# MABR technology application for nutrient removal upgrades and improving process resilience

April 7, 2020

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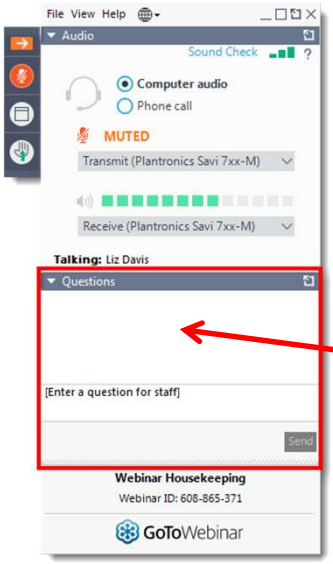
## How to Participate Today




- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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# look who's talking

Amit Kaldate, PhD
Domain Leader
SUEZ Water Technologies & Solutions
USA

Sandeep Sathyamoorthy, PhD
Principal Process & Innovation Leader
Black & Veatch
USA

Andrew Shaw, PhD, PE, BCEE
Global Practice and Technology Leader
for Sustainability & Wastewater
Black & Veatch
USA

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# contents

- ZeeLung* MABR technology overview
- MABR for nutrient removal upgrades
- MABR for process resilience
- Q&A

*Trademark of SUEZ; may be registered in one or more countries

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# ZeeLung MABR technology overview

Amit

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## ZeeLung solves treatment challenges

- increase capacity of existing plant assets… avoid building new tanks
- augment ammonia removal
- implement nitrogen removal
- implement biological phosphorous removal

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ZeeLung is a **biomass carrier** that supports the growth of a biofilm

the carrier material **"breathes"** and transfers oxygen to the biofilm at very **high efficiency** without the use of bubbles

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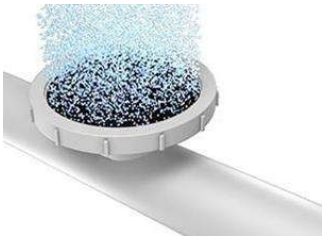
**ZeeLung is not…**

a filter



a fine bubble diffuser

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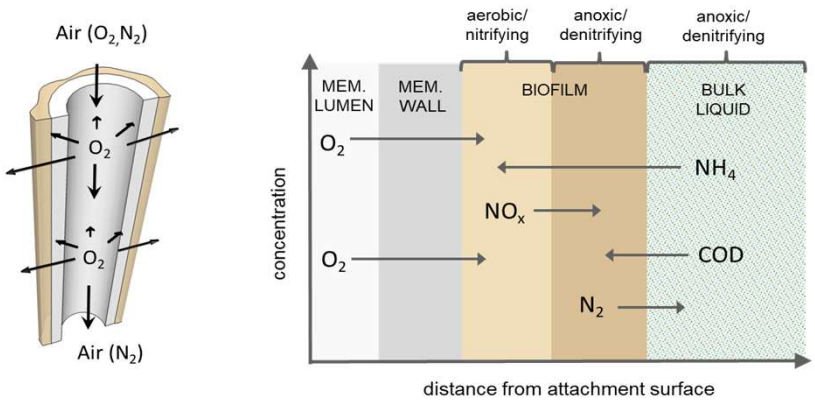
# what is MABR




- media-supported biofilm with its own built-in $O_2$ supply
- counter-diffusional biofilm with "magical" properties

For more information on the unique properties of counter-diffusional biofilms see Downing and Nerenberg (2008) Applied Microbiology and Biotechnology, 81:153–162

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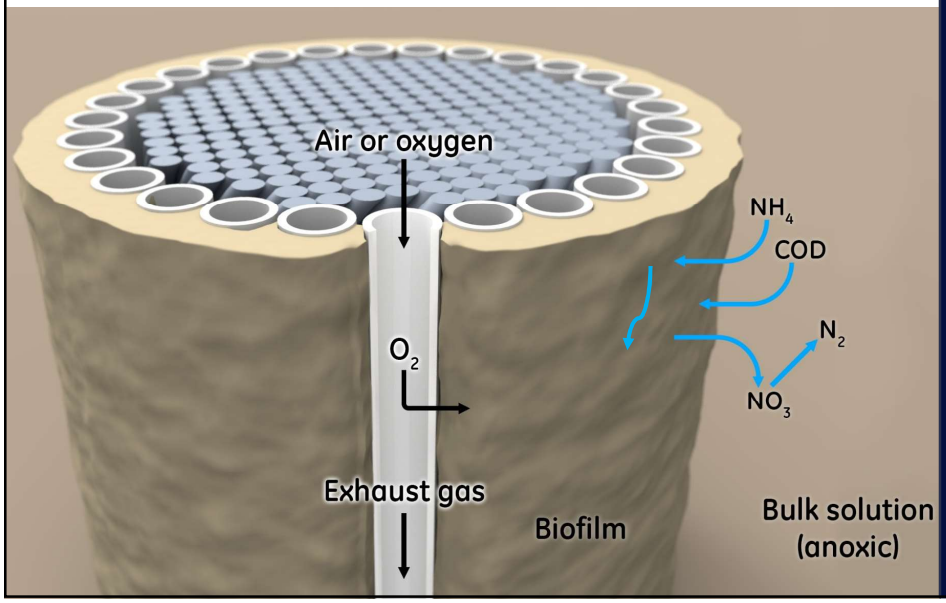
# ZeeLung process




highest efficiency of oxygen transfer by diffusion of $O_2$ into a biofilm

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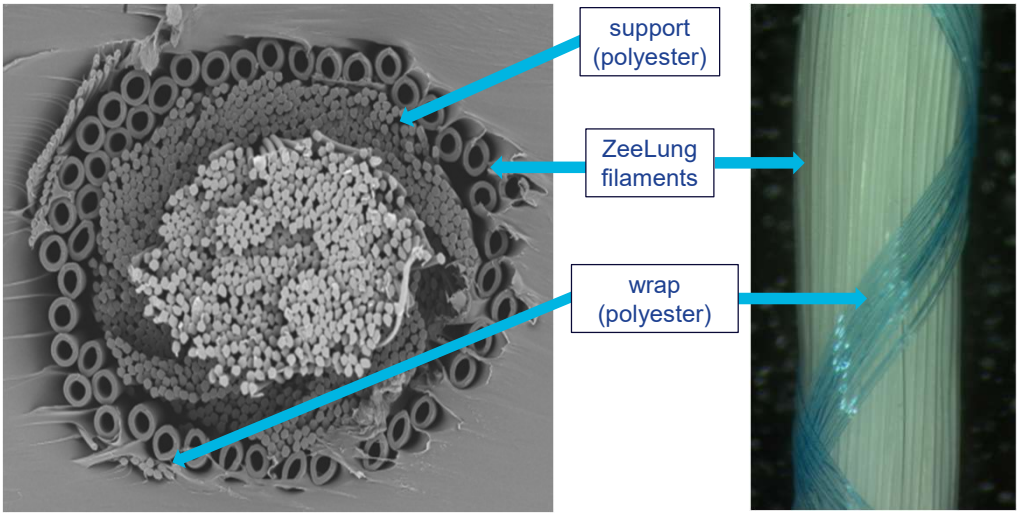
## ZeeLung cord construction ensures product robustness

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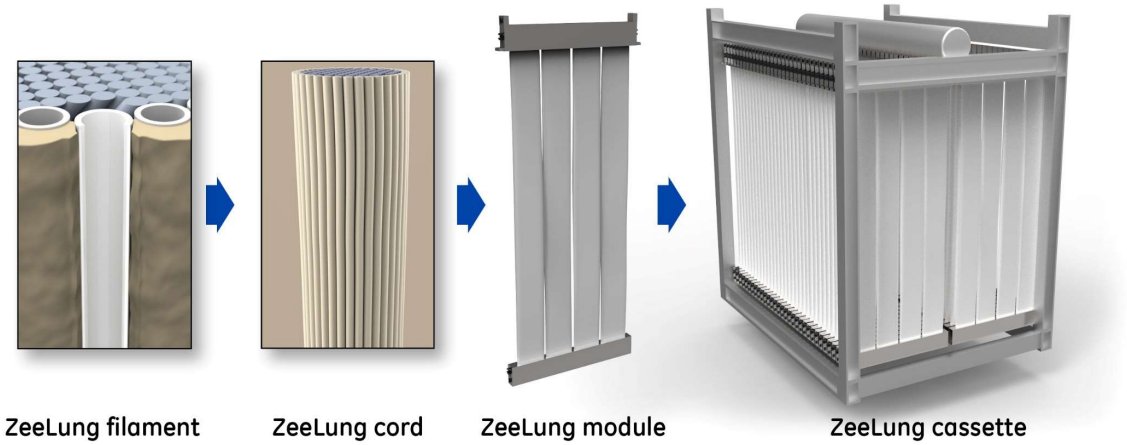
## ZeeLung product

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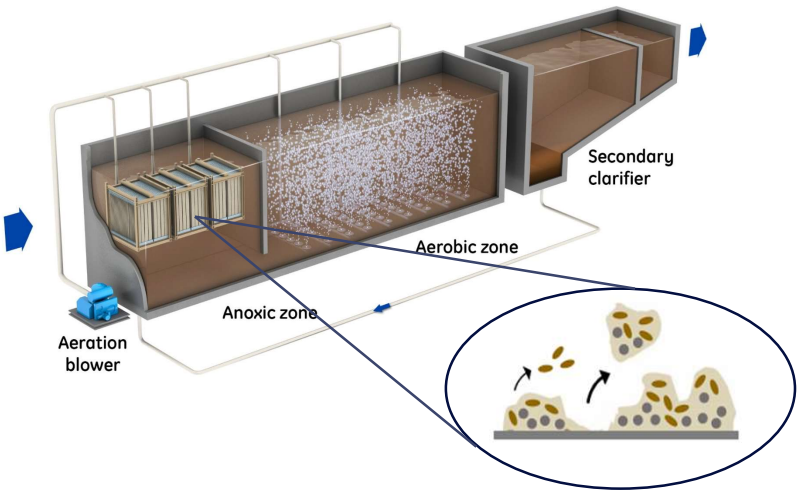
# ZeeLung enables process intensification

## by higher biomass inventory and reduced aerobic SRT




hybrid system with nitrification in biofilm and suspended biomass

ZeeLung cassettes at the "front" of the process remove 20-80% of ammonia

ZeeLung biofilm is rich in nitrifiers (10X more than suspended biomass)

biofilm nitrification provides seeding of nitrifiers and reduces load to suspended growth… enabling lower aerobic SRT

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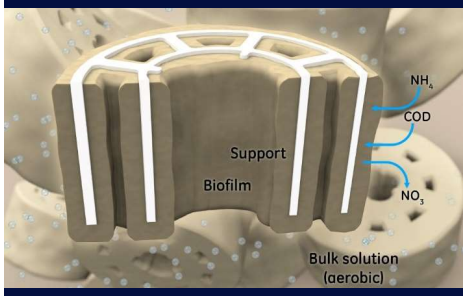
# ZeeLung enables process intensification

- ↑ bacteria inventory = ↑ treatment capacity
- plus… ZeeLung biofilm favors the growth of the bacteria we want – nitrifiers

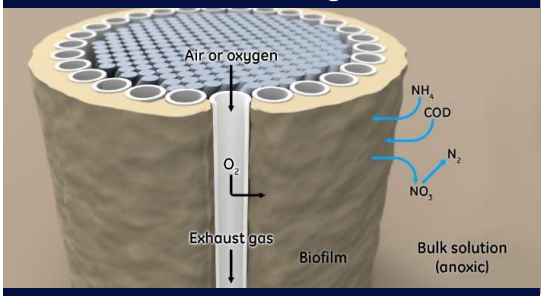
### conventional




reaction occurs at the surface

competition for $O_2$ between heterotrophs & autotrophs

### ZeeLung




reaction occurs in the biofilm

favors the growth of autotrophs (nitrifiers) at media surface

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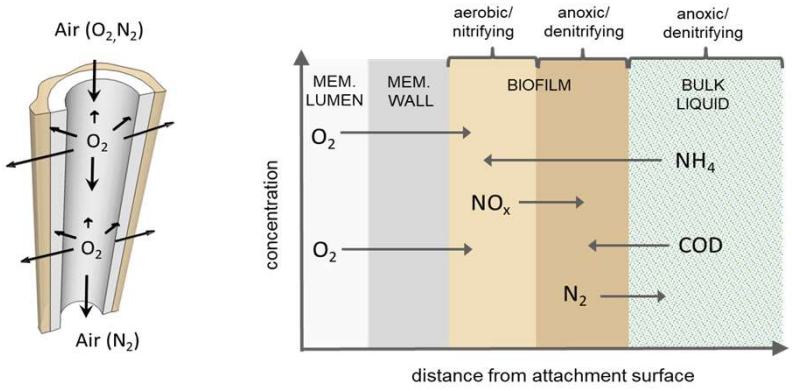
# ZeeLung enables SND




nitrification in the biofilm; counter-diffusion provides competitive advantage for nitrifiers

denitrification in the suspended biomass (anoxic conditions)

denitrification also in the outer layers of the biofilm

simultaneous nitrogen removal in a single reactor without recycle pumping

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# ZeeLung offers process resilience

- attached growth bacteria… not susceptible to washout
- rapid response to influent fluctuations
- stable cold temperature performance

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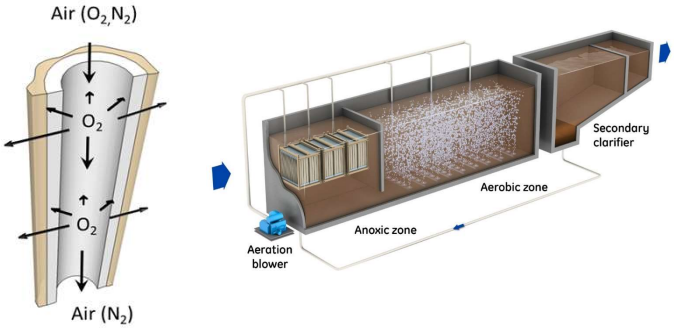
# ZeeLung saves energy




$O_2$ is delivered by molecular diffusion – without bubbles

direct contact between $O_2$ supply and demand in biofilm, no alpha-factor

… plus energy savings in other parts of the process

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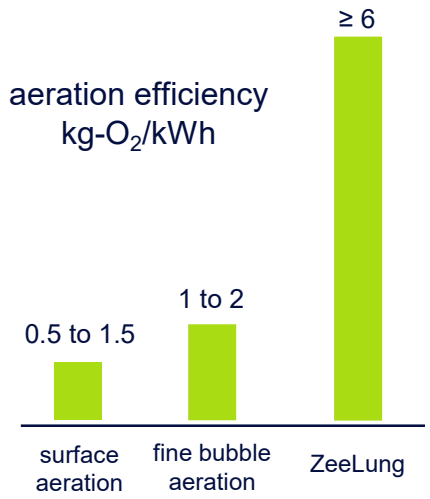
# ZeeLung saves energy

- transfer $O_2$ without bubbles
- 4X lower energy than bubble aeration
- reduce liquid pumping due to simultaneous nitrification & denitrification

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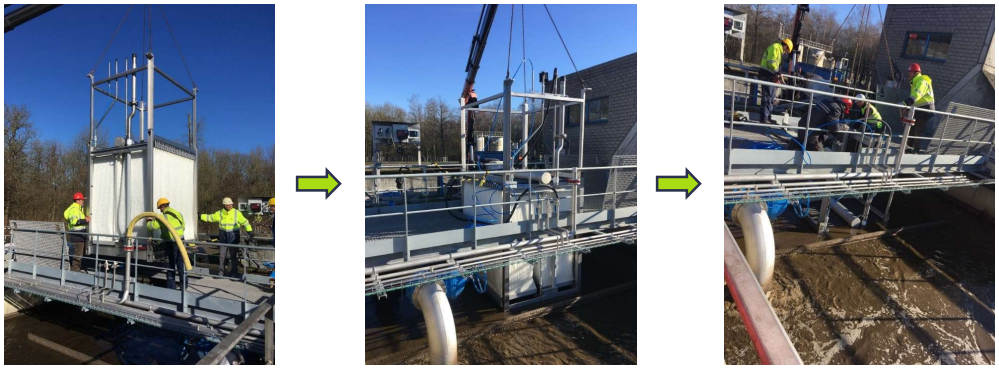
## ZeeLung is a simple solution

- installed in existing tanks
- fast deployment
- no impact on hydraulic gradeline



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## technology innovation through collaboration

| | |
|---|---|
| 20 | MLD of full-scale installed capacity |
| >30 | technology demonstrations |
| >10 | research partnerships |
| 21 | patents issued |

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# MABR for nutrient removal upgrades

Sandeep

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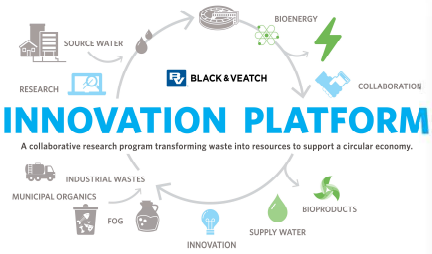


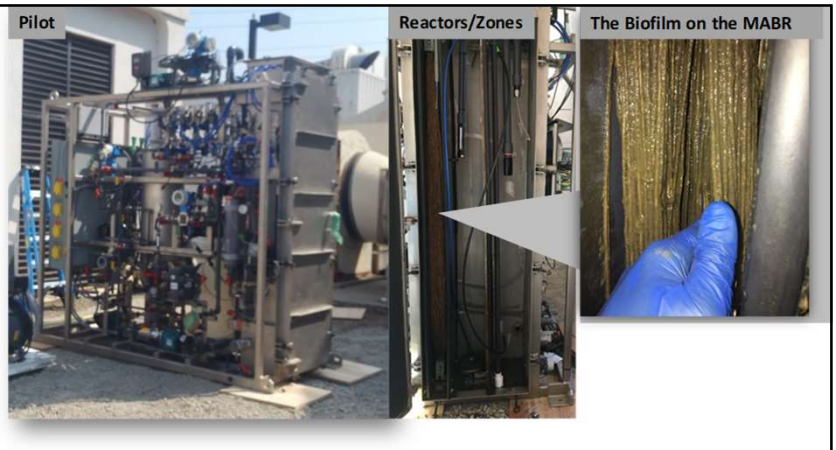


## MABR-Suspended Growth (MABR-SG) Hybrid Processes for BNR Upgrades

BUILDING A WORLD OF DIFFERENCE®

BLACK & VEATCH: SANDEEP SATHYAMOORTHY
YUEYUN TSE
KELLY GORDON

SUEZ: DWIGHT HOUWELING
DAN COUTTS

BLACK & VEATCH

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# MABR Pilot @ Hayward WPCF

~10 MGD
Primary Sed > Trickling Filter > Solids Contact > Chlorine Disinfection




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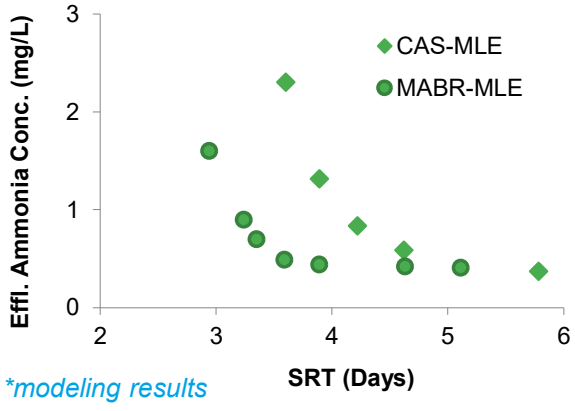
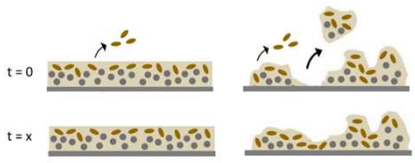
# MABR Pilot Research Question # 1

*Evaluate the **aerobic solids retention time (SRT)** required to achieve **nitrification** in an **MABR** configuration compared with a **Suspended Growth BNR** configuration*




**modeling results*

1. **Lower nitrification "work" required by suspended sludge**
2. **"Seeding" effect by the biofilm.**



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# Pilot (MABR+ Sus. Growth) Performance At Different SRTs


Soluble COD

- Each SRT Condition tested for > 5X SRT
- Flow-weighted average from duplicate 24-h intensive sampling (2h interval) results



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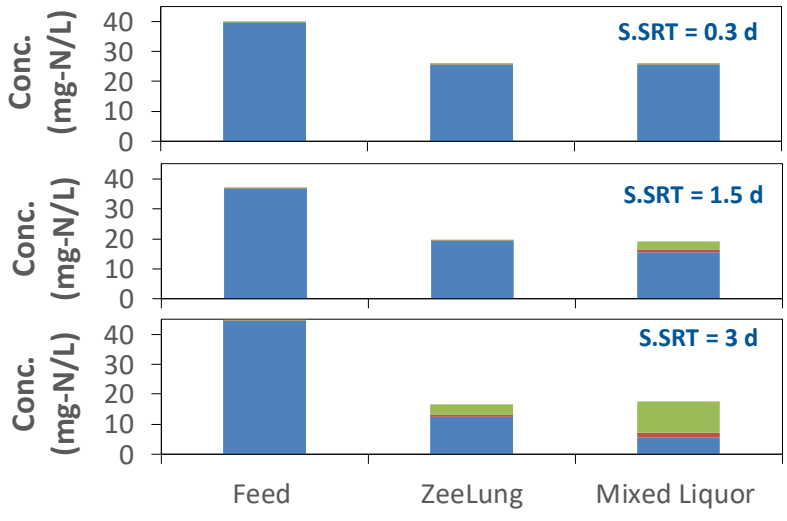
# Pilot (MABR+ Sus. Growth) Performance At Different SRTs




NHx-N
NO2-N
NO3-N

- Each SRT Condition tested for > 5X SRT
- Flow-weighted average from duplicate 24-h intensive sampling (2h interval) results



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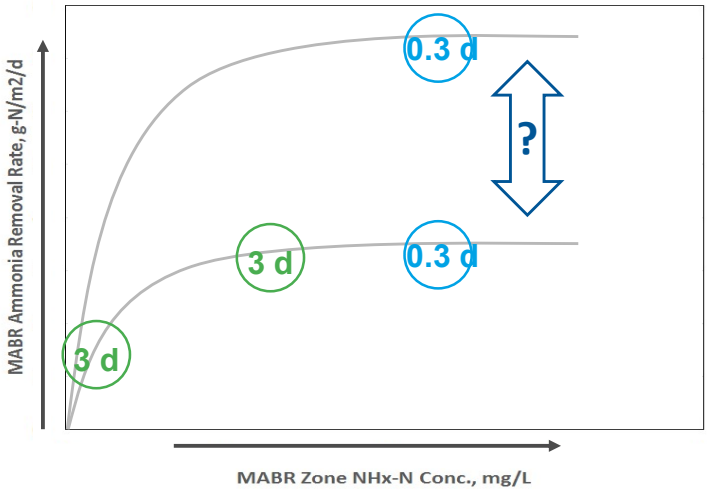
# MABR Pilot Research Question #2

*How does **Suspended Growth AE SRT** impact **Nitrification Rate** (g-N/d/m²) of MABR Biofilm?*




- Key Design Parameter
- Longer Suspended Growth AE SRT should lead to **lower NHx-N Concentration** in MABR Zone





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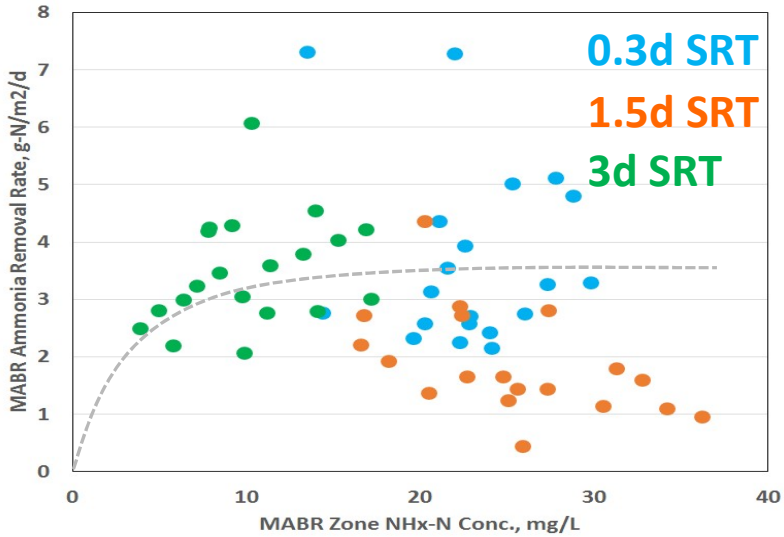
# MABR Ammonia Removal/Nitrification Rate




- Nitrification rates in the range of ~1.5 – 4 g-N/m².d
- Reduction in nitrification rates at higher NHx-N concentration related to:
  - Balance between availability of $NO_X$-N and $O_2$ in the MABR biofilm for COD and $NH_x$-N oxidation



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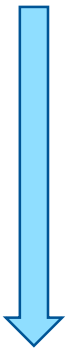
# MABR Pilot Research Question # 3

*Assess the impact of the **organic carbon to nitrogen loading rates (C/N)** on MABR performance.*

- Biofilm **Function**--C:N ratio affects competition between heterotrophs and nitrifying organisms for **oxygen**.
- Biofilm **Structure**-- C:N ratio affects competition between **heterotrophs and nitrifying organisms** for space in the biofilm
- Biofilm **Thickness**--Excessive carbon loads can result in thick biofilms and diffusional limitation.





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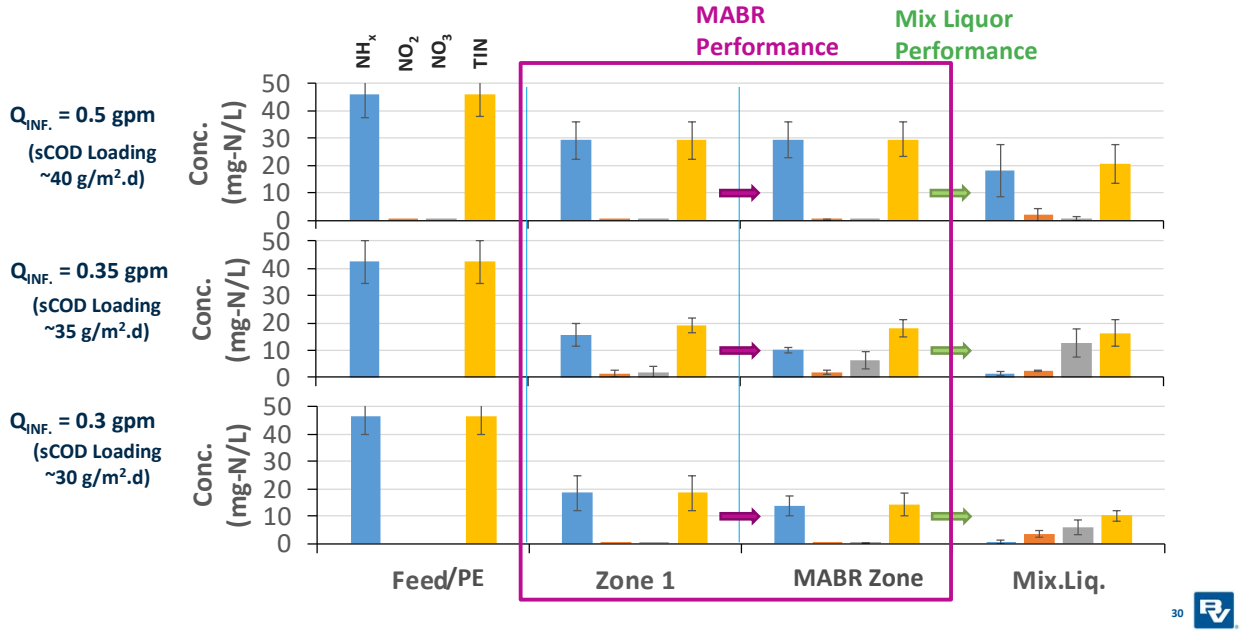
# Pilot Performance Under Different Flow Rate (~3 day SRT)




30

30

# What happens when COD loading is too high

HIGHER LOADING CONDITIONS
(sCOD Loading ~60 g/m².d)



LOWER LOADING CONDITIONS
(sCOD Loading ~20 g/m².d)

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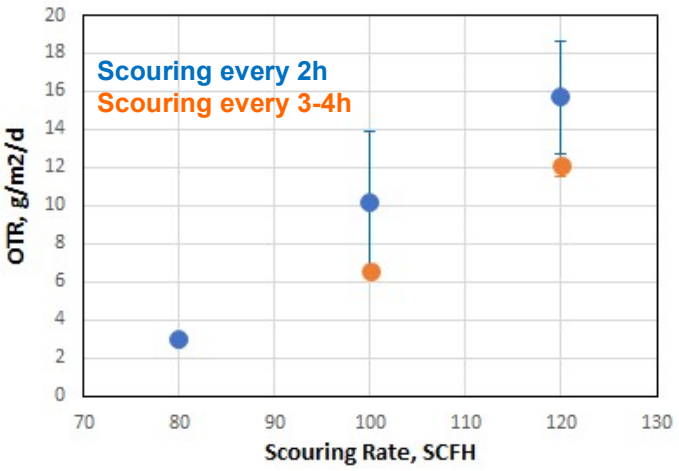
# Biofilm Management is Critical for Oxygen Transfer




- Scouring Intensity/Rate
- Scouring Frequency/Interval
- Scouring Duration

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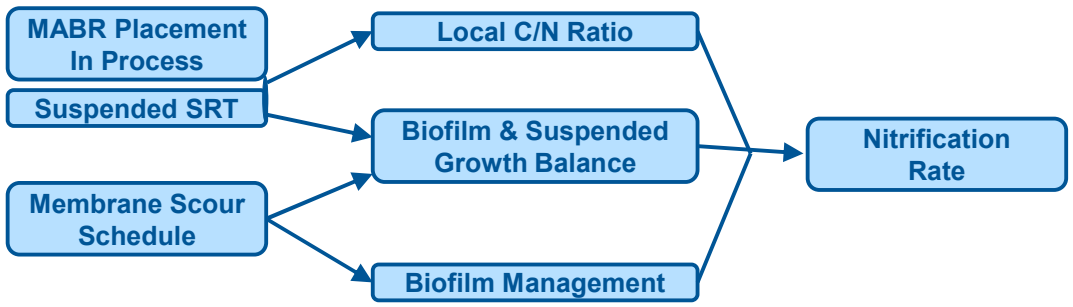
## Preliminary Conclusions - Factors to Consider for MABR-SG System Design



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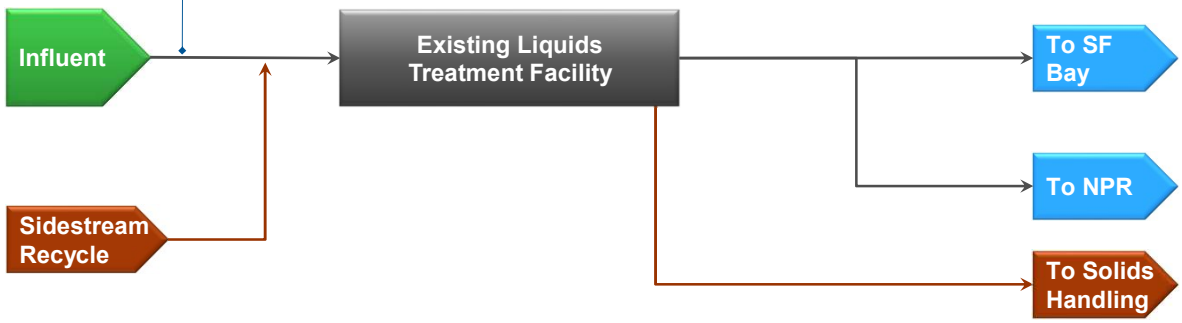
## Consider expansion of an existing WRRF at an adjacent site

| | Q MGD | NHx, mg-N/L | sTN, mg-N/L |
|---|---|---|---|
| AA | 22 | 24 | ~35-36 |
| MM | 28 | 22 | ~33-34 |

- Aging facility
- Low reliability, robustness



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## Consider expansion of an existing WRRF at an adjacent site




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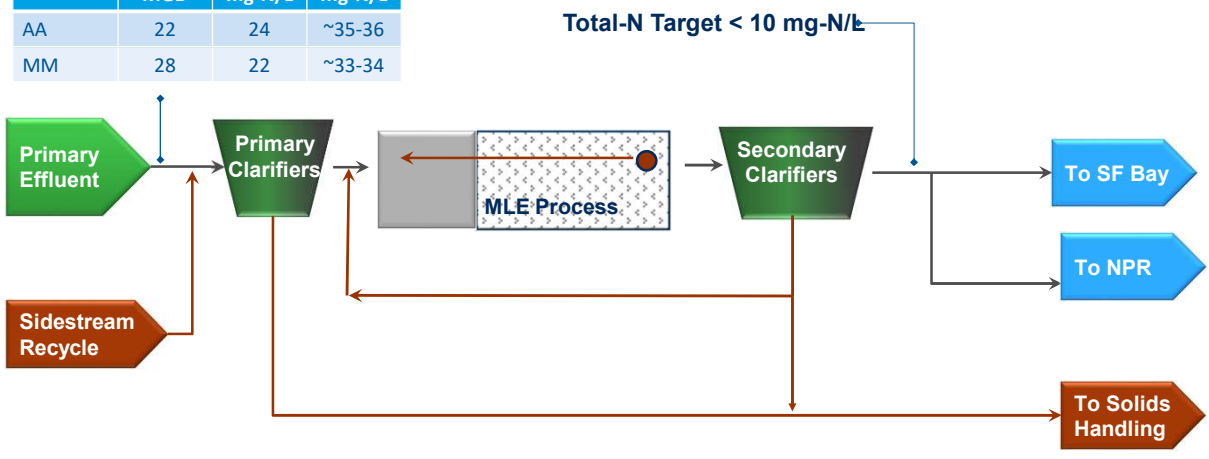
## New WRRF Design (at "greenfield" site)

| | Q MGD | NHx, mg-N/L | sTN, mg-N/L |
|---|---|---|---|
| AA | 22 | 24 | ~35-36 |
| MM | 28 | 22 | ~33-34 |



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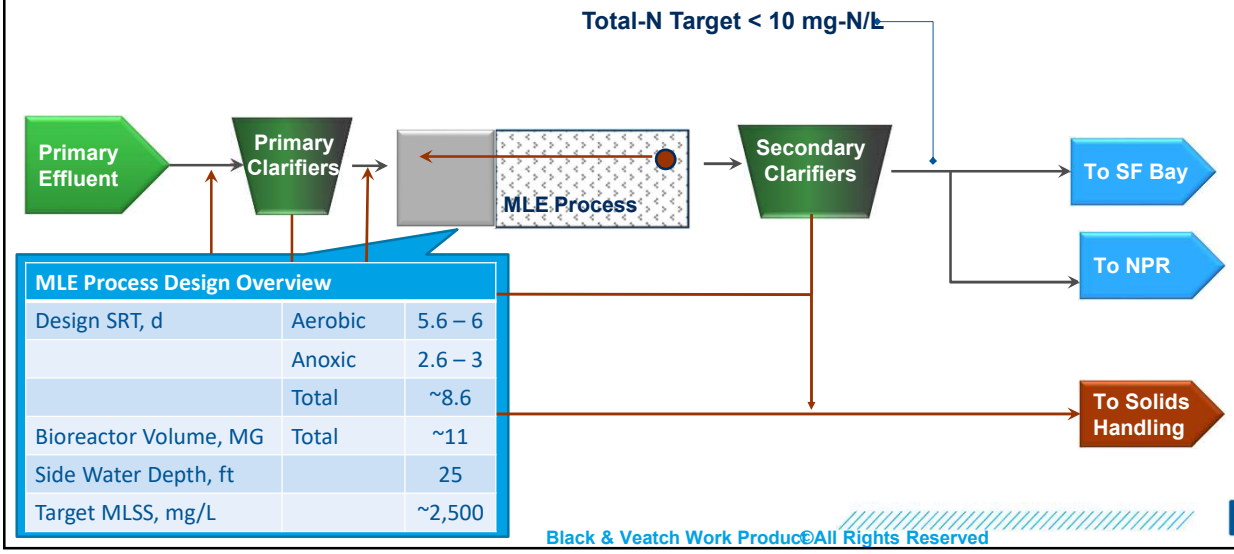
## New WRRF Design (at "greenfield" site) Process Design Summary




| MLE Process Design Overview | | |
|---|---|---|
| Design SRT, d | Aerobic | 5.6 – 6 |
| | Anoxic | 2.6 – 3 |
| | Total | ~8.6 |
| Bioreactor Volume, MG | Total | ~11 |
| Side Water Depth, ft | | 25 |
| Target MLSS, mg/L | | ~2,500 |



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## Can Process Intensification Help Enhance the Process Design?

- What is the potential suspended SRT (and resulting volume) reduction?
- What are some trade-offs to consider?



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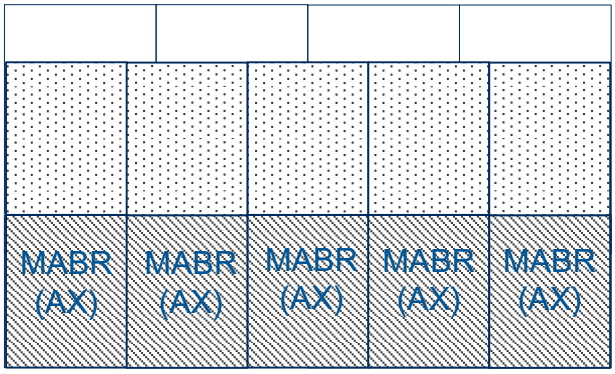
# Incorporation of MABRs into the MLE design




- **Current CAS Design**
  - ~ 11 MG
  - ~35% AX, 65% AE
  - $MLSS_{MAX.MONTH}$ ~ 2,500 mg/L
- **MABR-AS Design**
  - ~ 8 MG
  - ~ 50% AX
  - $MLSS_{MAX.MONTH}$ ~ 2,500 mg/L



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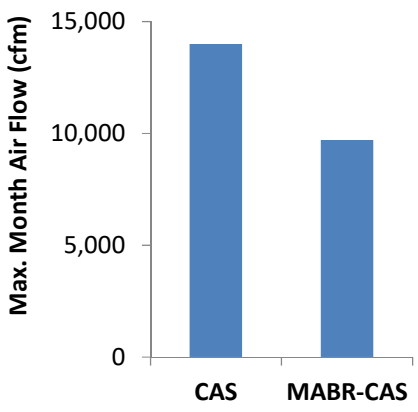
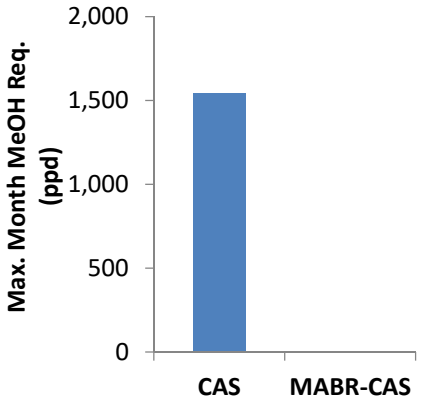
# Aeration & Chemical Use Benefits



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## Tradeoffs

- Replacing potentially expensive concrete with equipment
  - More detailed tradeoff analyses required – including LCC, etc.
- But – are there benefits of reducing the SWD and overall tank depth?
  - Safety, operability, etc.
- Can this not be planned for as part of a future "plug-and-play" solution?
  - Yes…& No
  - Overall plant design/integration and system design are critical
    - (any) technology needs to be "best positioned" for success
    - For MABRs – hydraulics are key: shortcuiting, bypassing, best use of membrane area, etc.



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## MABR for process resilience

Andy

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# MABR for Resilient Treatment

Andrew Shaw PhD, PE, BCEE
Global Practice and Technology Leader for Sustainability & Wastewater

BLACK & VEATCH

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## Outline

1. What is “Resilient” wastewater treatment?
2. Demonstration of MABR Resilience – Full Scale and Demo Scale
3. Upcoming Research

Black & Veatch

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## 1. What is "Resilient" wastewater treatment?

*resilience* n.
re·sil·ience | \ ri-ˈzil-yən(t)s
2: an ability to recover from or adjust easily to misfortune or change

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## 1. What is "Resilient" wastewater treatment?

**Resilient Treatment Systems are:**

1. Autonomous - Needs little or no attention. It just works on its own.
2. Dormancy Capabilities - If it is shut down, there are no problems when it starts up again.
3. Robust/rugged – The process can withstand operating outside the normal physical conditions expected of the system *i.e.* the design basis

*→ MABR biofilms provide a unique means for achieving resilience*

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# 2. YBSD Overview

## Yorkville-Bristol Sanitary District, Illinois

**ZeeLung Drivers:**

- 3.62 mgd plant near design load
- Increased organic load from new industries
- Future regulation for P
- Existing site is built-out… conventional upgrade requires construction of a new plant

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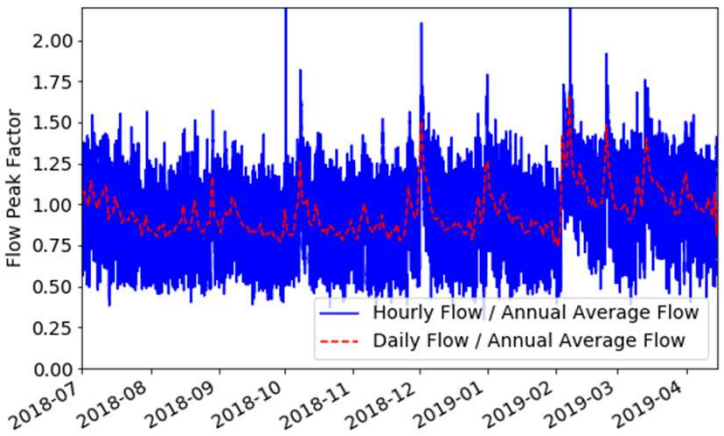
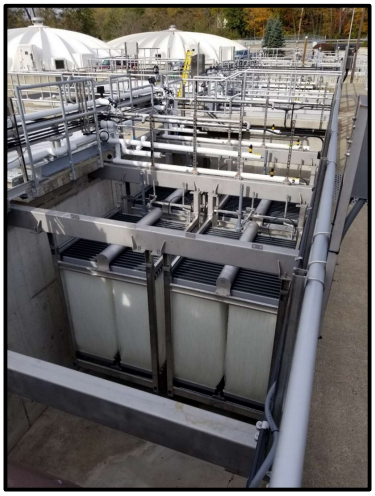
# 2. Demonstration of MABR Resilience: YBSD

## Performance during wet weather events



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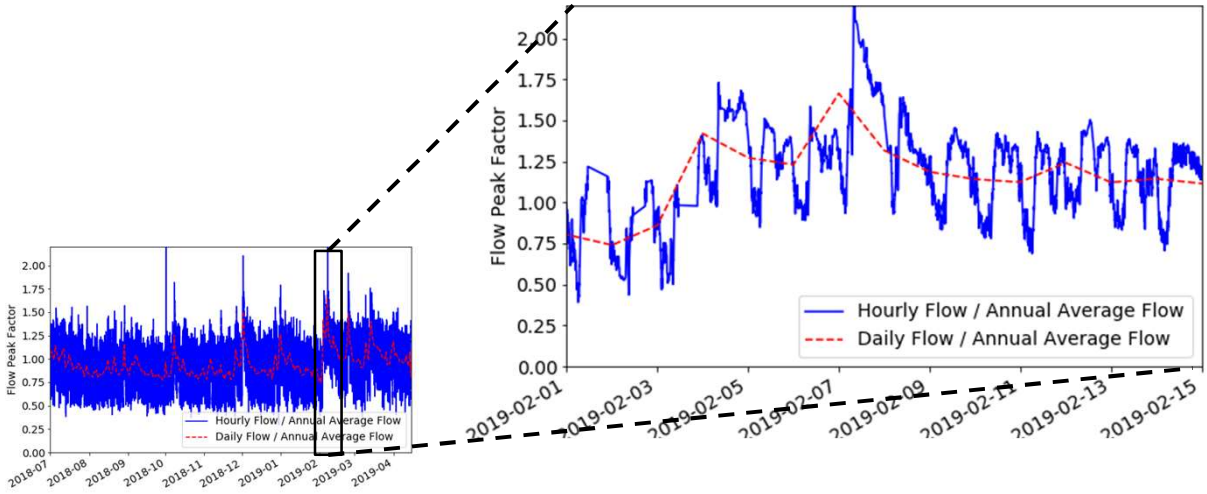
# 2. Demonstration of MABR Resilience: YBSD

## Performance during wet weather events

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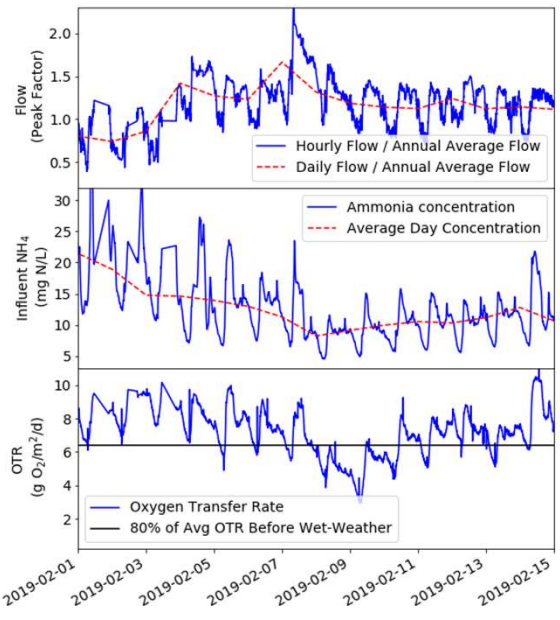
# 2. Demonstration of MABR Resilience: YBSD




- Evaluate performance according to oxygen transfer to biofilm before, during and after wet weather event
- How long does it take to recover average of performance before wet weather event?

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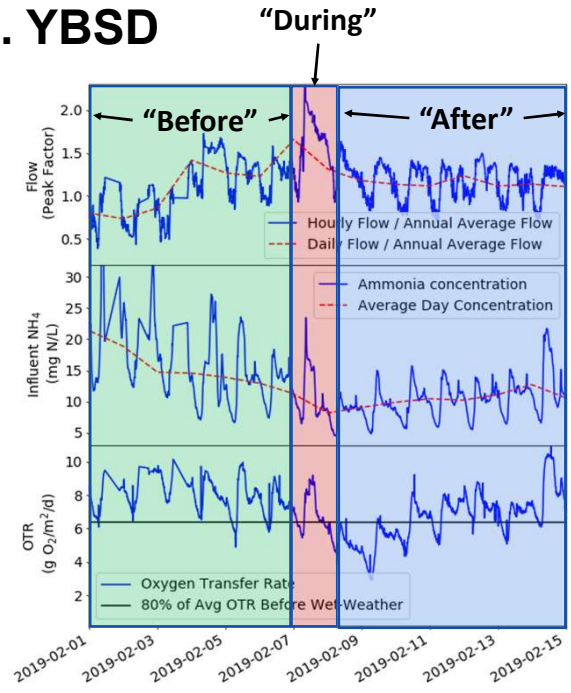
## 2. YBSD




- Evaluate performance according to oxygen transfer to biofilm before, during and after wet weather event
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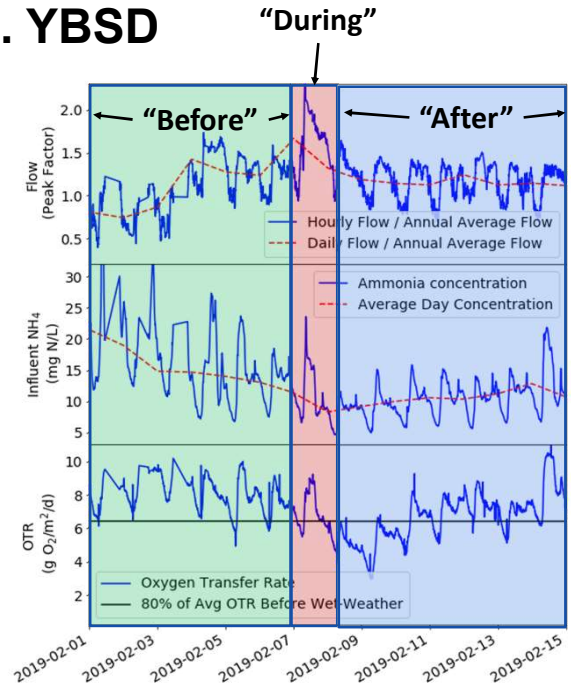
## 2. YBSD




- Very little loss of performance during the wet weather event
- Performance drops below average the day following event due to weaker sewage
- Performance back to average in four days when sewage strength returns to normal

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# 2. Demonstration of MABR Resilience: Adelaide, ON

| # | Test |
|---|---|
| 1 | 24-hour Shutdown |
| 2 | 48-hour Shutdown |
| 3 | 24-hour, Flooding Event |

Shutdowns represent potential:
- Power outages
- Blower or equipment failures
- Flooding events

*Criteria for “process recovery” is achieving 80% of pre-shutdown average

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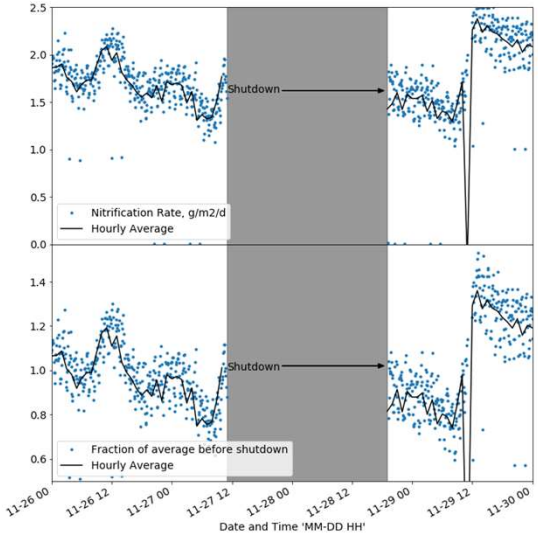
# 2. Demonstration of MABR Resilience: Adelaide, ON

## 24-hour Shutdown:

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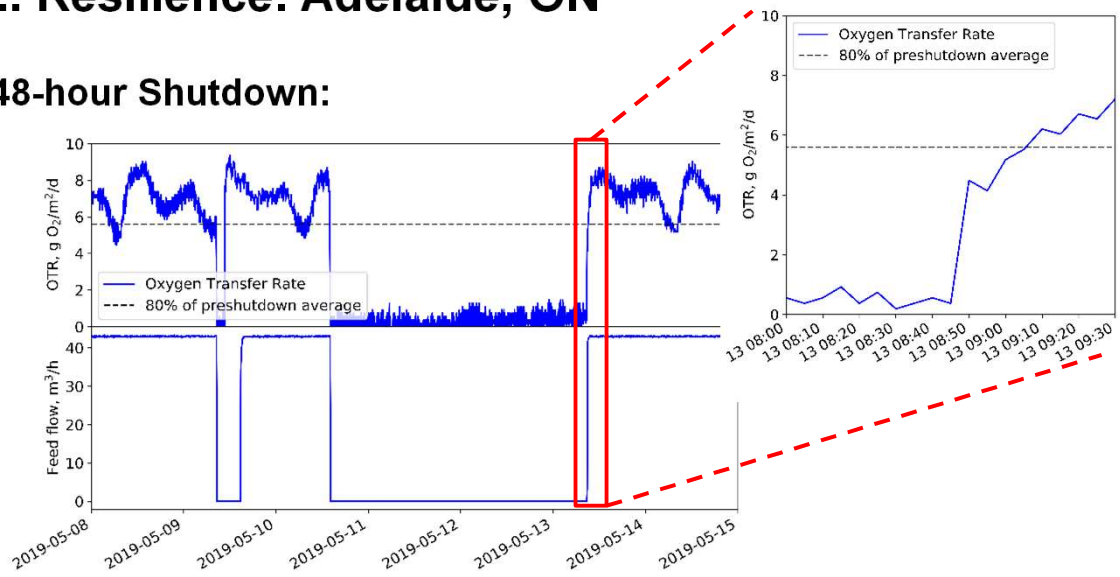
## 2. Resilience: Adelaide, ON

### 48-hour Shutdown:

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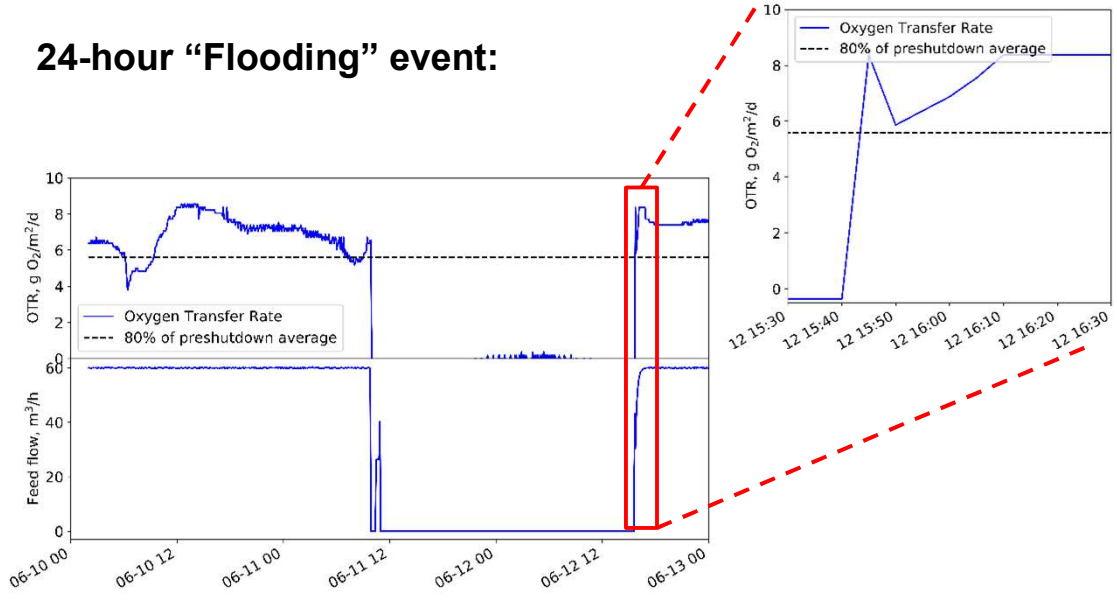
## 2. Resilience: Adelaide, ON

### 24-hour "Flooding" event:

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## 2. Demonstration of MABR Resilience: Adelaide, ON

| # | Test | Description | Results |
|---|---|---|---|
| 1 | 24-hour Shutdown | Feed and mixing shutoff for more than 24 hrs. | Immediate recovery of performance on startup |
| 2 | 48-hour Shutdown | Similar to test 2, but with a shutdown of more than 48 hours | Recovery of performance within 20 minutes of startup |
| 3 | 24-hour, Flooding Event | Feed shutoff, tank drained and then refilled with potable water to simulate flooding event | Recovery of performance within 10 minutes of startup |

"In the timescales used for wastewater treatment (hours and days), this recovery period can be considered almost immediate."

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## 2. Demonstration of MABR Resilience: Recap

**Process resilience checklist:**

- ☑ Performs well despite sensor or actuator failures?
- ☑ Recovers quickly after a shut-down?
- ☑ Can withstand extreme weather events?
- ☑ Resists biomass washout during high flow or even flooding events?
- ☑ Can run using standby power?
- ☑ Runs smoothly when the expert operator is on vacation?
- ? ☐ Runs smoothly when_____ ?

Operation does not require sensors or actuators

4x OTE means blower can run using generator

Low complexity

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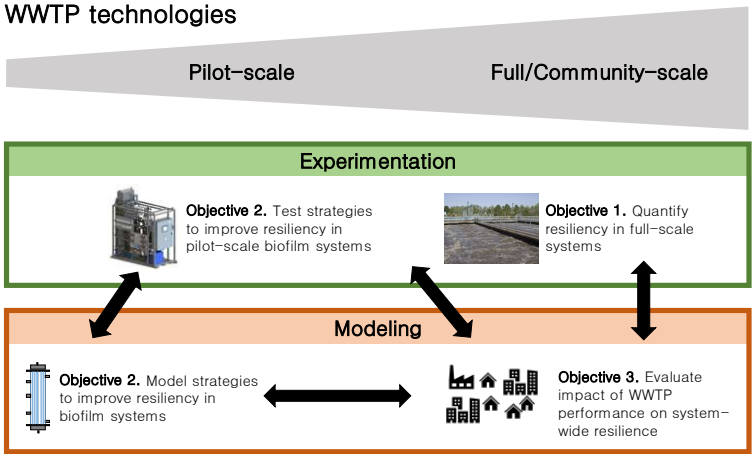
# 3. Upcoming Research

- NSF Funded Project to Investigate Resilience
- Includes MABR and MBBR pilots
- PIs: Dr. Lauren Stadler, (Rice U); Jeseth Delgado Vela (Howard); Lu Liu (Rice U); Andy Shaw (Black & Veatch)
- Starts early 2020?

GOAL: Advance resiliency metrics for current and emerging WWTP technologies

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# 3. Upcoming Research

**Ready to roll!**

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# Q&A

Amit

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## 3 things to remember

- ZeeLung increases treatment capacity & performance while also reducing energy
- Benefits include resilience, simplicity and ease of implementation
- Solves big challenges… intensification, nutrients, energy, sustainability

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