Denitrification
  - SANI
  - ASR/OAR
- Immobilization - Microvi
- Algae
  - Clearas
  - RAB

Bioaugmentation

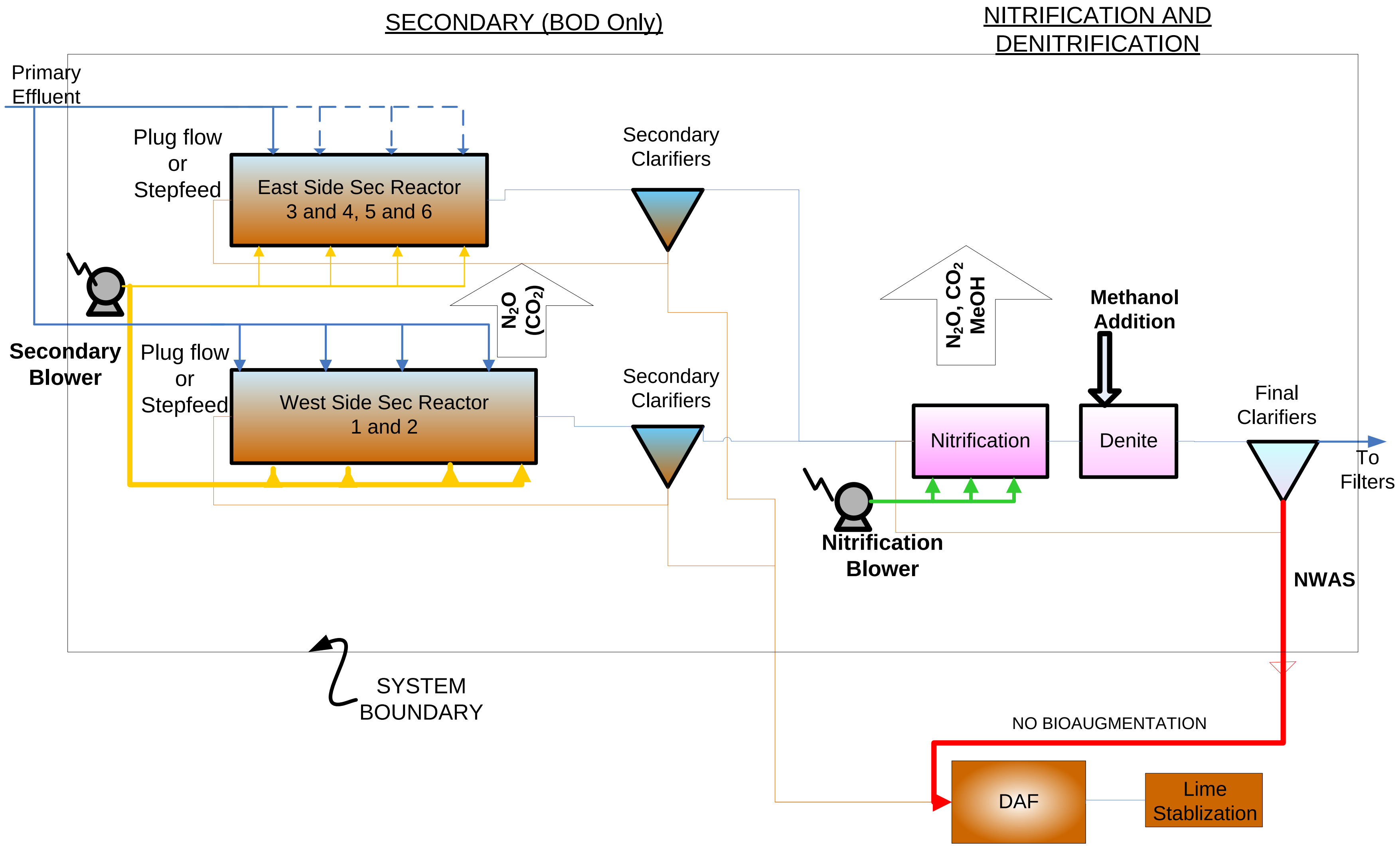


“Turbo Charging” your process!

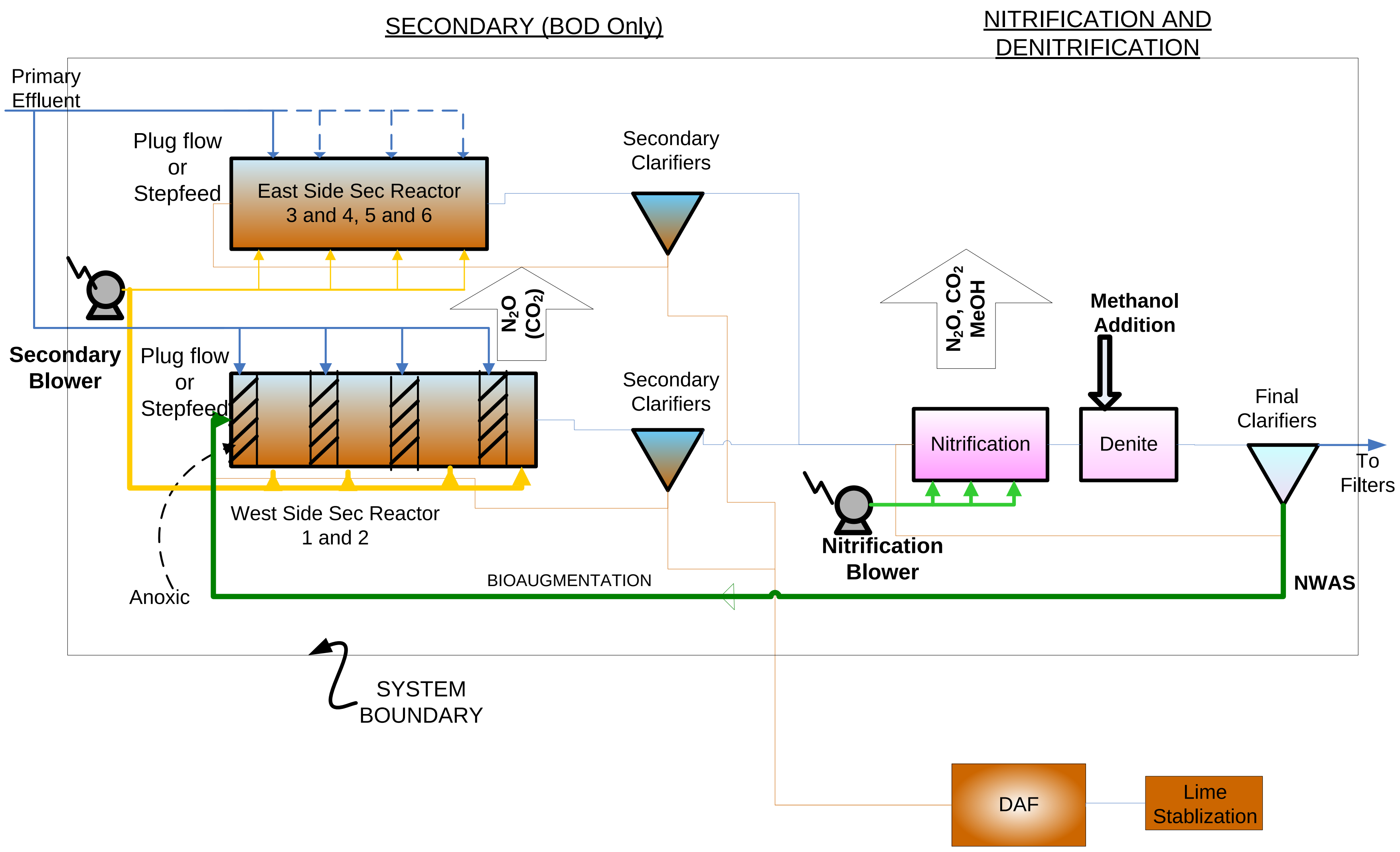
Bioaugmentation – Nitrification Example



Blue Plains AWTP



Bioaugmentation



Overall Effects

Secondary Effluent Nitrogen Reduced by 25%

Reduced Methanol Costs

Increased Aeration in "BOD" Stage

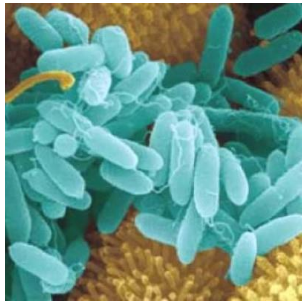
Autotrophic Denitrification

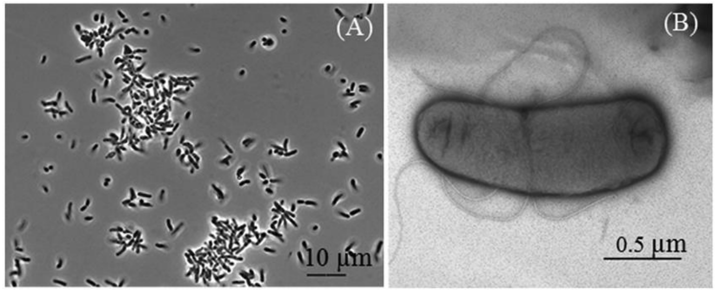
- Uses Chemo-lithotrophic organisms
  - Reduced Sulfur – Energy Source
  - Nitrate & Nitrite – Oxygen Source

$$S^{2-} + 0.4NO_3^- + 2.4H^+ \rightarrow S^o + 0.2N_2 + 1.2H_2O$$

$$S^{2-} + 1.6NO_3^- + 1.6H^+ \rightarrow SO_4^{2-} + 0.8N_2 + 0.8H_2O$$

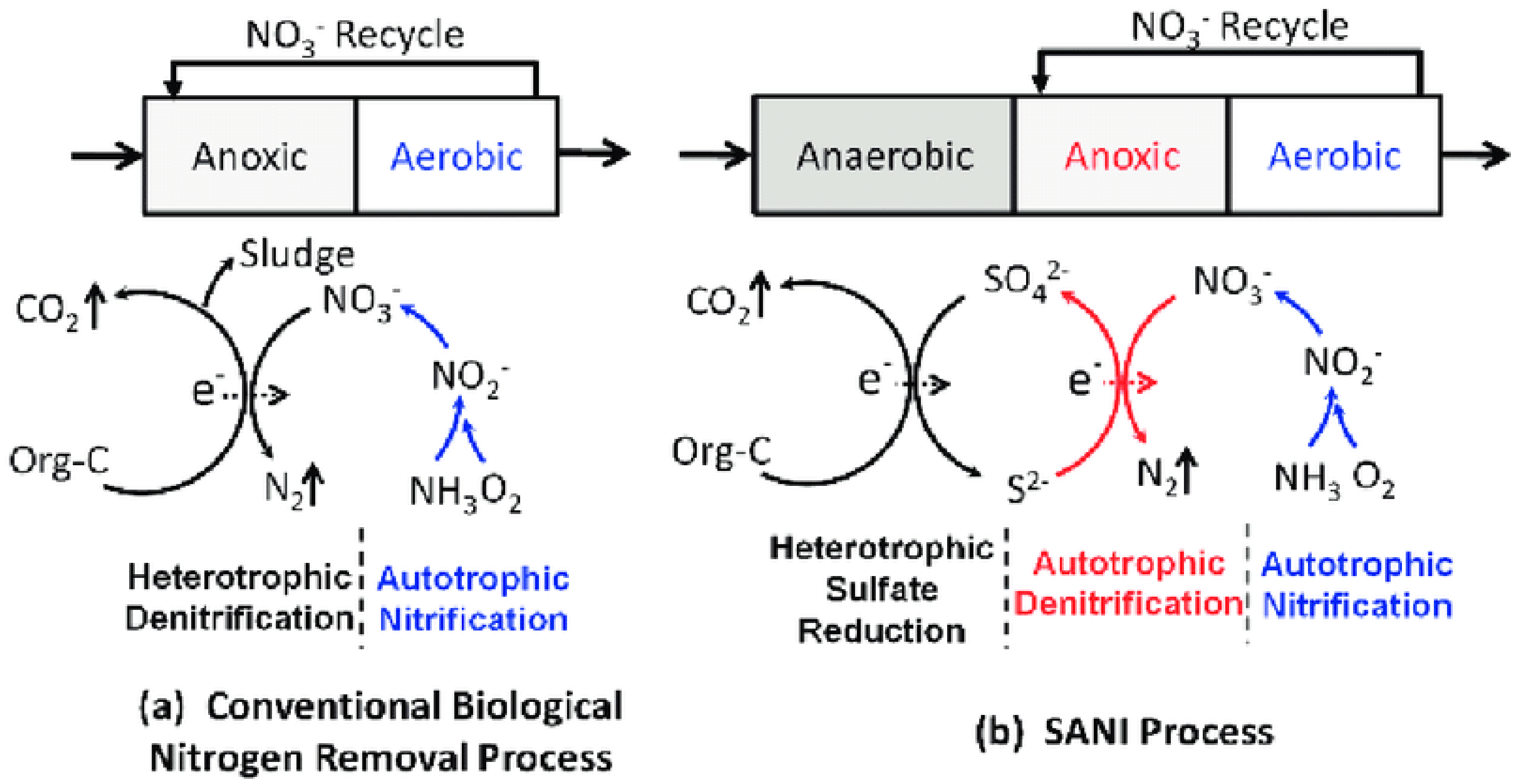
- Sulfur reducing organisms – anaerobic zone
- Sulfide oxidizing organisms – anoxic zone
- Organisms Responsible:
  - Thiobacillus
  - Shinella
  - Sulfurovum
  - Others



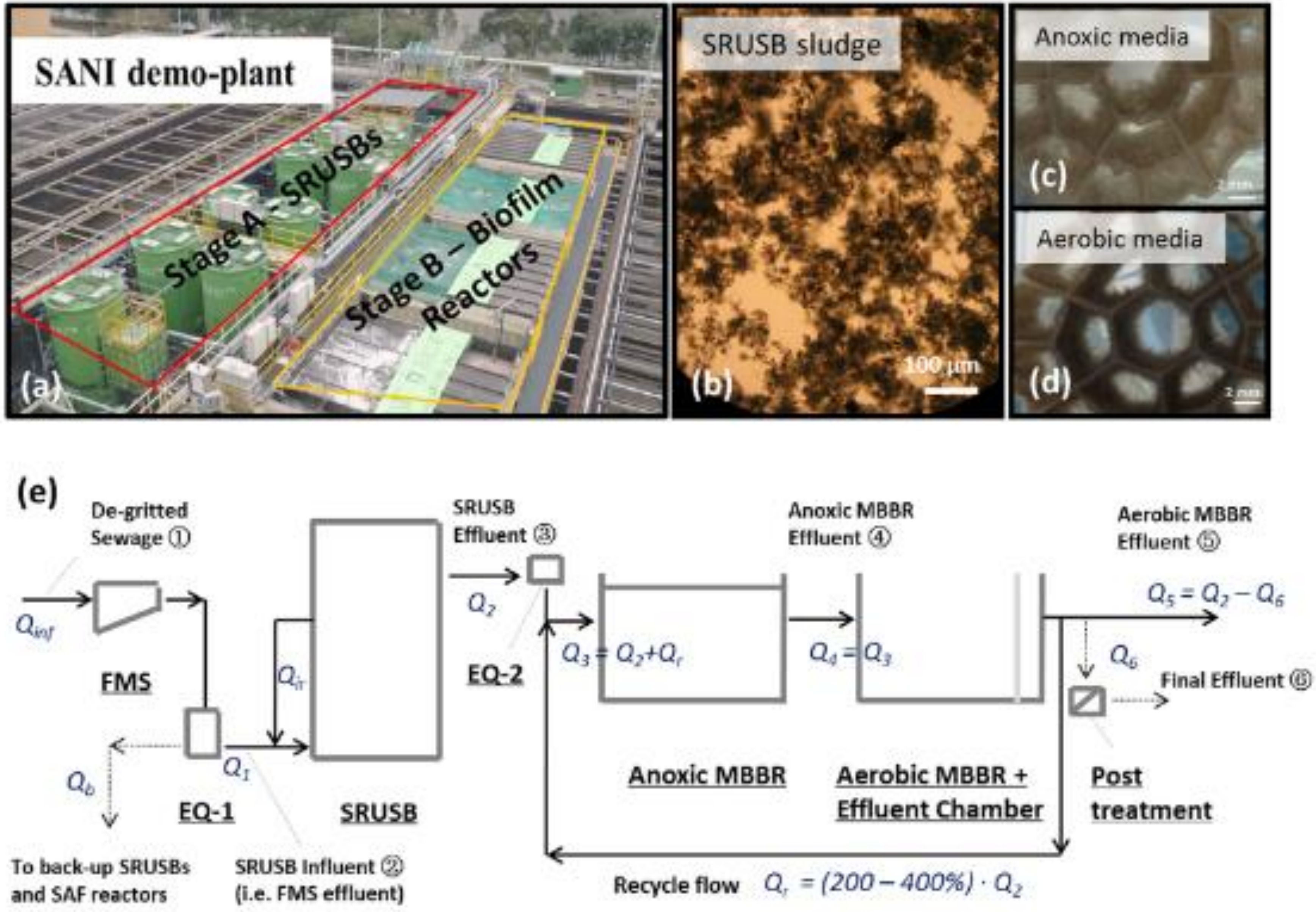


Autotrophic Denitrification Optimization

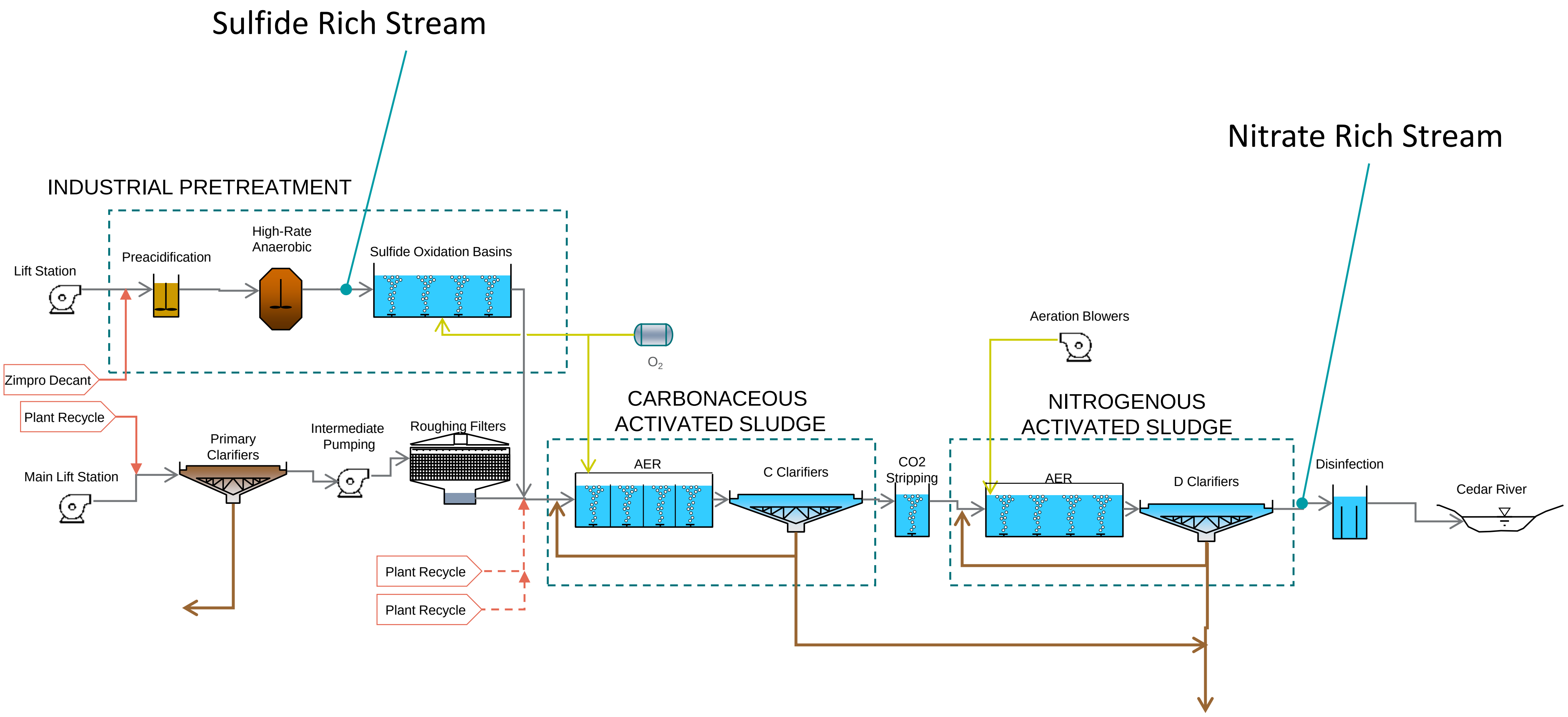
- Recycle Nitrate Rich Stream with Sulfide Rich Stream to unaerated Zone
- Replace oxygen with nitrate recycle stream in sulfide oxidization basins
- Low->neutral pH



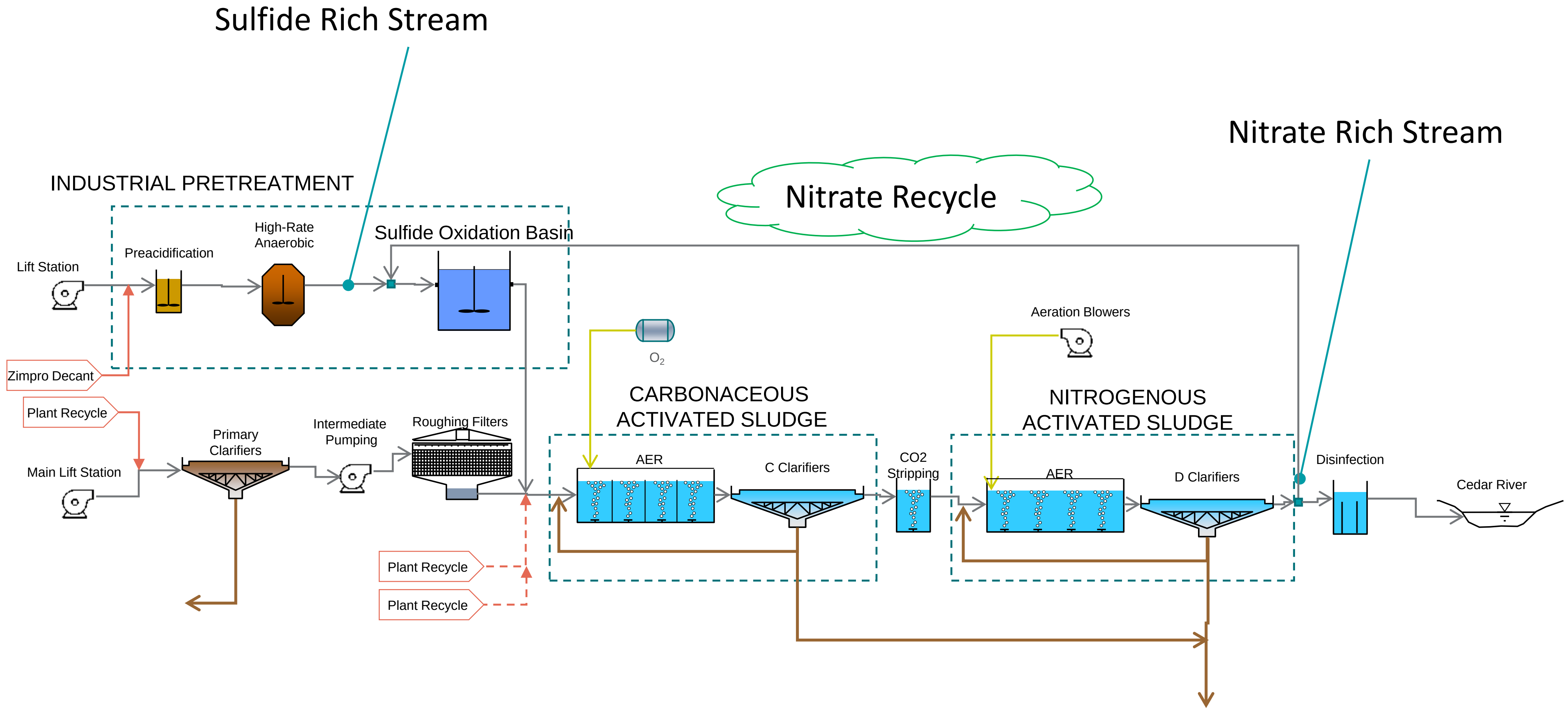
Hong Kong Demo



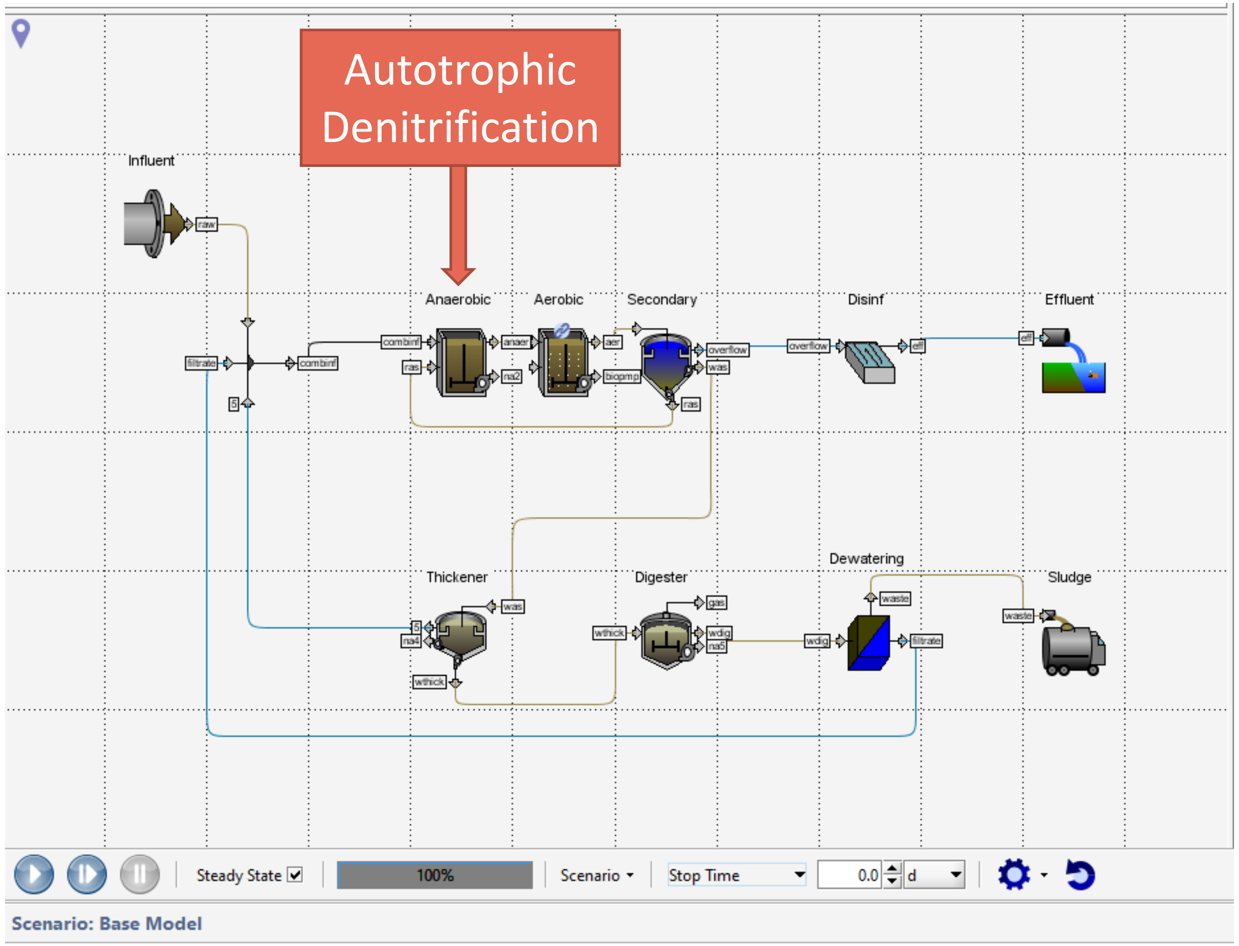
Example: WRRF with High Sulfide + High Nitrate Streams

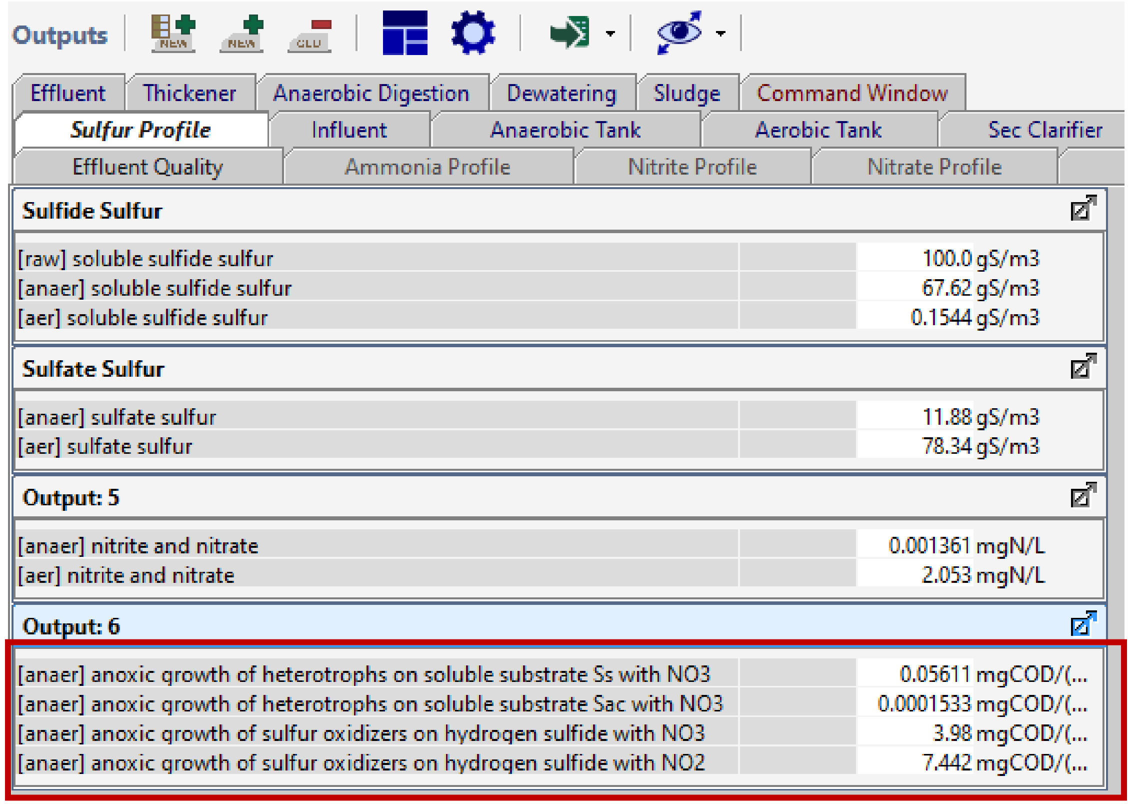


Example: WRRF using Possible Optimization with Autotrophic Denitrification

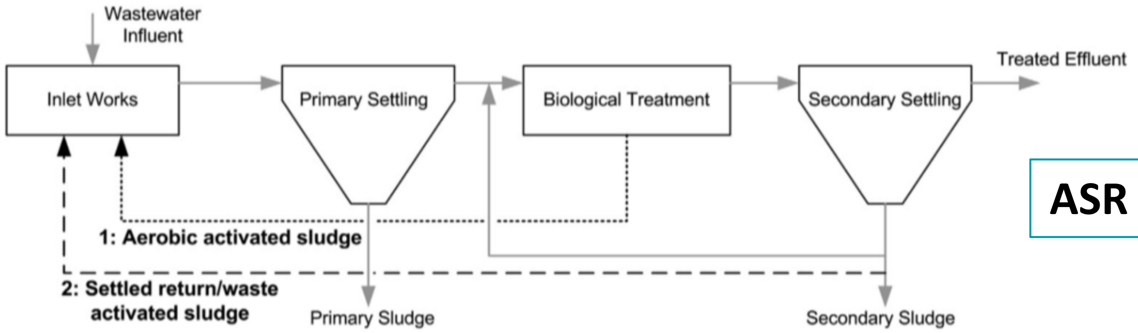


Simulators with Sulfur Models

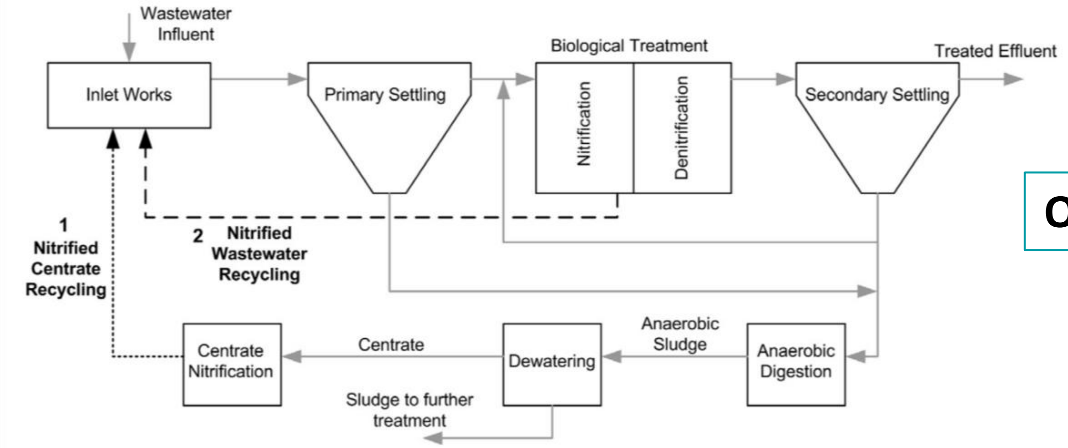




Activated Sludge Recycle (ASR) or Oxidized Ammonia Recycle (OAR) for Odor Control



ASR



OAR

Bioresource Technology 196 (2015) 685–693

Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/biortech

Review

Integral approaches to wastewater treatment plant upgrading for odor prevention: Activated Sludge and Oxidized Ammonium Recycling

José M. Estrada [a], N.J.R. Kraakman [b,c], R. Lebrero [a], R. Muñoz [a,*]

[a] Department of Chemical Engineering and Environmental Technology, University of Valladolid, Dr. Mergelina, 47011 Valladolid, Spain
[b] Department of Biotechnology, Delft University of Technology, Julianalaan 67, 2628 BC Delft, The Netherlands
[c] CH2M, Level 7, 9 Help Street, Chatswood, NSW 2067, Australia

HIGHLIGHTS

- Activated Sludge Recycling and Oxidized Ammonium Recycling significantly reduce odors.
- Both alternatives can be easily implemented with minimum investment costs.
- Both strategies provide significant savings in further odor abatement.
- Activated Sludge Recycling can be expected to be electron acceptor-limited.
- Oxidized Ammonium Recycling is expected to be limited by biological activity.

GRAPHICAL ABSTRACT

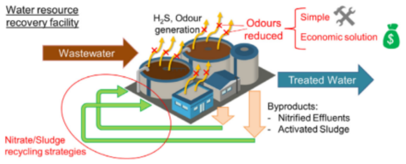
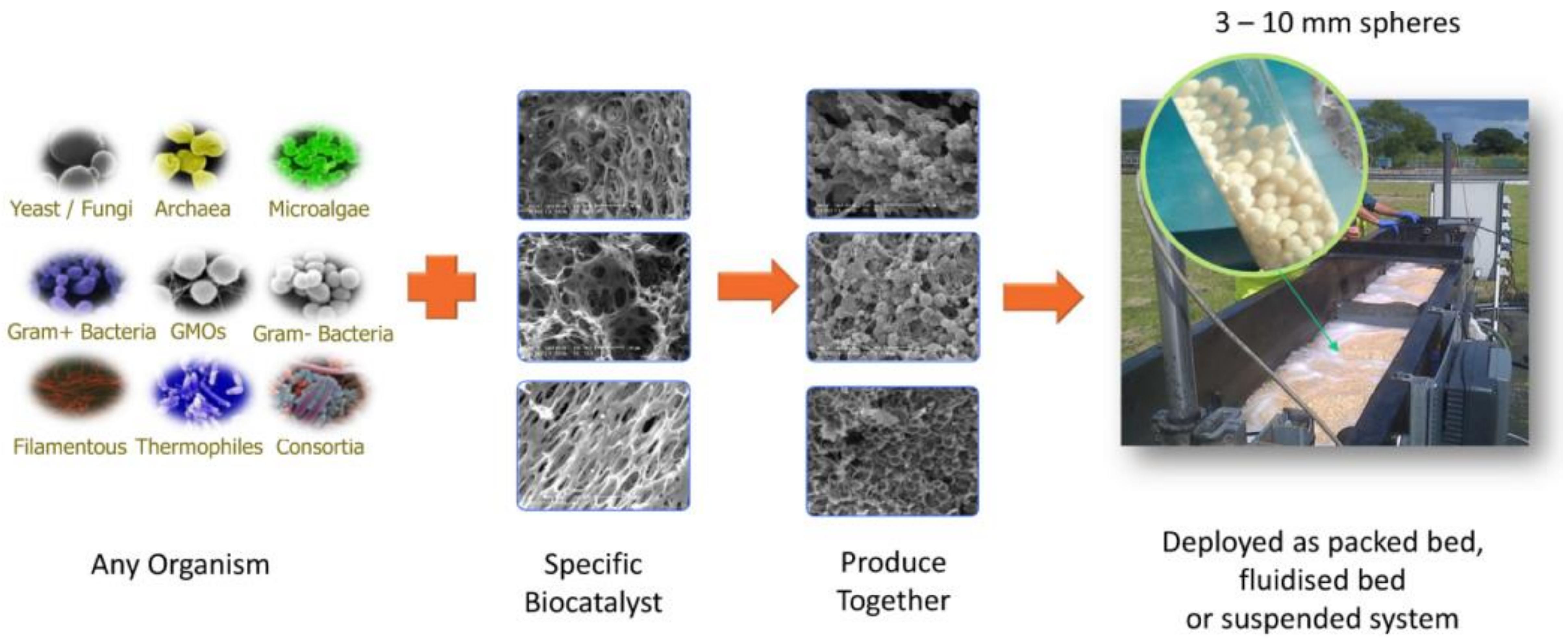


Table 2
Common odorants in WWTPs (Lebrero et al., 2013a; Zarra et al., 2008) and indigenous microorganisms typically present in activated sludge able to degrade them.

Malodorous compound	Microorganisms (species or class/order)	References
Sulfur compounds: hydrogen sulfide, dimethyl sulfide, trimethyl sulfide, methyl mercaptan	*Thiobacillus denitrificans* *Thiobacillus thioparus* *Pseudonocardia sulfidoxydans* *Acinetobacter* species Uncultured *Betaproteobacteria* (AB255098, EF467563)	Estrada et al. (2012c), Lebrero et al. (2013b), Ralebitso-Senior et al. (2012), Snaidr et al. (1997)
BTEX[1]	*Nitrospira defluvii* *Acinetobacter generi* *Burkholderia* species *Mycobacterium* species *Sphingomonas* species *Oceanibaculum* uncultured clone (FJ433554) Xanthomonadales	Estrada et al. (2012c), Lebrero et al. (2013a), Ralebitso-Senior et al. (2012), Snaidr et al. (1997)
Limonene	*Actinobacteria* phylum *Mycobacterium fortuitum*	Lebrero et al. (2013a), Ralebitso-Senior et al. (2012)
Ammonia	*Nitrospira* species *Nitrosomonas* species *Pseudoxanthomonas* species	Estrada et al. (2012c), Juretschko et al. (1998), Ralebitso-Senior et al. (2012)
VFA[2]	*Propionibacterium* sp. (AB540663)	Lebrero et al. (2013a)

[1] BTEX = Benzene, Toluene, Styrene and Xylene.
[2] VFA = Volatile Fatty Acids.

Immobilization – Microvi



Microvi

✓ **High Reaction Rates**
✓ **Small Footprint**

- **Secondary, Tertiary Nutrient Removal**

  Denitrovi™ –Denitrification

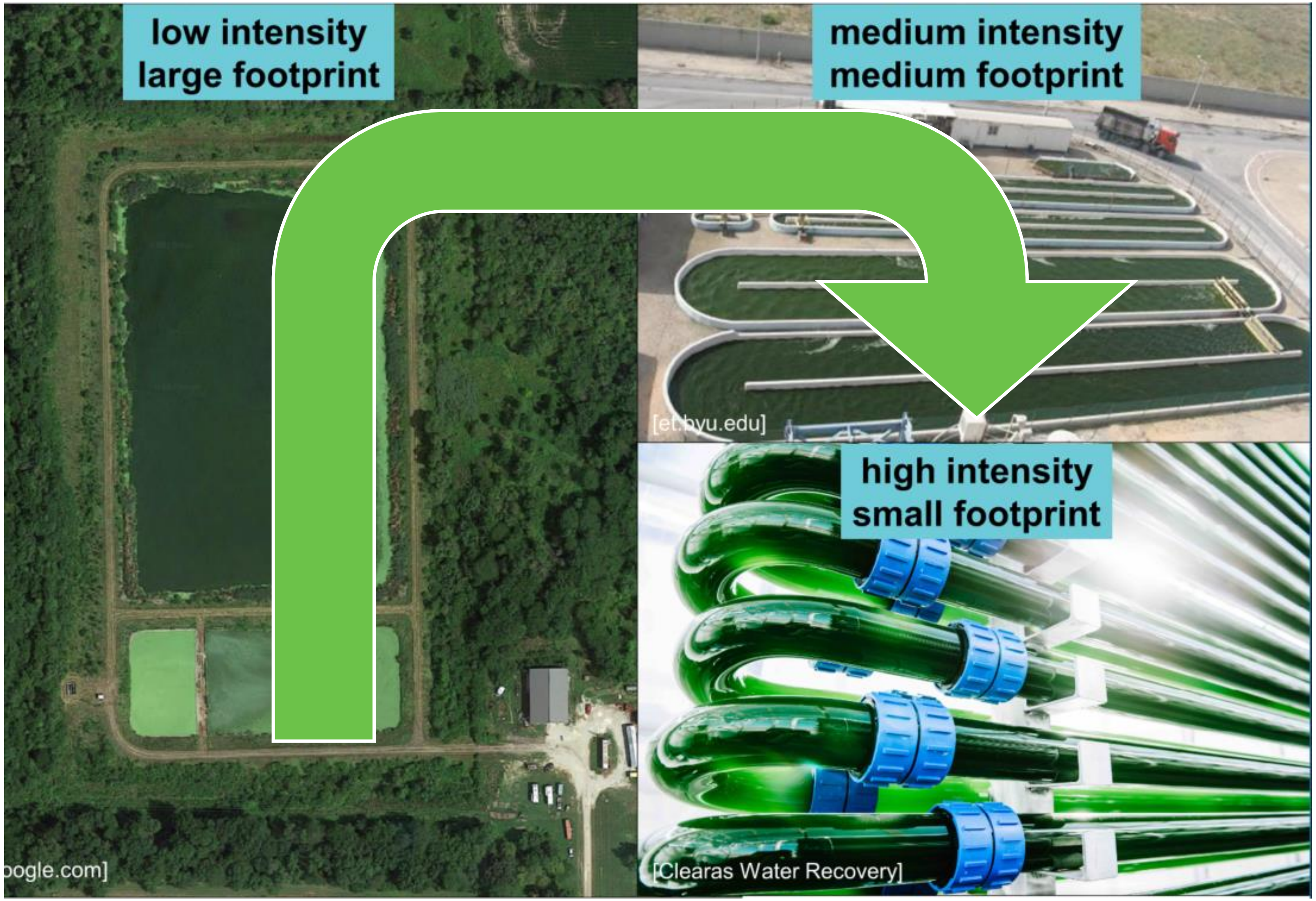
  Aerovi™ –Nitrification,

  Provi™ –Tertiary Nitrification and P removal

Oro Loma, CA (Pilot)

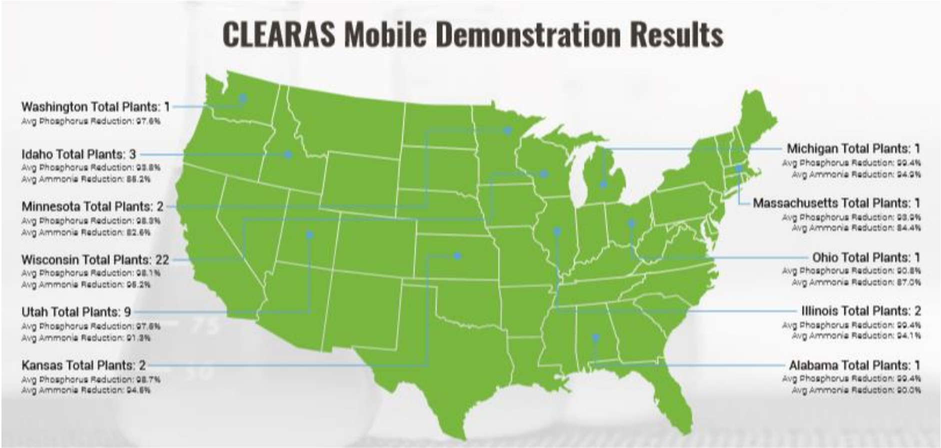
- **Side-stream TN Removal**

  Coupled with ANNAMOX


low intensity
large footprint
medium intensity
medium footprint
high intensity
small footprint
[et.byu.edu]
oogle.com]
[Clearas Water Recovery]

Algae

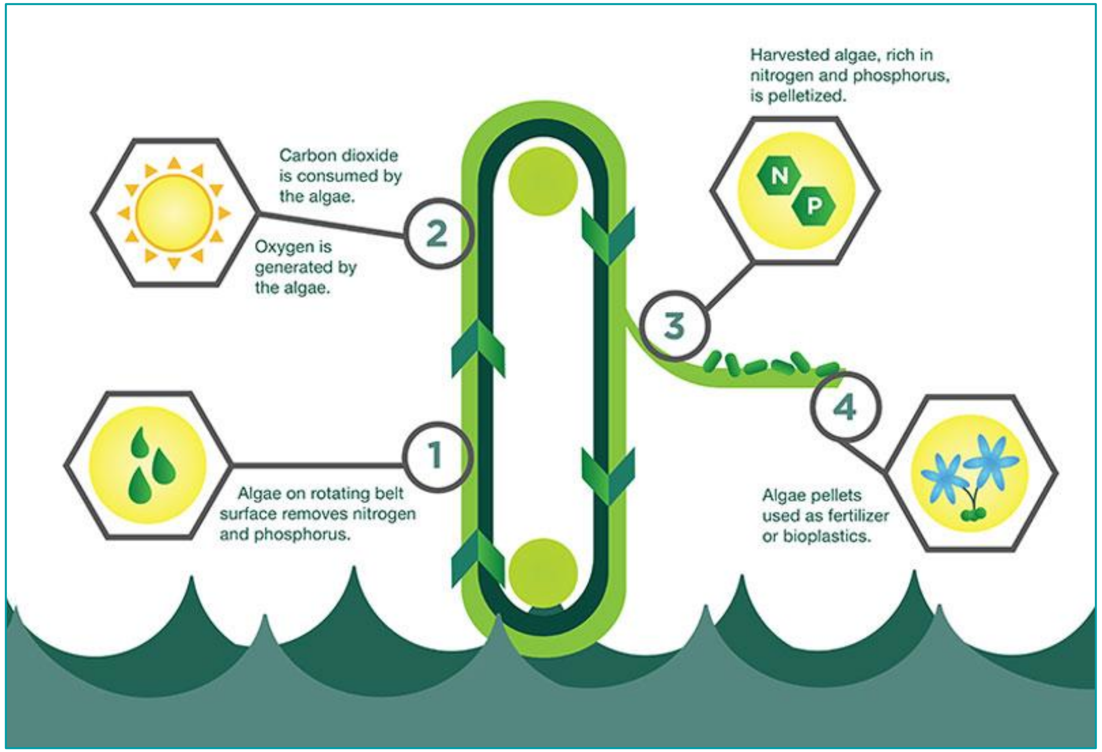
Clearas – Advanced Biological Nutrient Recovery (ABNR™)

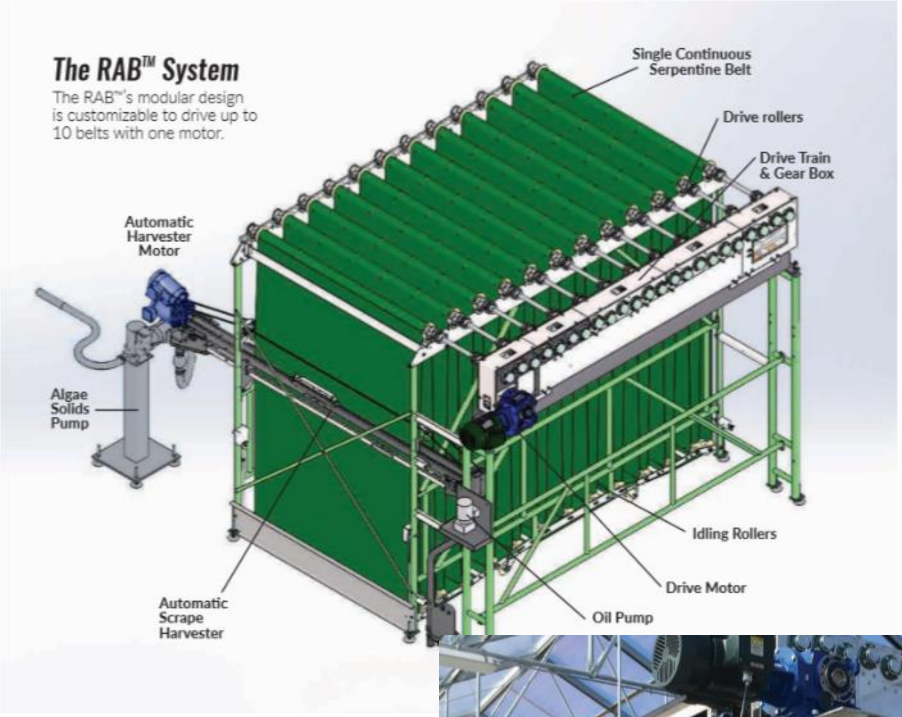


https://youtu.be/Saw9LdCEljk

https://www.clearaswater.com/

Gross-Wen Technologies (GWT)
– Revolving Algal Biofilm (RAB™)





https://youtu.be/cANXskEKZJQ

https://algae.com/

"Live" Interaction Using Menti Meter

Go to:	menti.com
Enter Code:	9097 3512

Follow cues on your device screen

Remember to SUBMIT your answer

Some questions allow multiple entries

WRF 4973 Nutrient Optimization

Clarifier Improvements

Mario Benisch, HDR Inc.

SCL ≠ SCL

SCL ≠ SCL

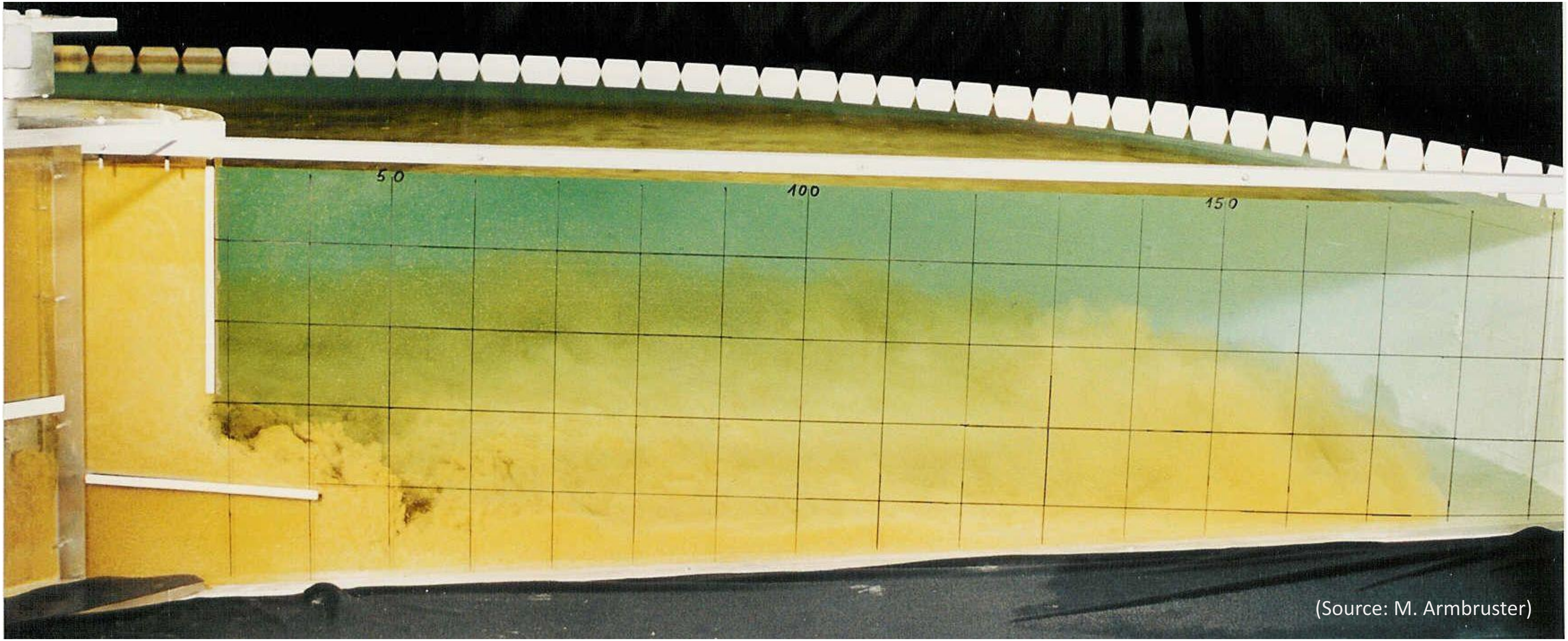
What's in BNR Effluent Solids

• TSS	100%	15 mg/L
• BOD	33%	5 mg/L
• P	3 – 5%	**0.5 mg/L – 0.7 mg/L**
• N	6 – 8%	**0.9 mg/L – 1.2 mg/L**

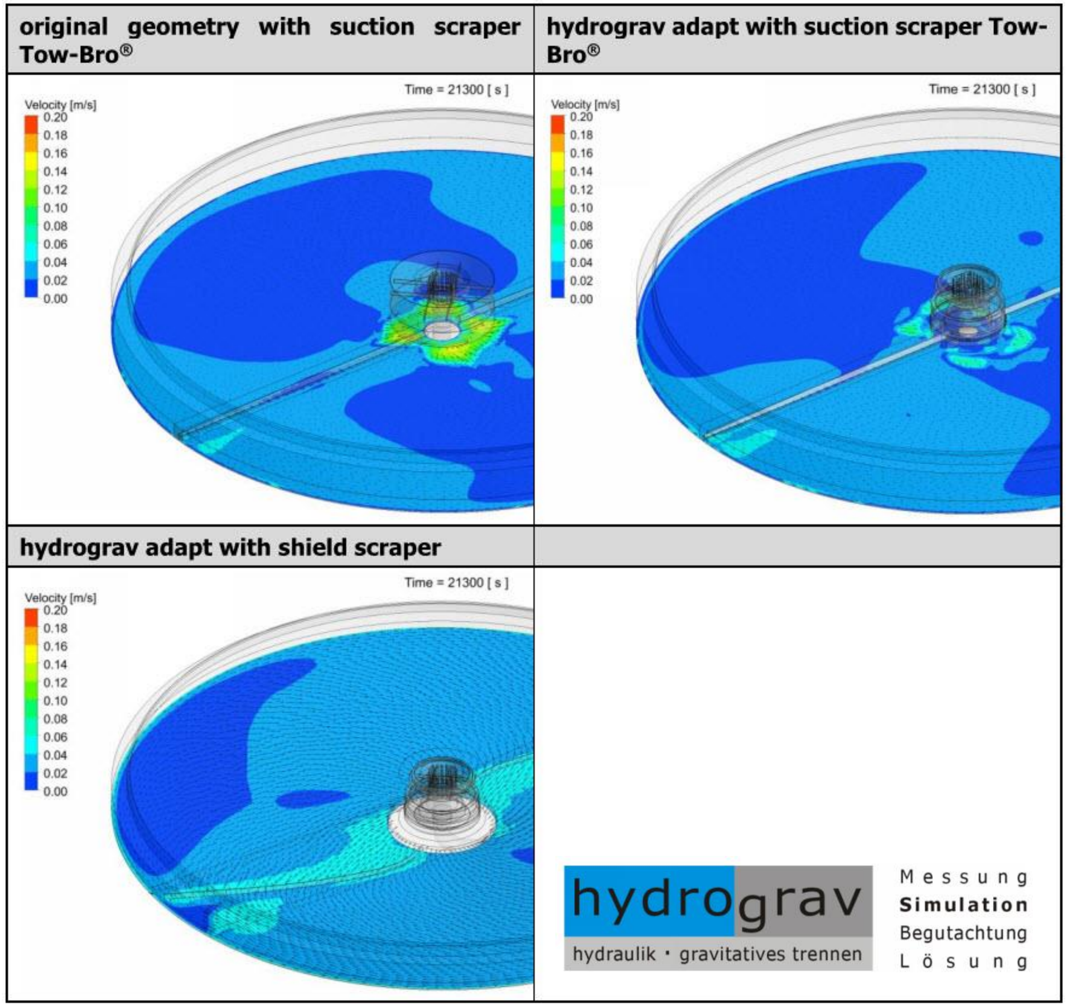
What drives Clarifier Performance

- SVI
- Loading Rate
- RAS Rate
- Clarifier Hydraulics
- Clarifier SWD
- Dissolved gases/micro bubbles
- Inlet design/energy dissipation

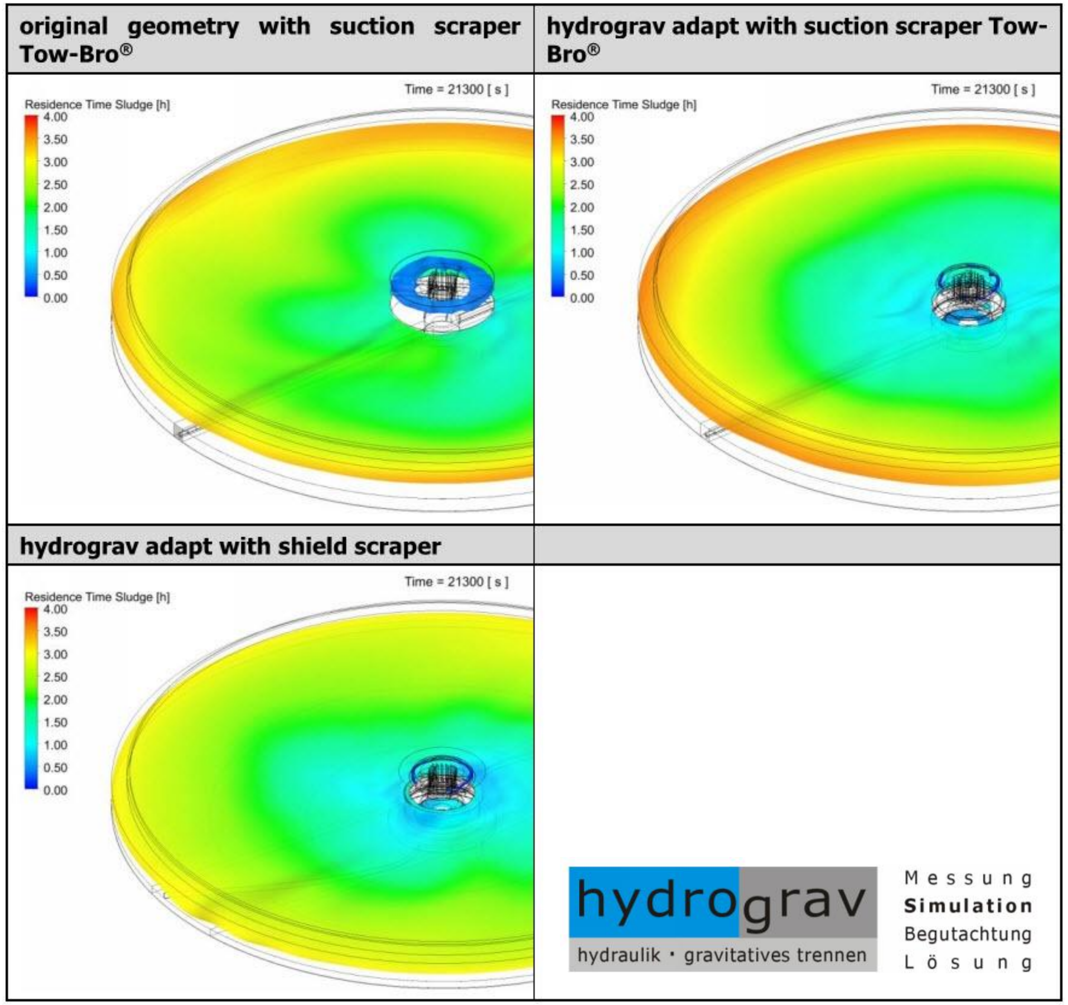
Inside a Secondary Clarifier



Inside a Secondary Clarifier



Velocities



HRT

Elements of Modern Clarifiers

Larger Centerwell

Suction Scraper

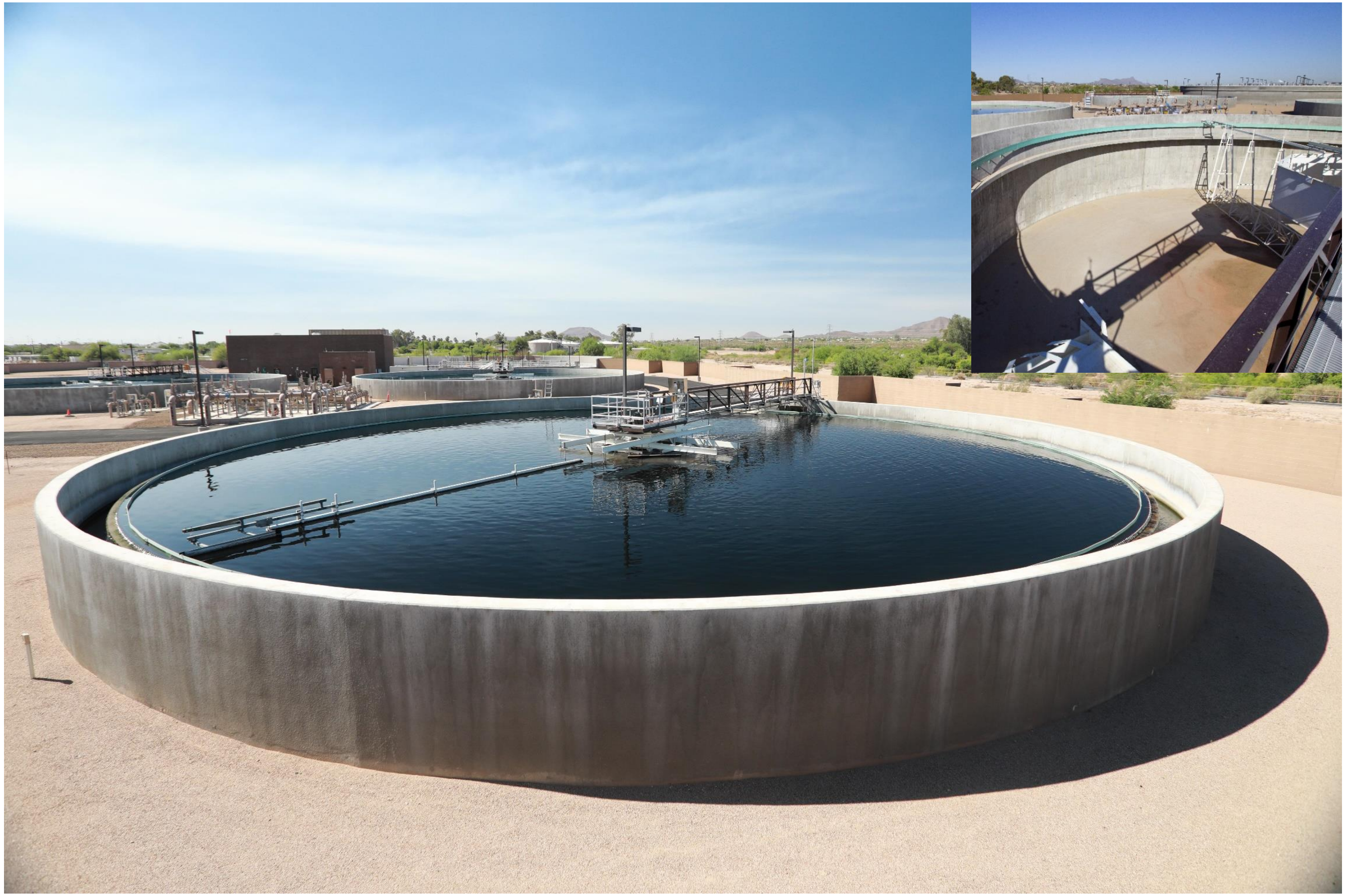
Deep

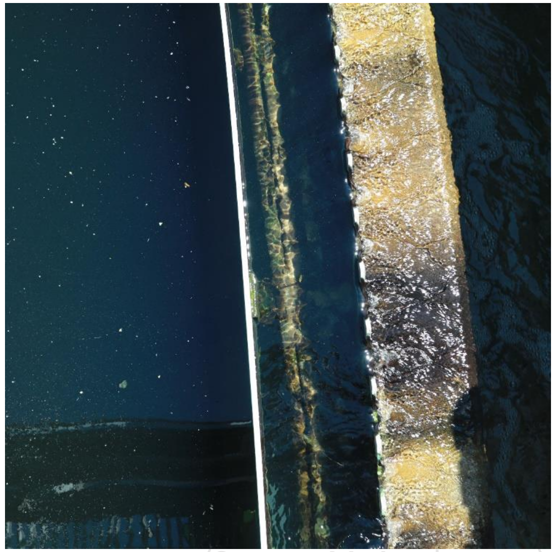
Baffles

Blanket sensors

It’s the Inlet ?!

It’s the Inlet ?!

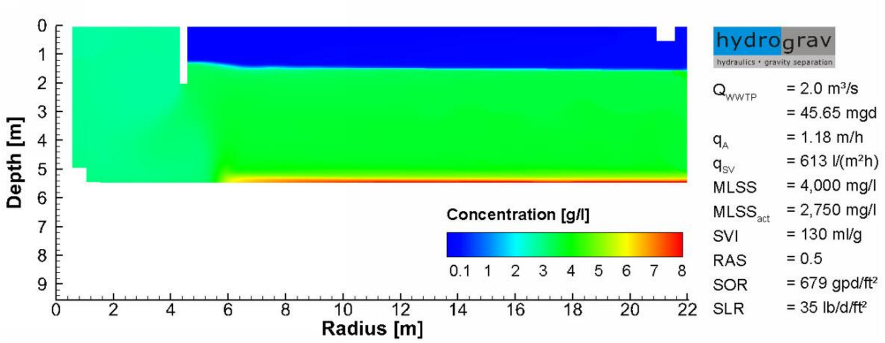


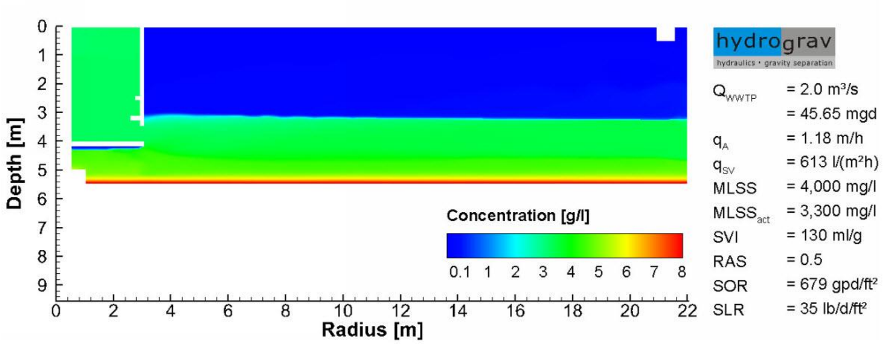


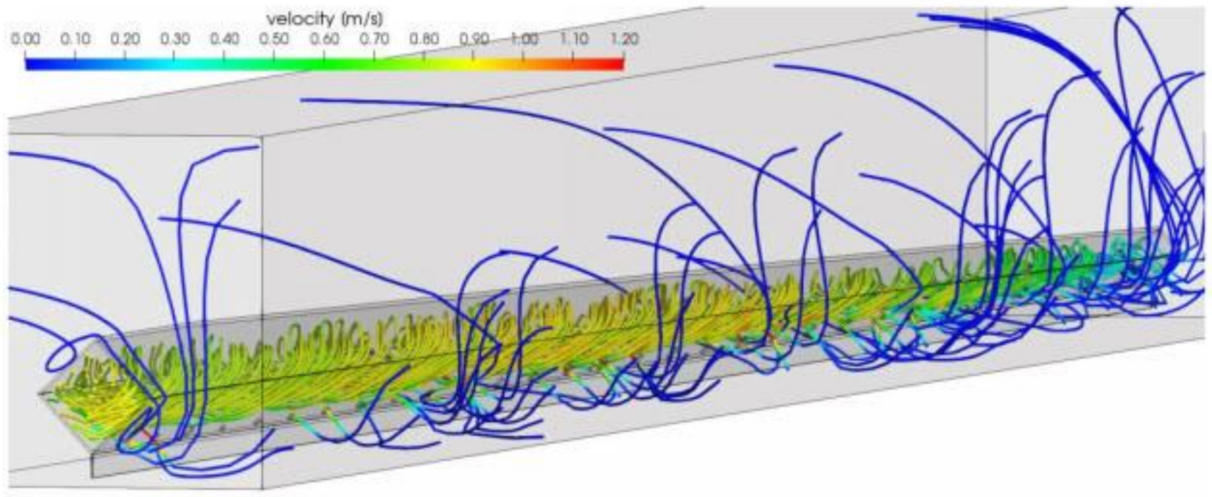
(Source: M. Armbruster)

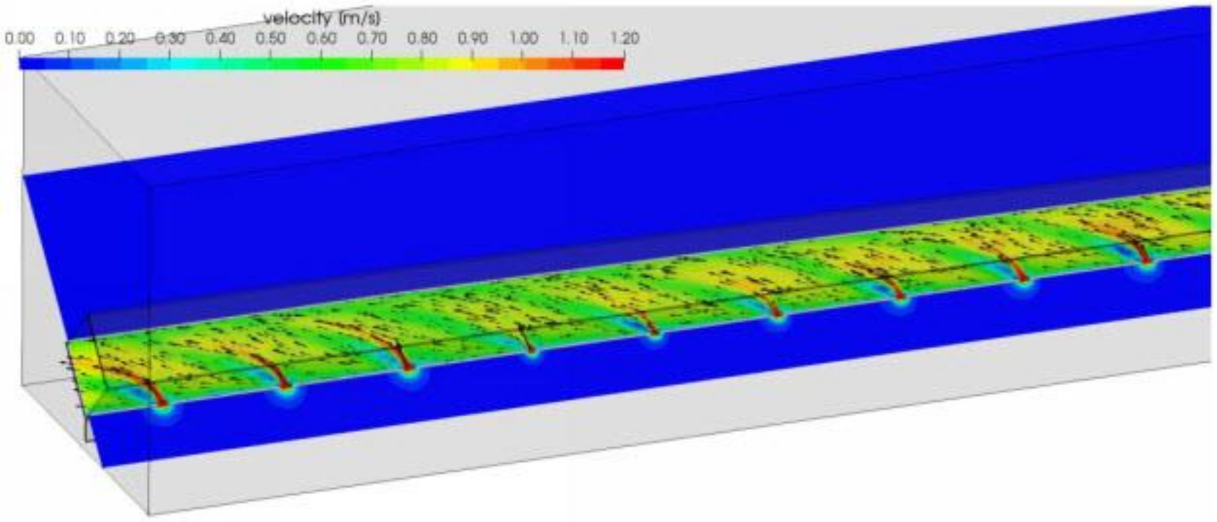
Secondary Clarifier Optimization

CFD Analysis



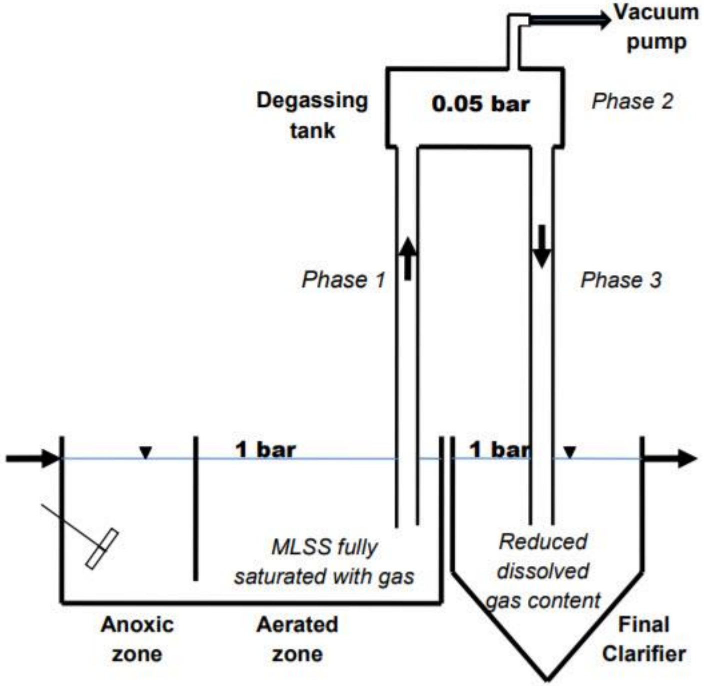






Degassing - BIOGRADEX

Figure 4: Qinghe WWTP, Section 2, North Train – overall view of bioreactors, secondary clarifiers and the vacuum towers



Source

MIXED LIQUOR VACUUM DEGASSING (MLVD) – A HIGHLY EFFECTIVE AND EFFICIENT METHOD OF ACTIVATED SLUDGE BULKING AND FLUSH-OUT PREVENTION IN THE WASTEWATER TREATMENT, WITH SIMULTANEOUS IMPROVEMENT OF TOTAL NITROGEN REMOVAL

Maciejewski, M.[1], Oleszkiewicz, J.A.[2], Drapiewski, J.[3], Gólcz, A.[4] and Nazar, A.[4]
[1]CH2M HILL, Canada, [2]University of Manitoba, Civil Engineering, Canada, [3]GLAN AGUA Ltd. Ireland, [4]BIOGRADEX Holding Ltd., Poland
Corresponding Author Tel: 00353 909630301 Email. jdrapiewski@glanagua.com

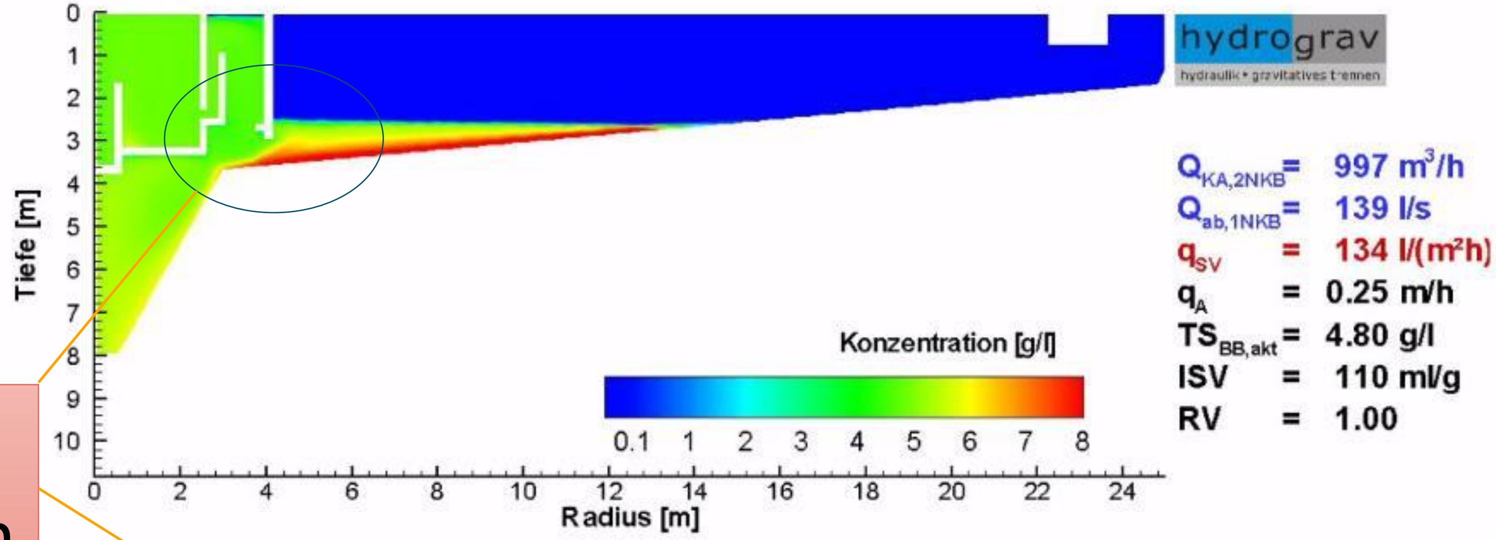
Adaptive Inlet - Hydrograv

Picture: Dry weather

Wet weather

Heavy Storm Water

Sludge profile



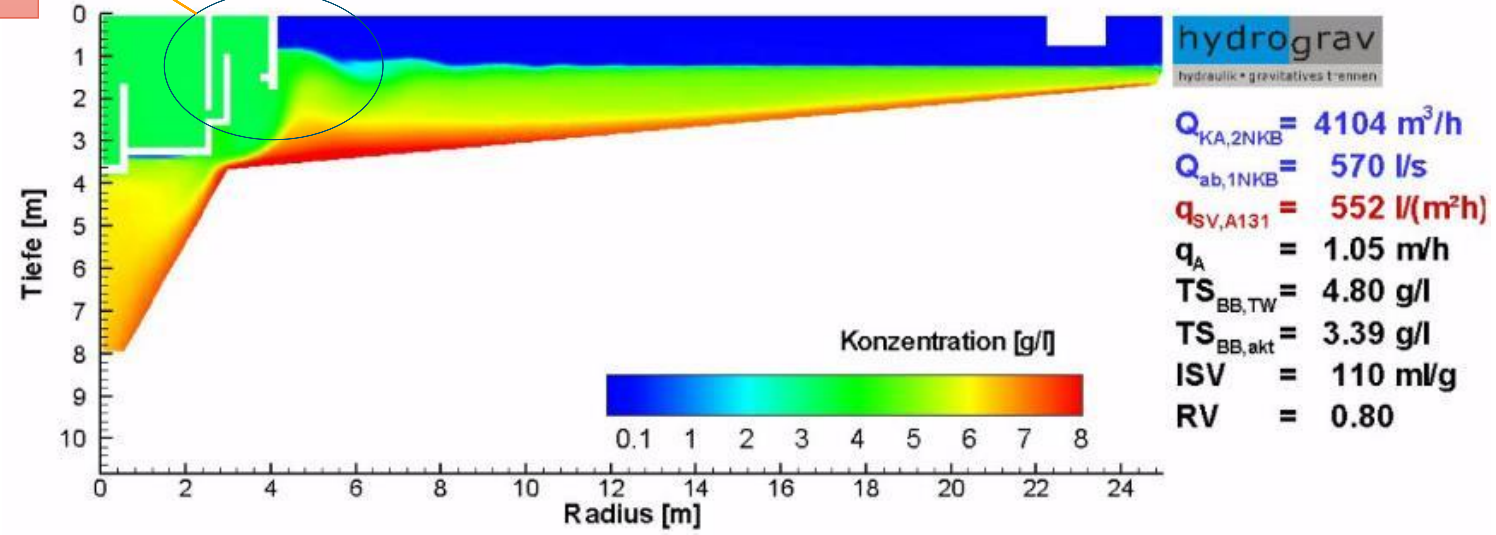
(= SVI x MLSS x HLR)

131 gal/sf/d (x 526)

RAS Rate

10.5 lb/sf/d

Blanket Filtration

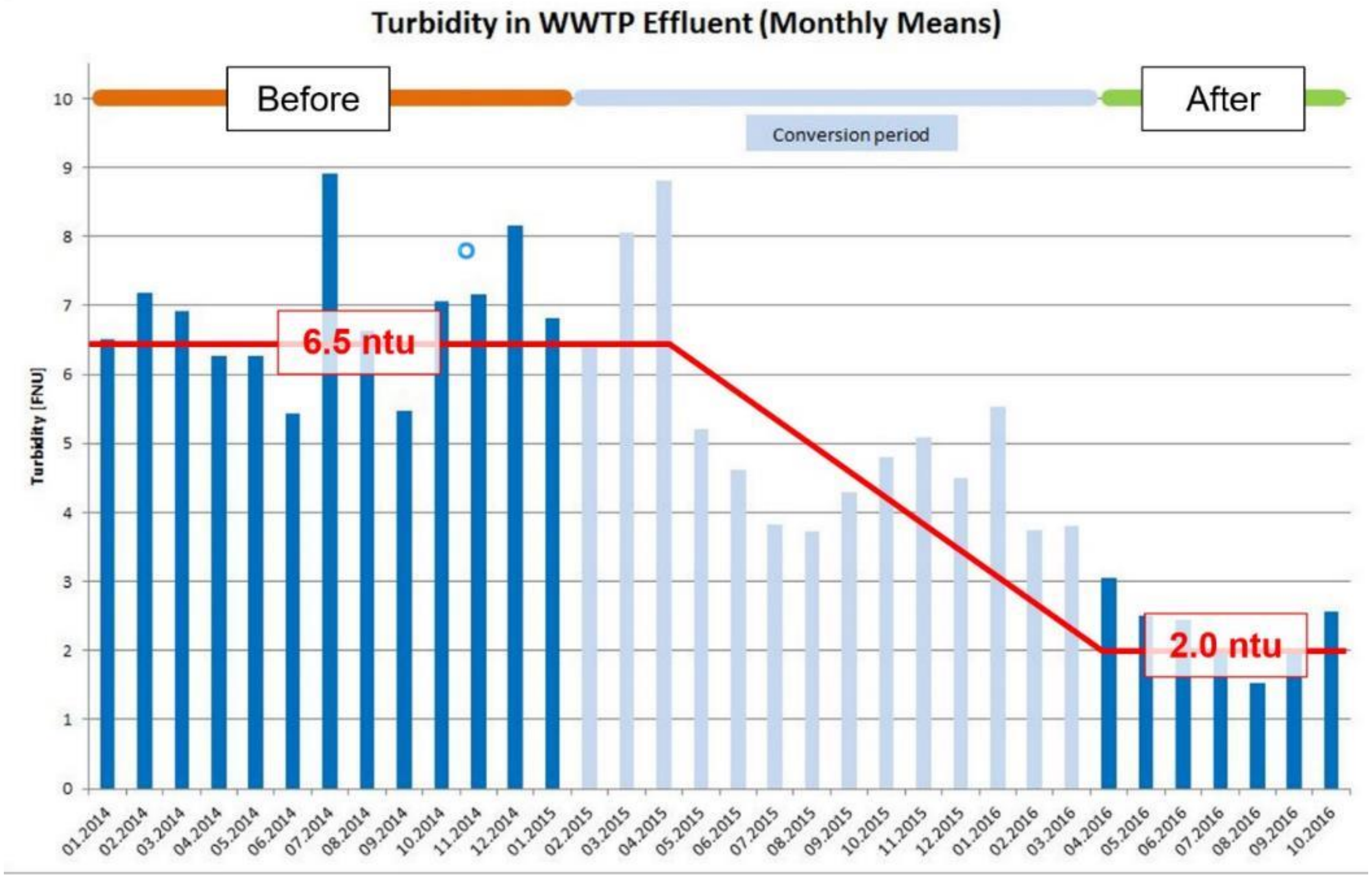


552 gal/sf/d (x 526)

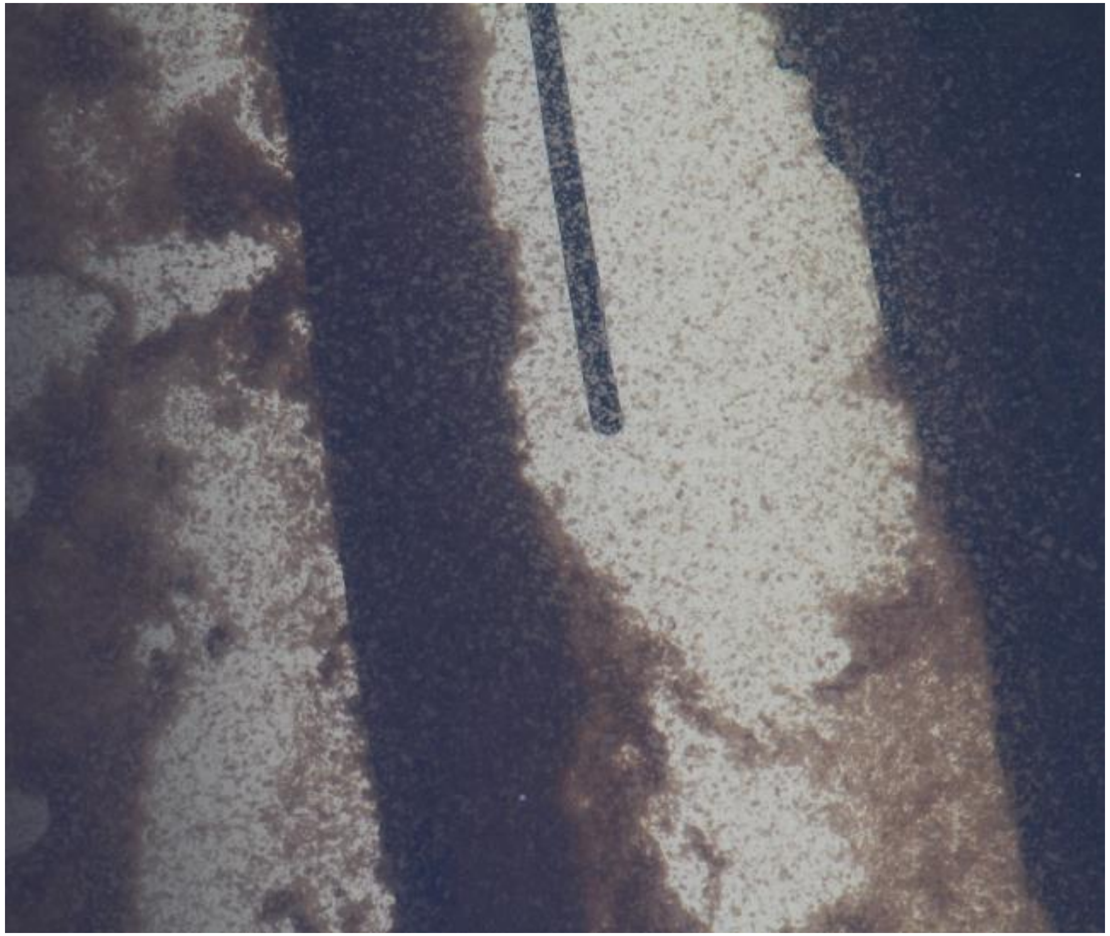
44.2 lb/sf/d

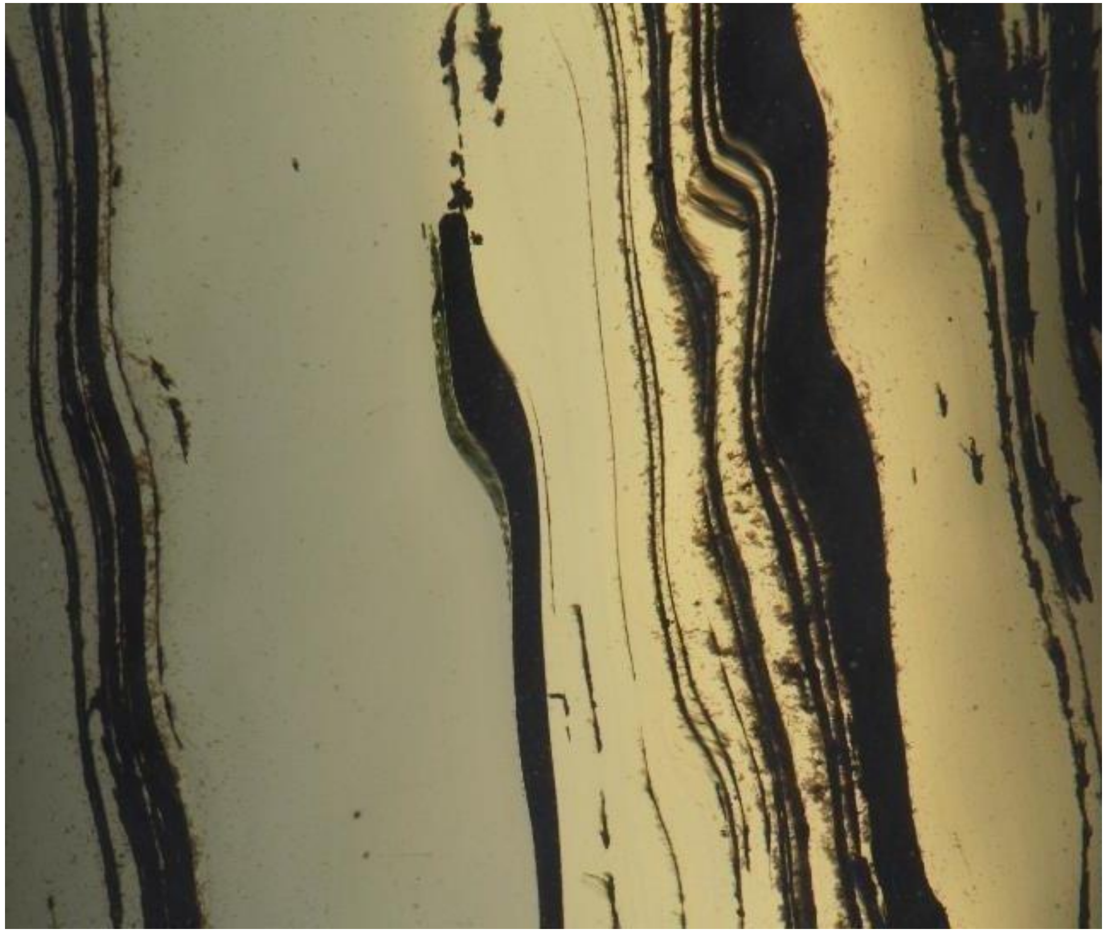
(Source: M. Armbruster)

Example Dresden (800,000 PE)

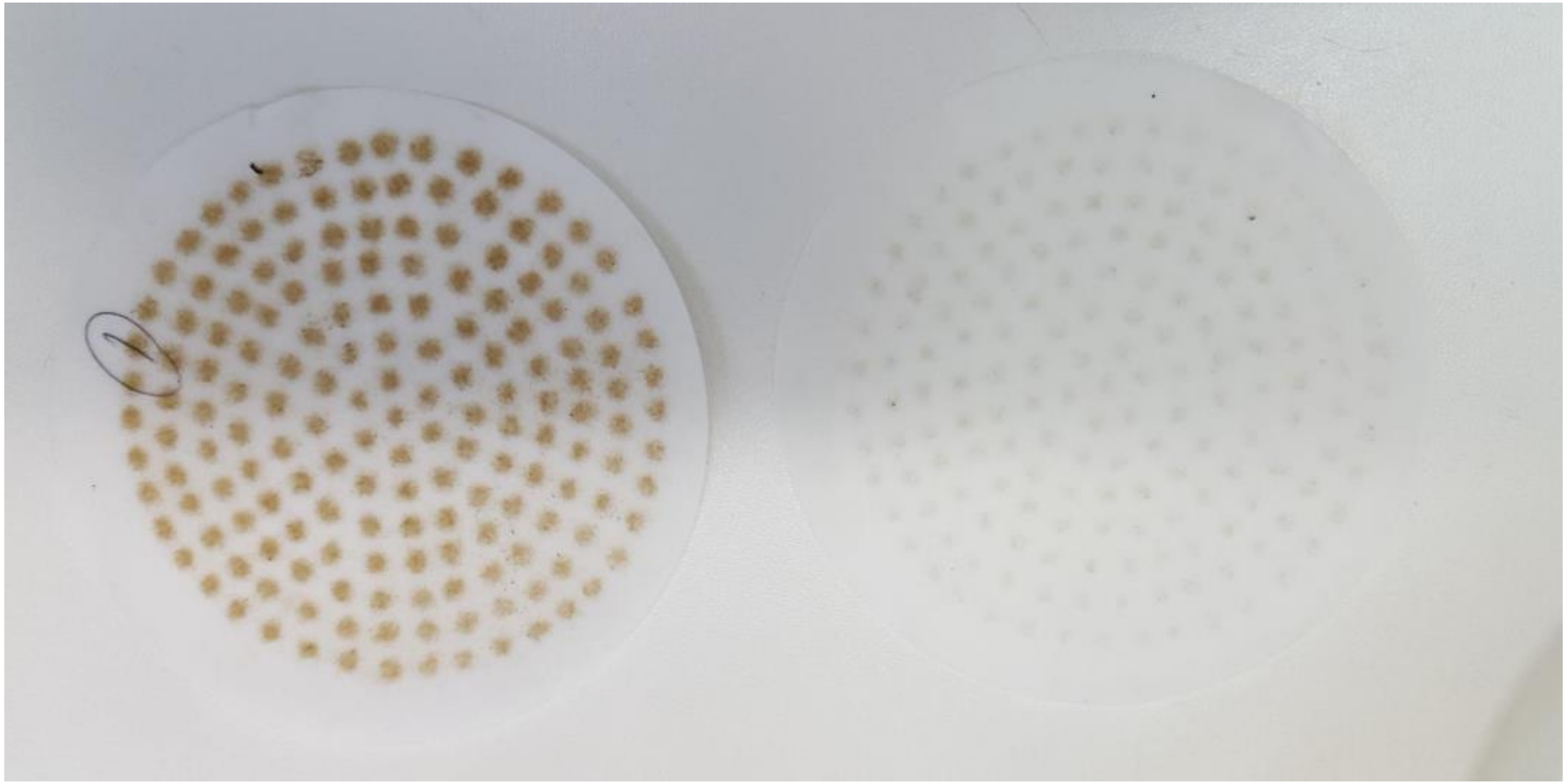


Stress test @ moers Gerd





Stress test @ moers Gerd



Closing

- Clarifier optimization
  - Custom job
  - Does not fix upstream issues
  - CFD modeling very helpful but expensive
- Adaptive Inlet
  - Very low effluent TSS
  - Increased capacity
- Baffling
- Energy dissipation

"Live" Interaction Using Menti Meter

Go to:	menti.com
Enter Code:	9097 3512

Follow cues on your device screen

Remember to SUBMIT your answer

Some questions allow multiple entries

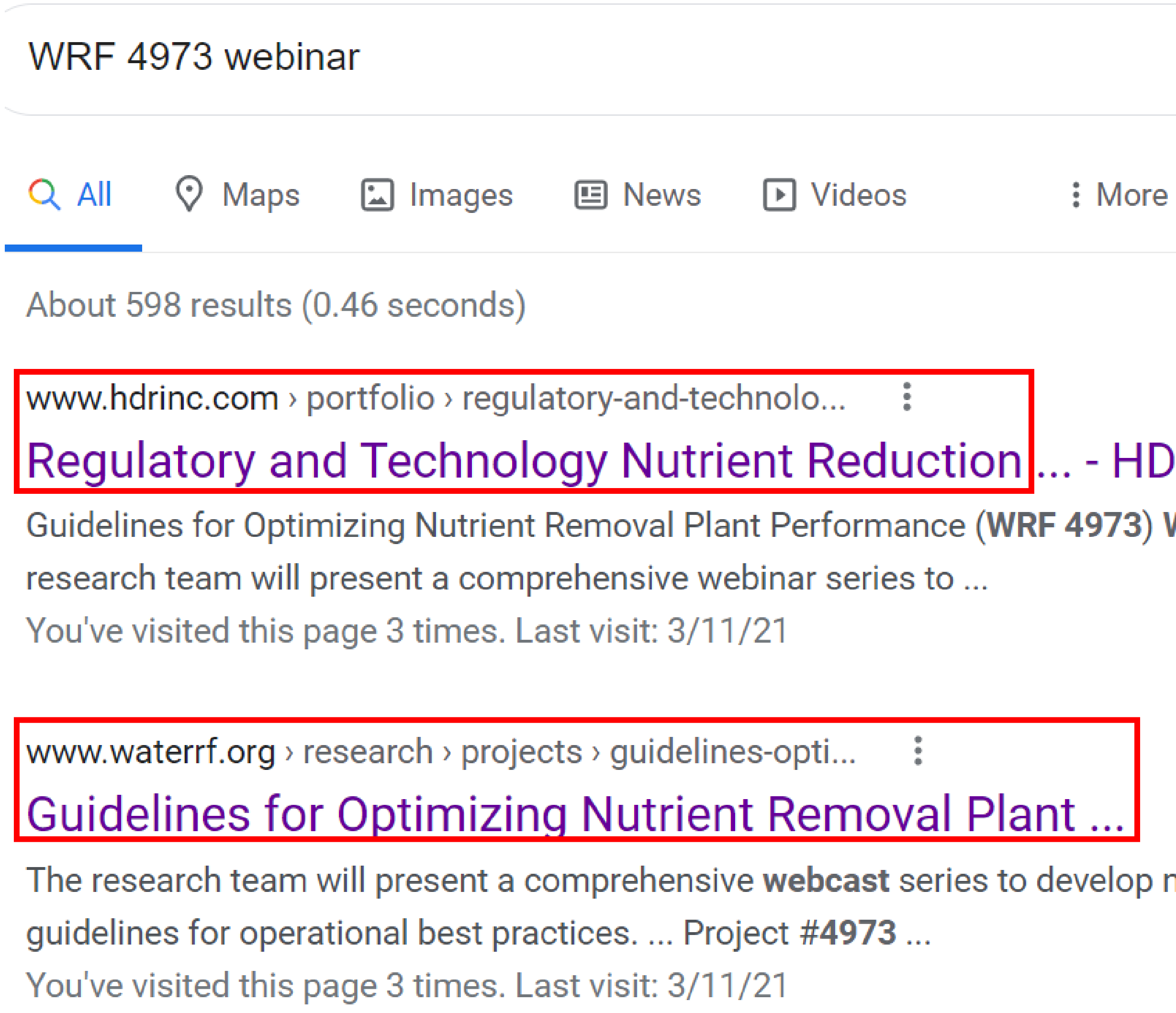

Closing

Certificate of Completion (for CEU/PDH)

- WRF cannot give out the certifications, but we provide a certificate of completion
- Instructions
  - Email WRF (MSuazo@waterrf.org) to obtain a Certificate of Completion
  - Contact your state/province licensing agency to verify that CEUs/PDHs will be awarded for the webcast and any other materials are required. Certification contacts are listed on the Association of Boards of Certification Website (Search for **ABCCERT Certification Contacts**)
    - www.abccert.org/certification_contacts
- This information is COPIED INTO THE CHAT of this webinar

WRF 4973 – Upcoming Webinars

- Approximately every 2 weeks, Wednesday noon ET (9 PT)
- Beyond Liquid Treatment: Reduce Nutrient Discharge Loads by Other Means – 4/14/21
- Sidestream Management to Optimize WRRF Nutrient Removal = 4/28/21
- Search: WRF 4973 webinar



WRF 4973 Nutrient Optimization

Thank you

Comments or questions, please contact:

Stephanie Fevig: sfevig@waterrf.org

For more information, visit www.waterrf.org

WRF 4973 - Guidelines for Optimizing Nutrient Removal Plant Performance

