BUILDING A WORLD OF DIFFERENCE

MEMBRANE AERATED BIOFILM REACTORS –OXYGENATED FUN WITH LESS CARBON COST

KELLY MARTIN AND SANDEEP SATHYAMOORTHY

BLACK & VEATCH
Building a world of difference.®

AGENDA

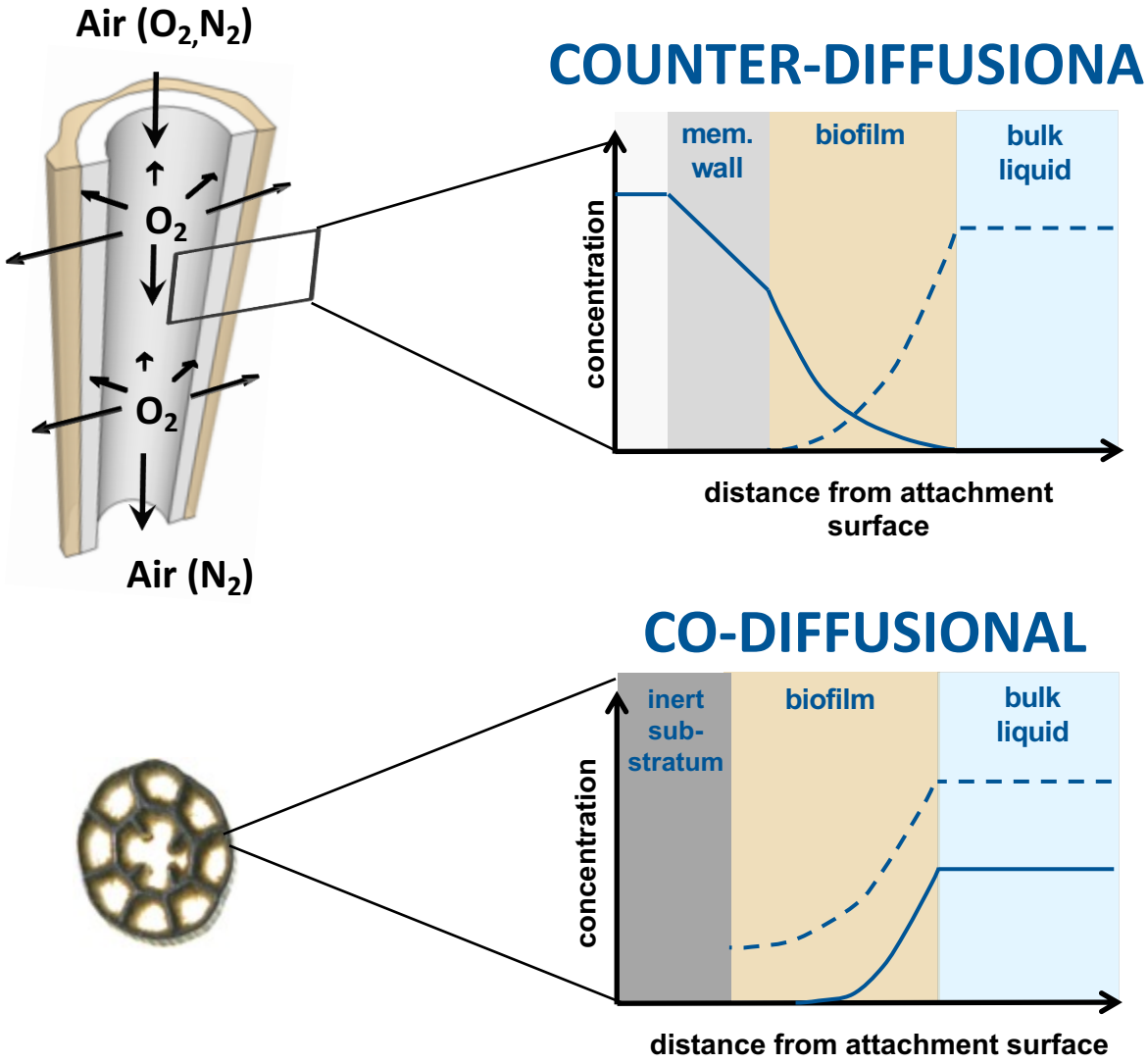
- Background
- Commercialized Technology
- Concept Evaluation

BACKGROUND

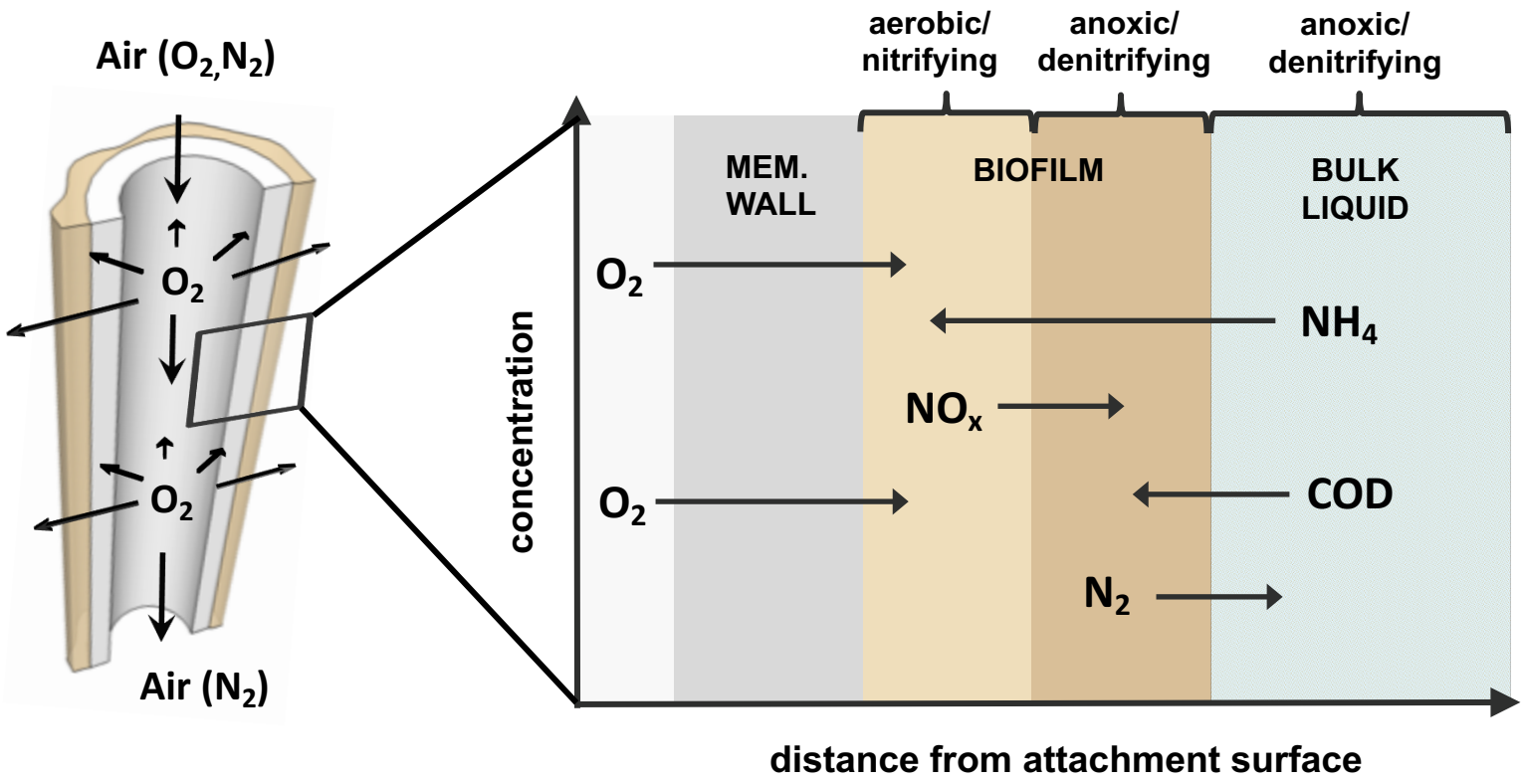
THE MABR PROVIDES ENERGY-EFFICIENT AERATION TO A BIOFILM

gas-supplying membranes support biofilm growth

THE MABR SUPPORTS BIOFILM ON OXYGEN-SUPPLYING MEMBRANES



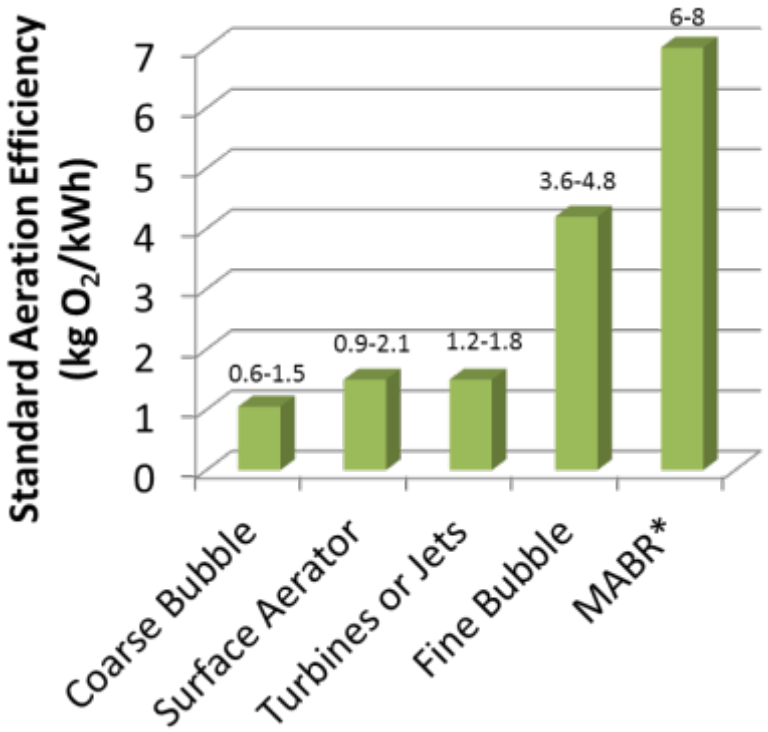
THE MABR SUPPORTS TOTAL NITROGEN REMOVAL



Oxygen is consumed within the biofilm, supporting anoxic conditions for denitrification in outer biofilm and/or bulk liquid.

THE MABR COMBINES THE BENEFITS OF A BIOFILM TECHNOLOGY WITH ENERGY EFFICIENT AERATION

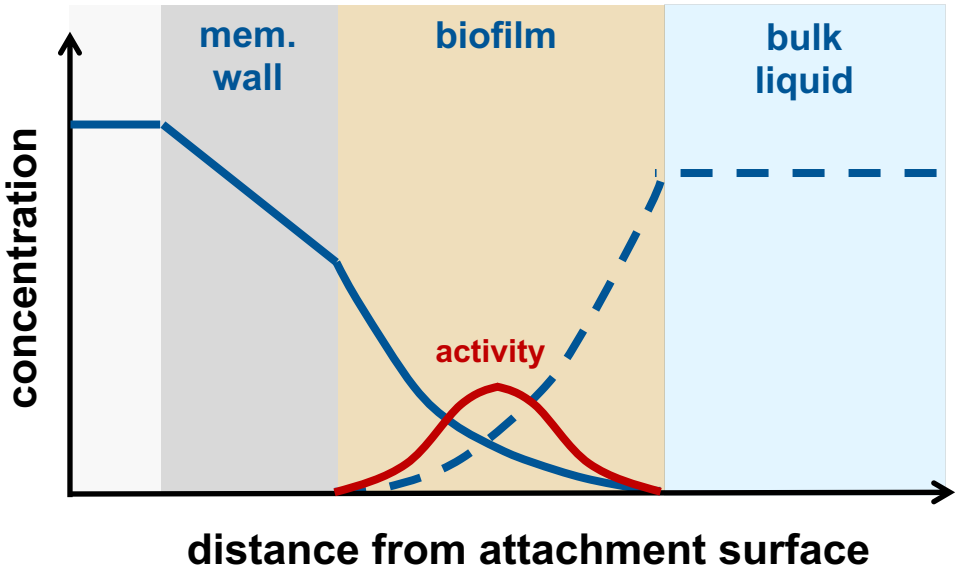
- **Energy Efficiency**
  - OTEs of ~60%, can achieve higher if necessary
- **Total Nitrogen Removal**
- **Lower Sludge Production**
- **Reduced Footprint**



*MABR values provided by manufacturers other SAE values from Stenstrom and Rosso, 2008

UNIQUE MABR CHALLENGE: MAINTAIN A CRITICAL BIOFILM THICKNESS

Support biofilms… ***but not too much.***



MABR TECHNOLOGY DEVELOPMENT

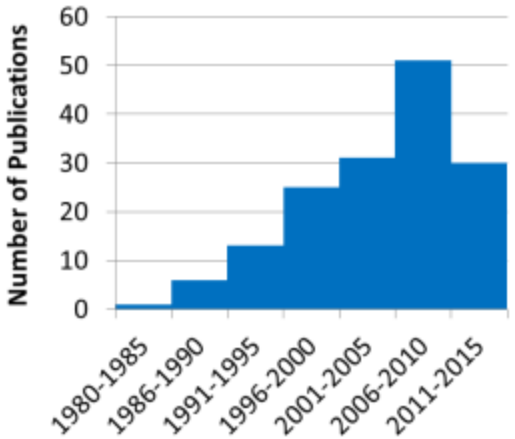
1970s

membranes used to aerate biofilms for wastewater treatment (Yeh and Jenkins, 1978)

1980

First Patent Onishi et al. 1980

lab and pilot scale research



2008-present

Emergence of 3 commercialized technologies

2008: Emefcy SABRE
2013: Oxymem
2015: GE Zeelung

TECHNOLOGY PROVIDERS

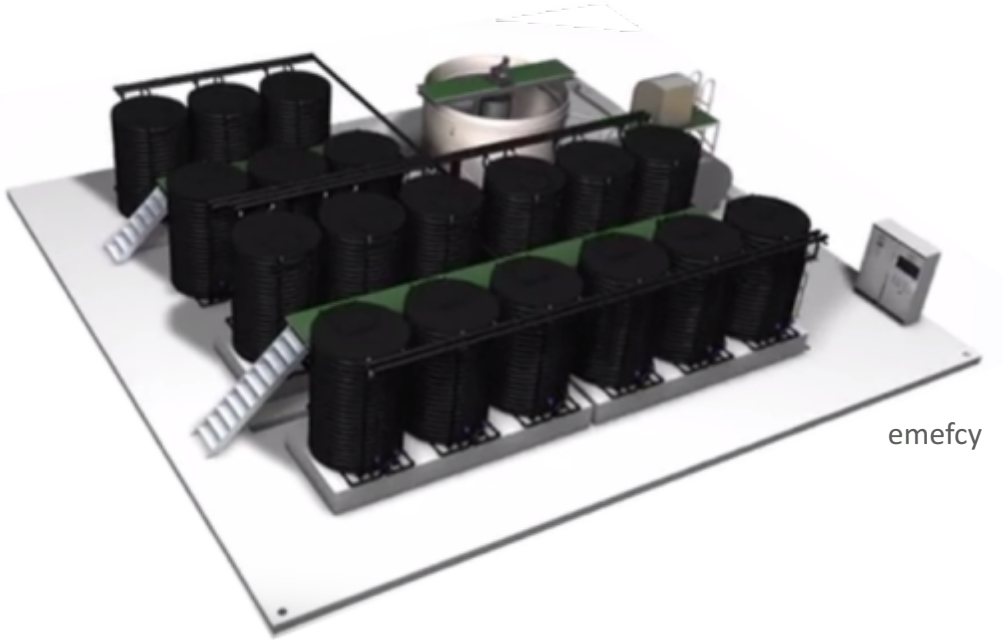
TECHNOLOGY PROVIDERS

Emefcy

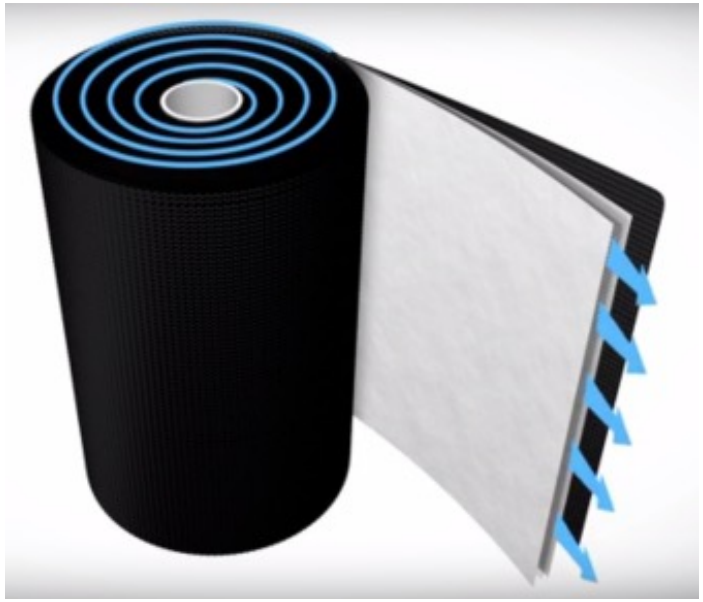
ZeeLung™

OXYMEM
SMART AERATION

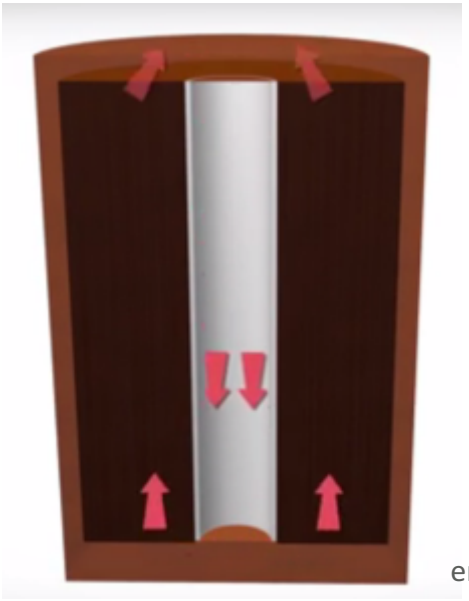
- **Company founded in 2008**
- **Offices in Israel and Australia**
- **Focused on decentralized, remote or developing areas**



emefcy



Spiral-wound module of membrane and spacer



Bubble pulses create airlift-type mixing between spacers

ETHIOPIA

- Hospital Sanitary Wastewater
- 85,000 gpd

ISRAEL

- Reclaimed water from dairy farming wastewater
- 35,000 gpd

ST. THOMAS US VIRGIN ISLANDS

- Rural municipal wastewater
- 25,000 gpd

emefcy

CHINA

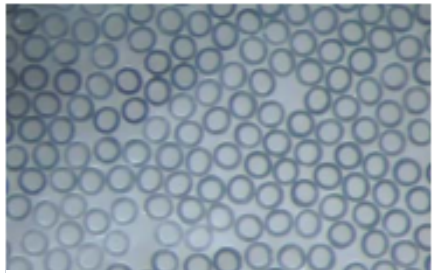
- Demonstration of rural wastewater treatment
- Building of dedicated manufacturing plant

ZeeLung™

- **Uses ZeeWeed™ configuration**
- **Scouring and mixing by aeration grid integral to module**

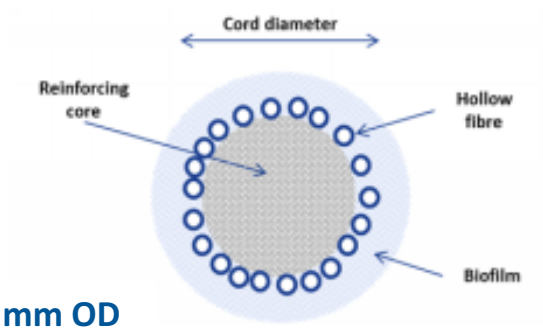
ZeeLung™

a) Hollow fibers



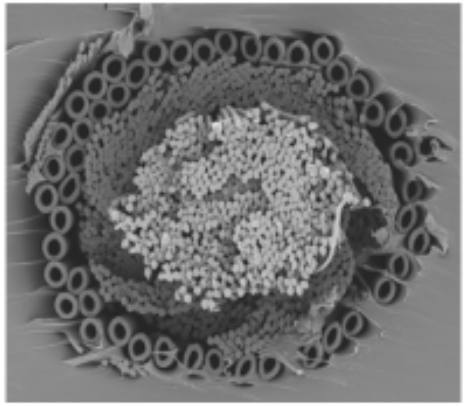
Small diameter <100 µm
Thin wall 15-20 µm

b) Conceptual membrane cord

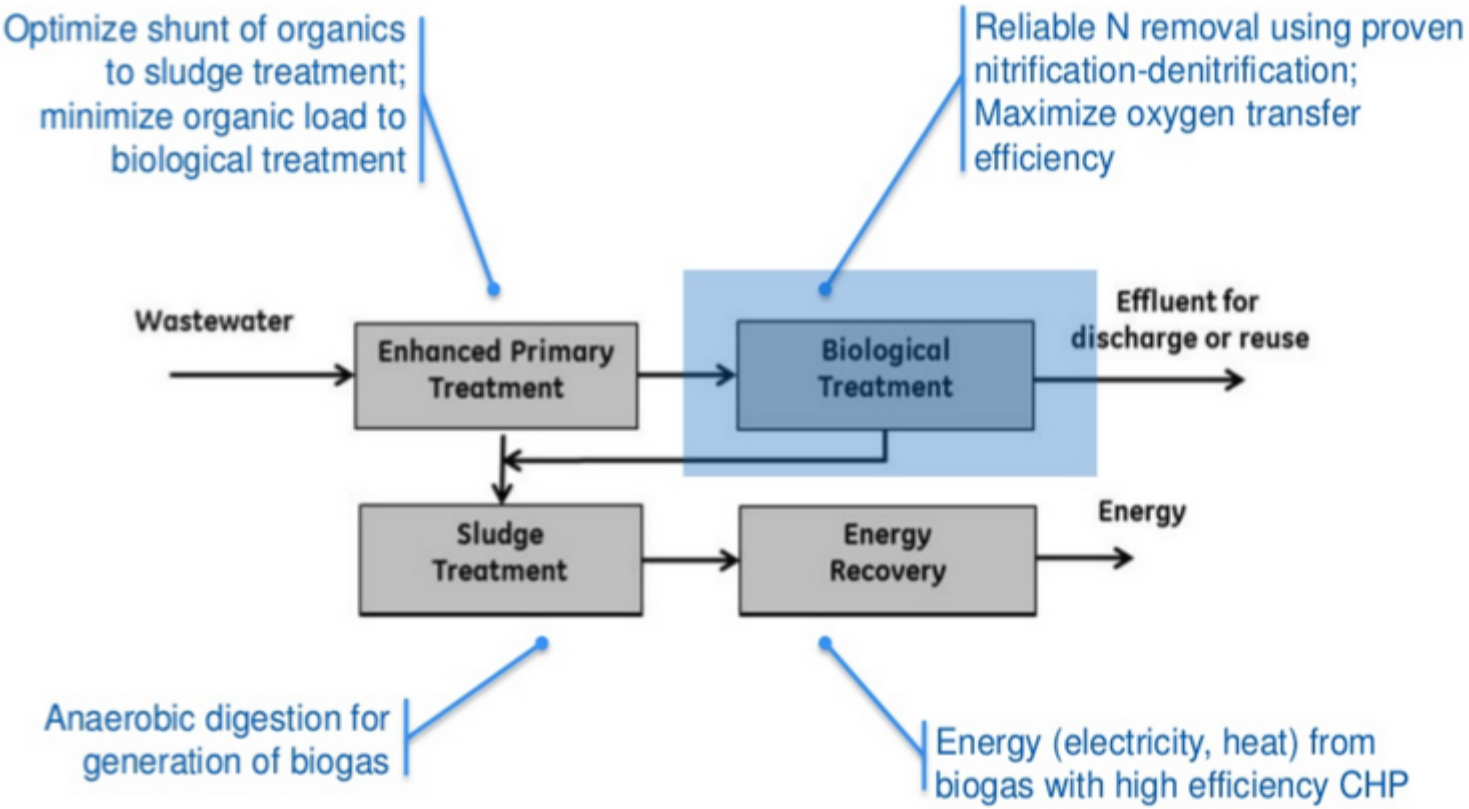


1.2 mm OD

c) Cross-section of membrane cord

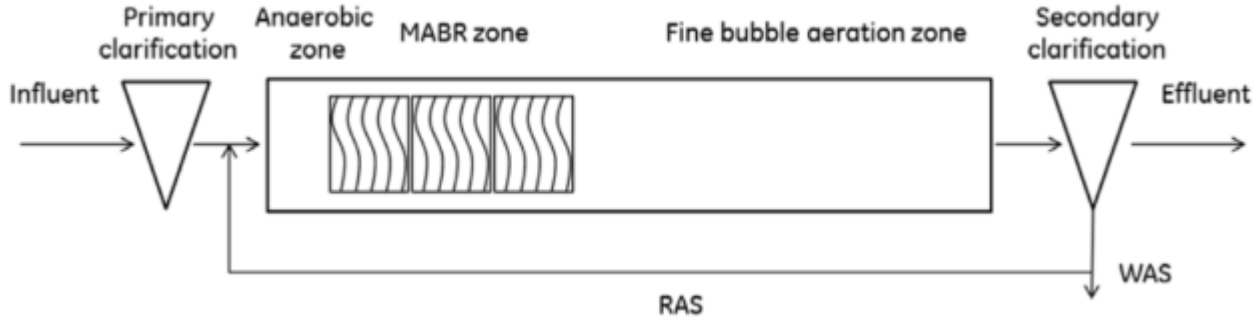


ZeeLung™


Optimize shunt of organics to sludge treatment; minimize organic load to biological treatment
Reliable N removal using proven nitrification-denitrification; Maximize oxygen transfer efficiency
Wastewater
Enhanced Primary Treatment
Biological Treatment
Effluent for discharge or reuse
Sludge Treatment
Energy Recovery
Energy
Anaerobic digestion for generation of biogas
Energy (electricity, heat) from biogas with high efficiency CHP

ZeeLung™ CHICAGO O'BRIEN DEMO

- **Increase in nitrification capability during first flush events**
- **Process intensification for retrofit of CAS to EBPR (Kuentz et al., WEFTEC 2016)**

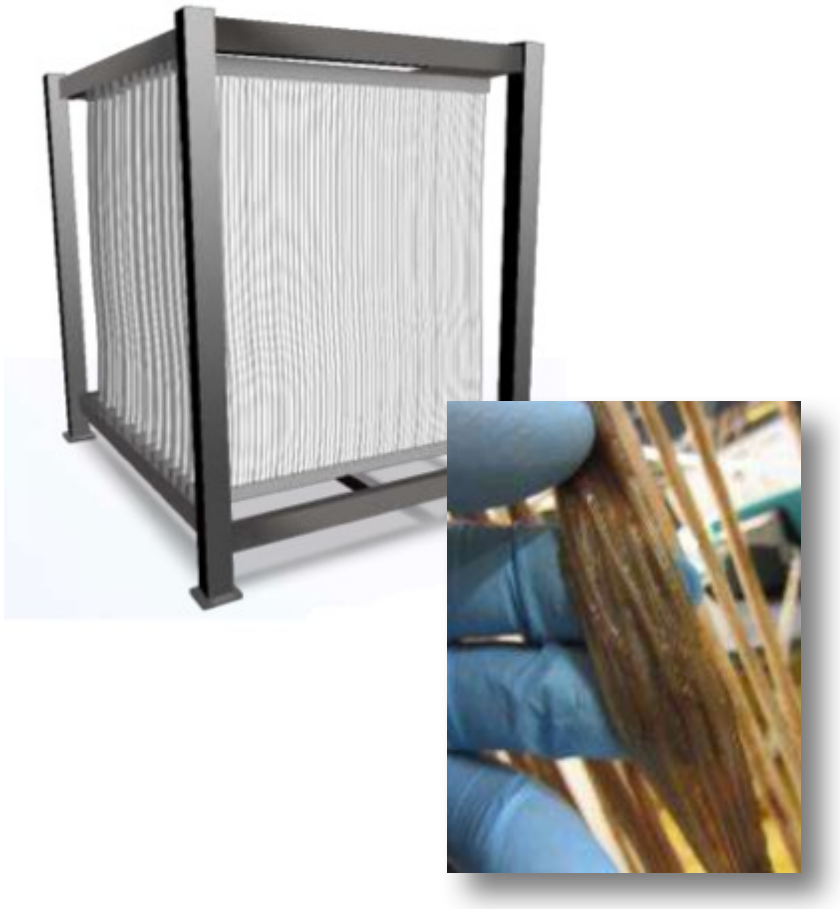


Full scale implementation of the MABR would reduce aeration demand by 30%.

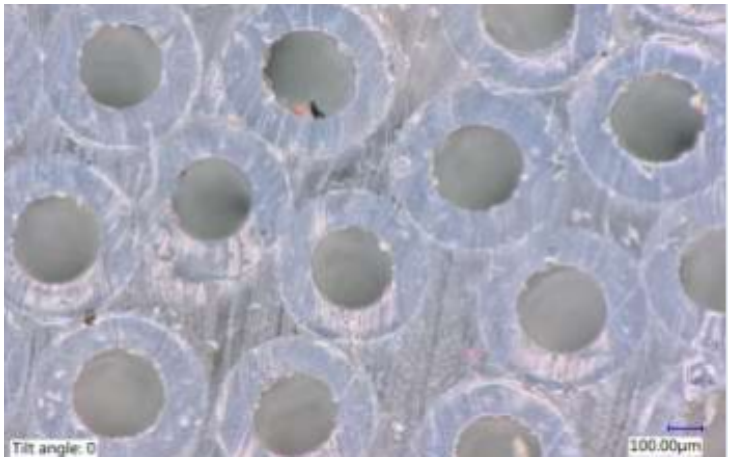
OXYMEM
SMART AERATION

- Technology developed at UC Dublin
- Company founded in 2013
- Patented biofilm control strategy, which uses air scour
- Membrane cassette, package, and standalone options

OXYMEM
SMART AERATION



Silicone membranes
Outer diameter 500 µm
Wall thickness 100 µm



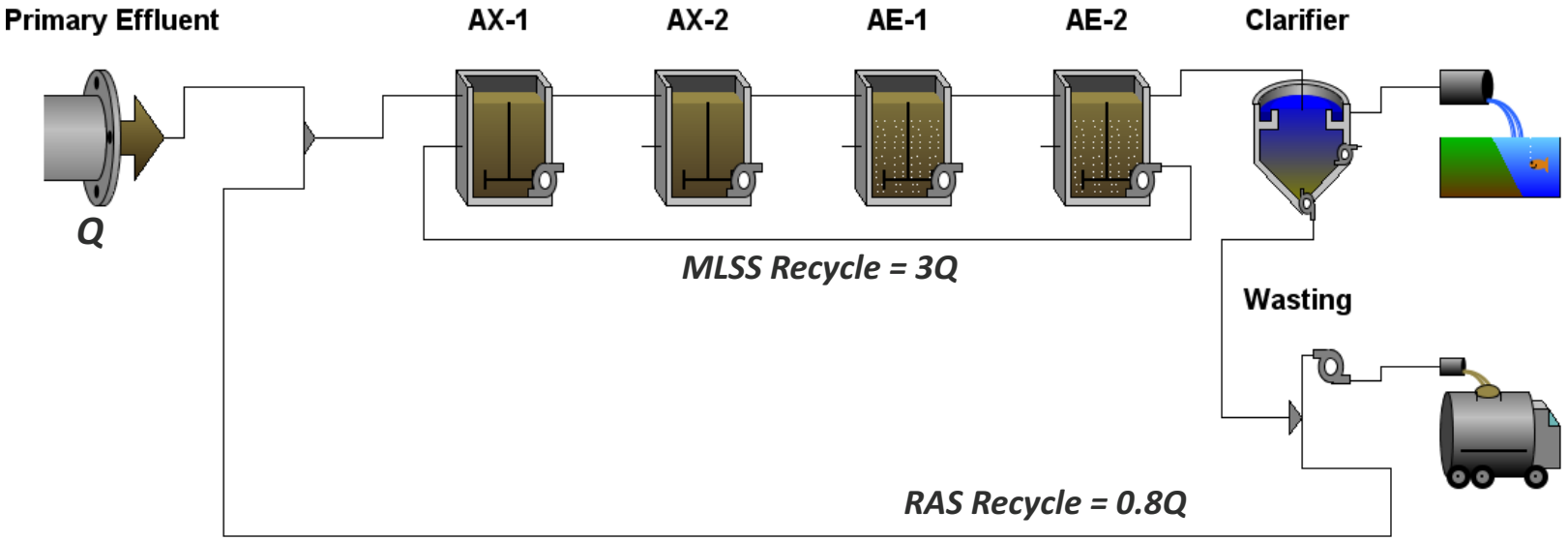
OXYMEM
SMART AERATION

Multiple demonstrations and pilots performed:

- Severn Trent Minworth
  - COD<40 mg/L
  - BOD< 5mg/L
  - NH_4<1 mg/L
  - TSS<30 mg/L
- Case Studies in Brazil and Spain

CONCEPT EVALUATION

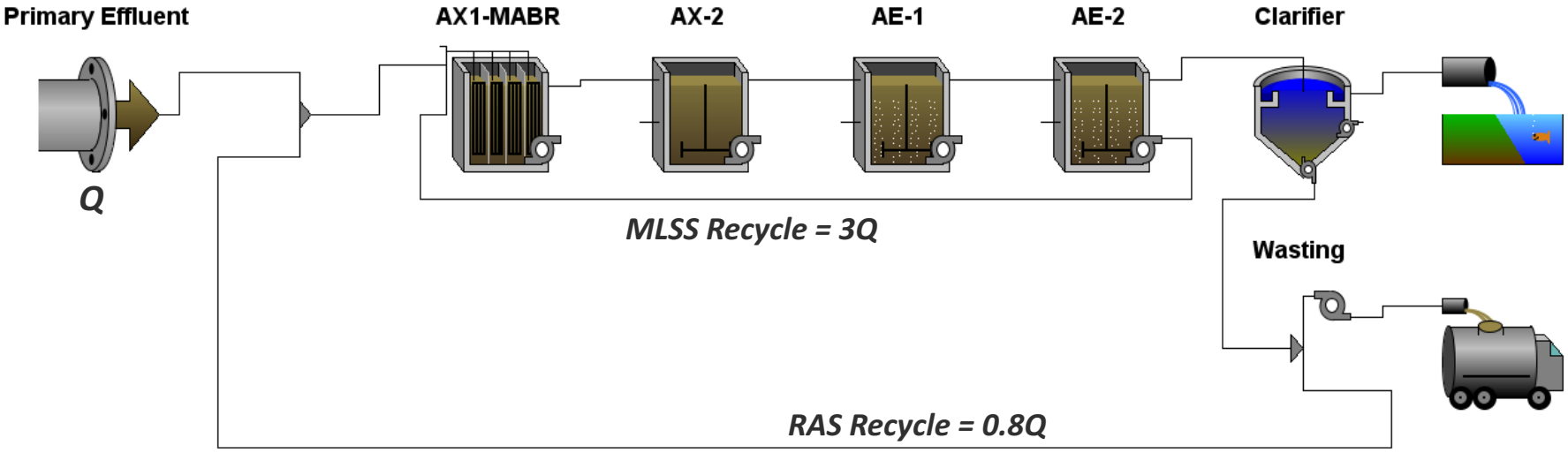
CASE STUDY: MLE



Primary Effluent		
Parameter	Unit	Value
$COD/cBOD_5$	mg/L	270/145
TSS/VSS	mg/L	100/80
NH_4/TKN	mg N/L	35/46.7
PO_4/TP	mg P/L	6/8
Temp.	°C	16.5

Basins		
Zone	DO (mg/L)	HRT (hr)
AX-1	0	1
AX-2	0	1
AE-1	2	1.75
AE-2	2	2

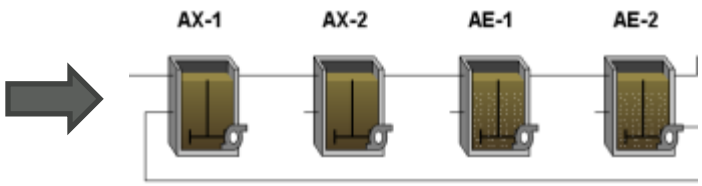
CASE STUDY: MLE-MABR



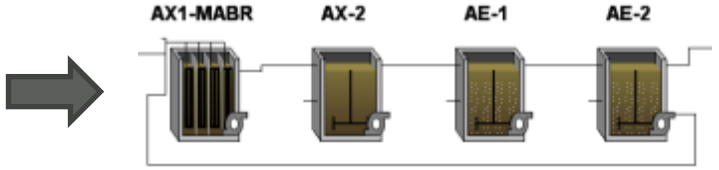
MABR Settings		
Parameter	Unit	Value
Biofilm thickness	µm	250
Mem. surface area	m^2	9
O_2 partial pressure in	atm	0.32
O_2 partial pressure out	atm	0.12

CASE STUDY: MLE-MABR

MLE



MLE-MABR



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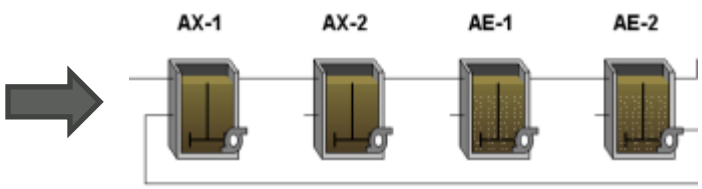

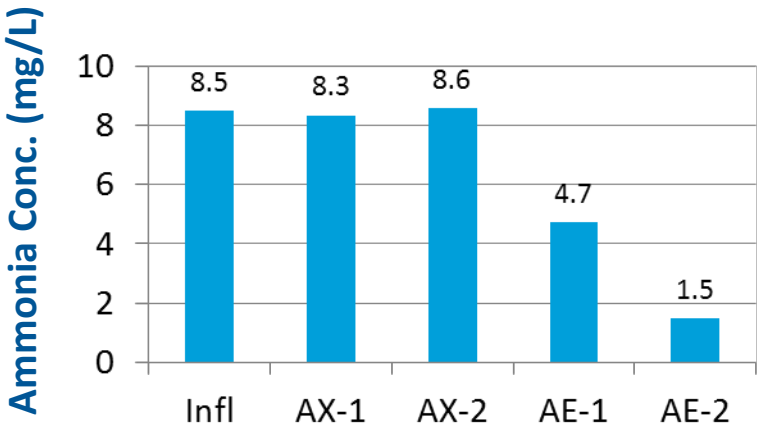

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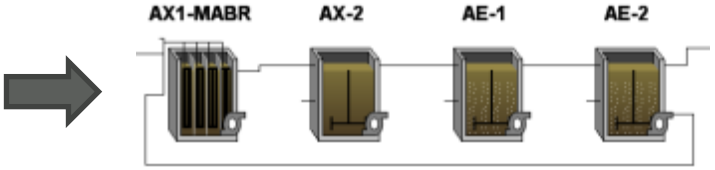

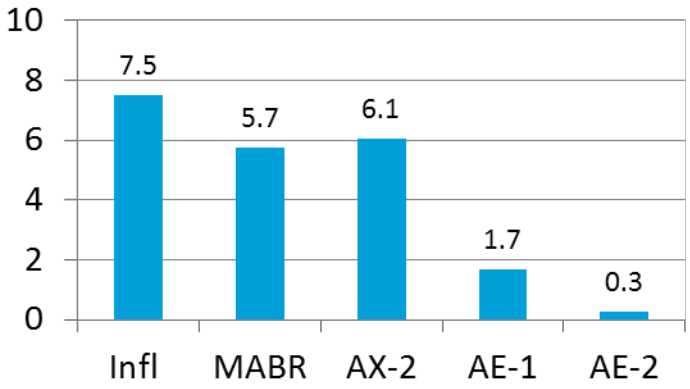

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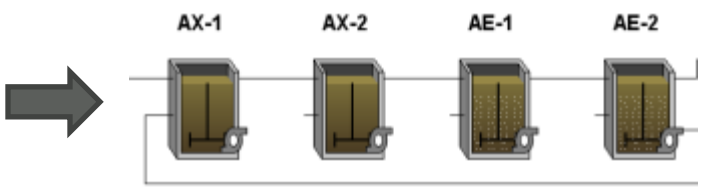

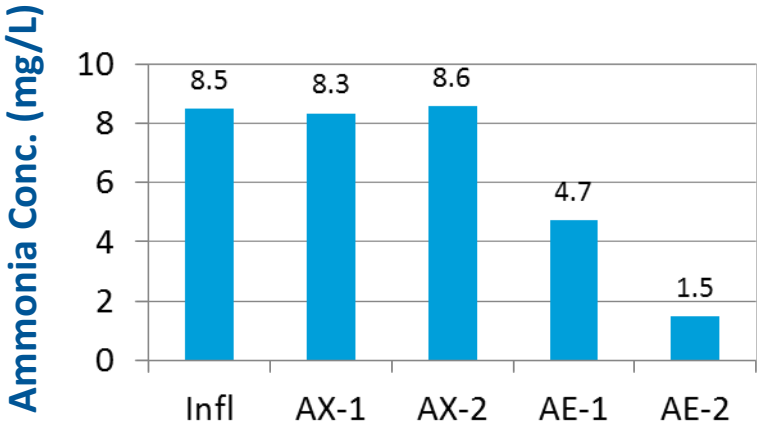

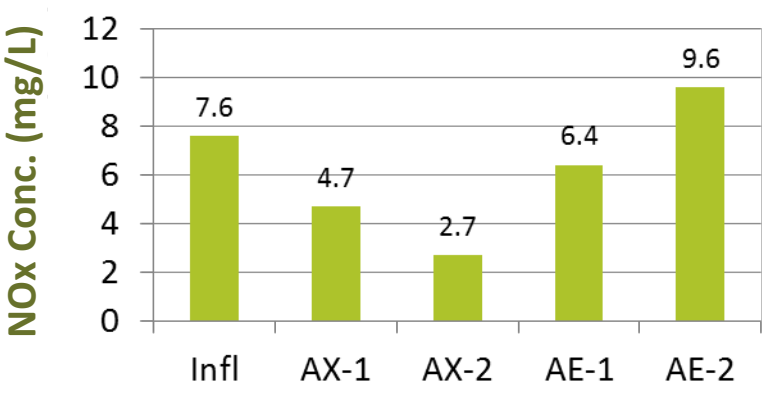

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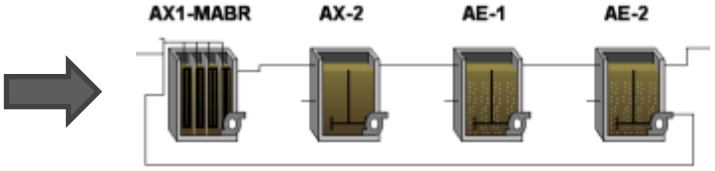

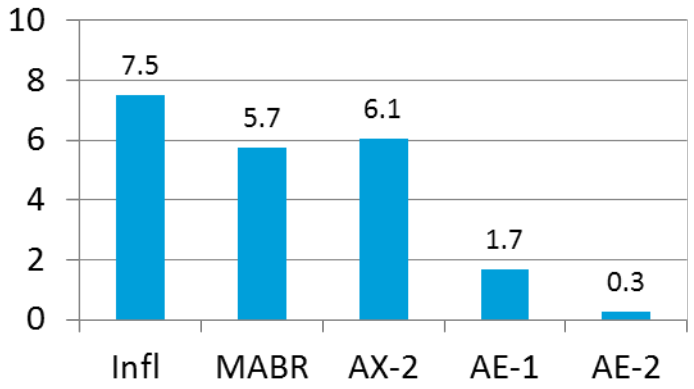

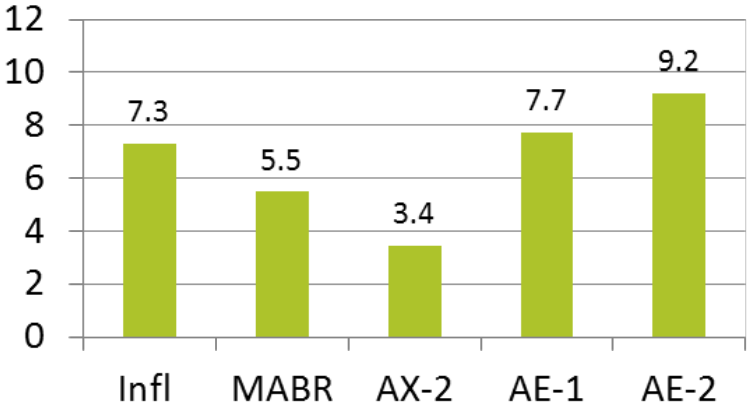

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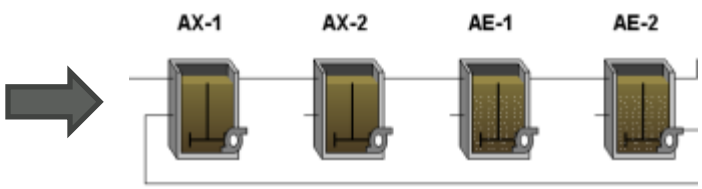

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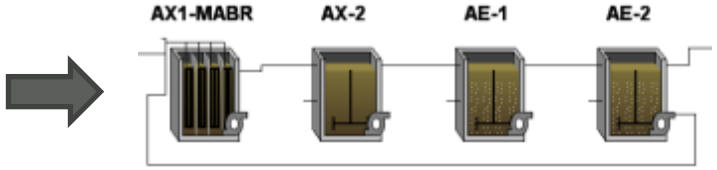

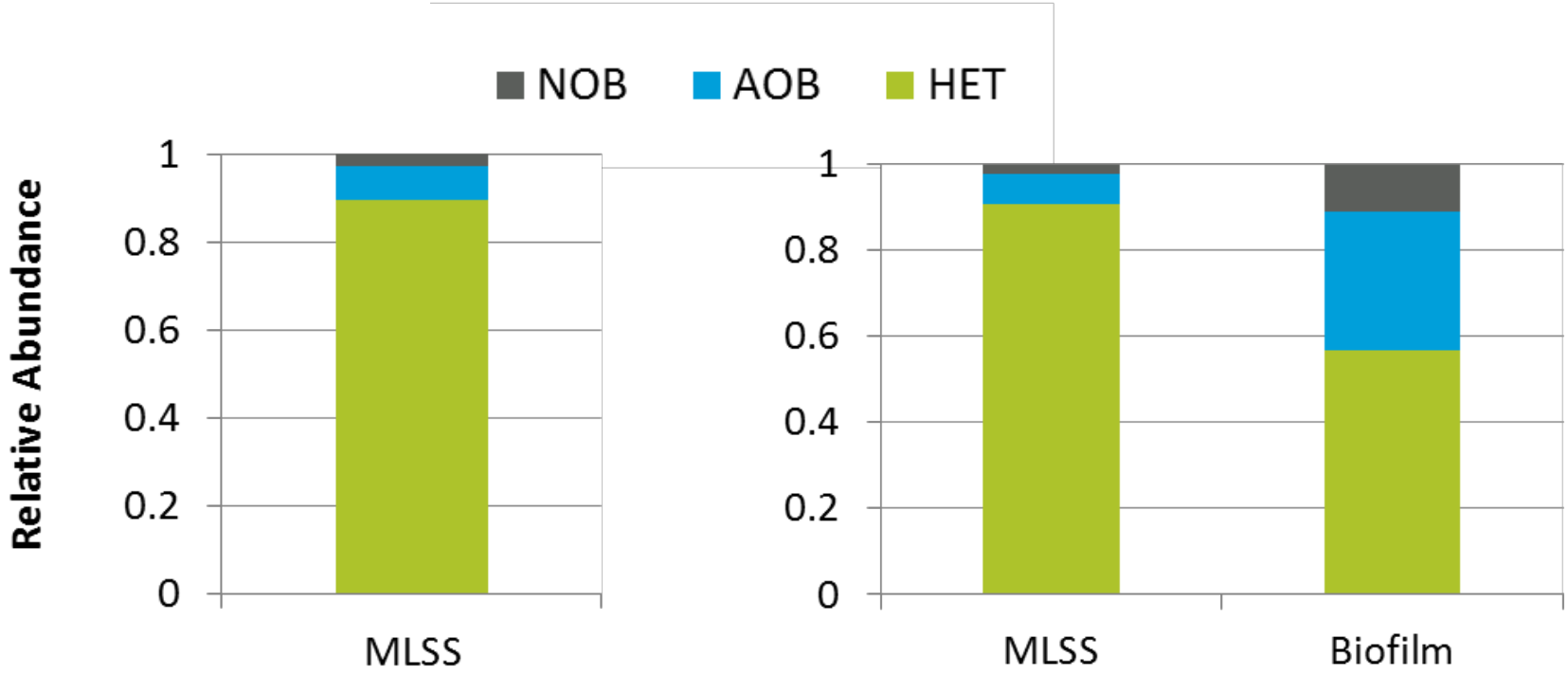

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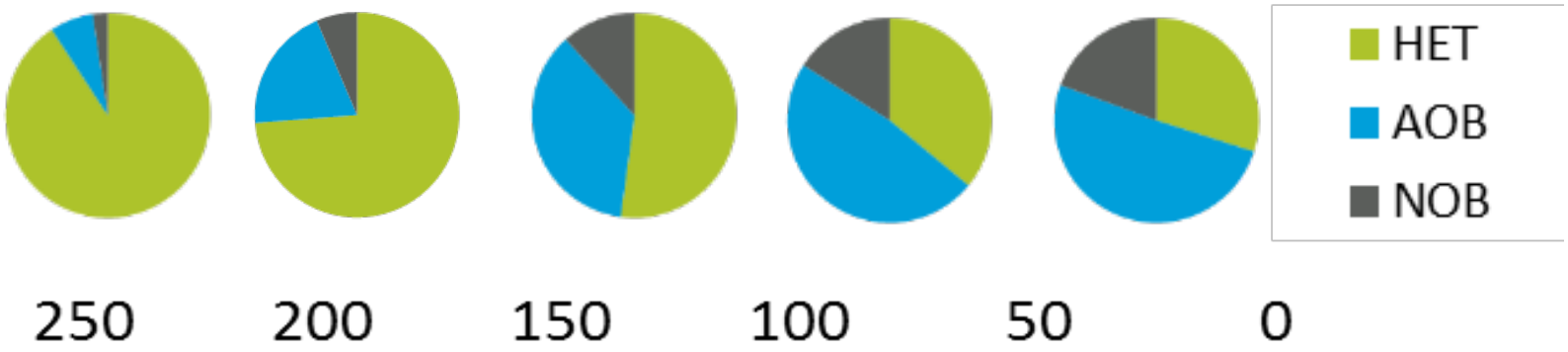
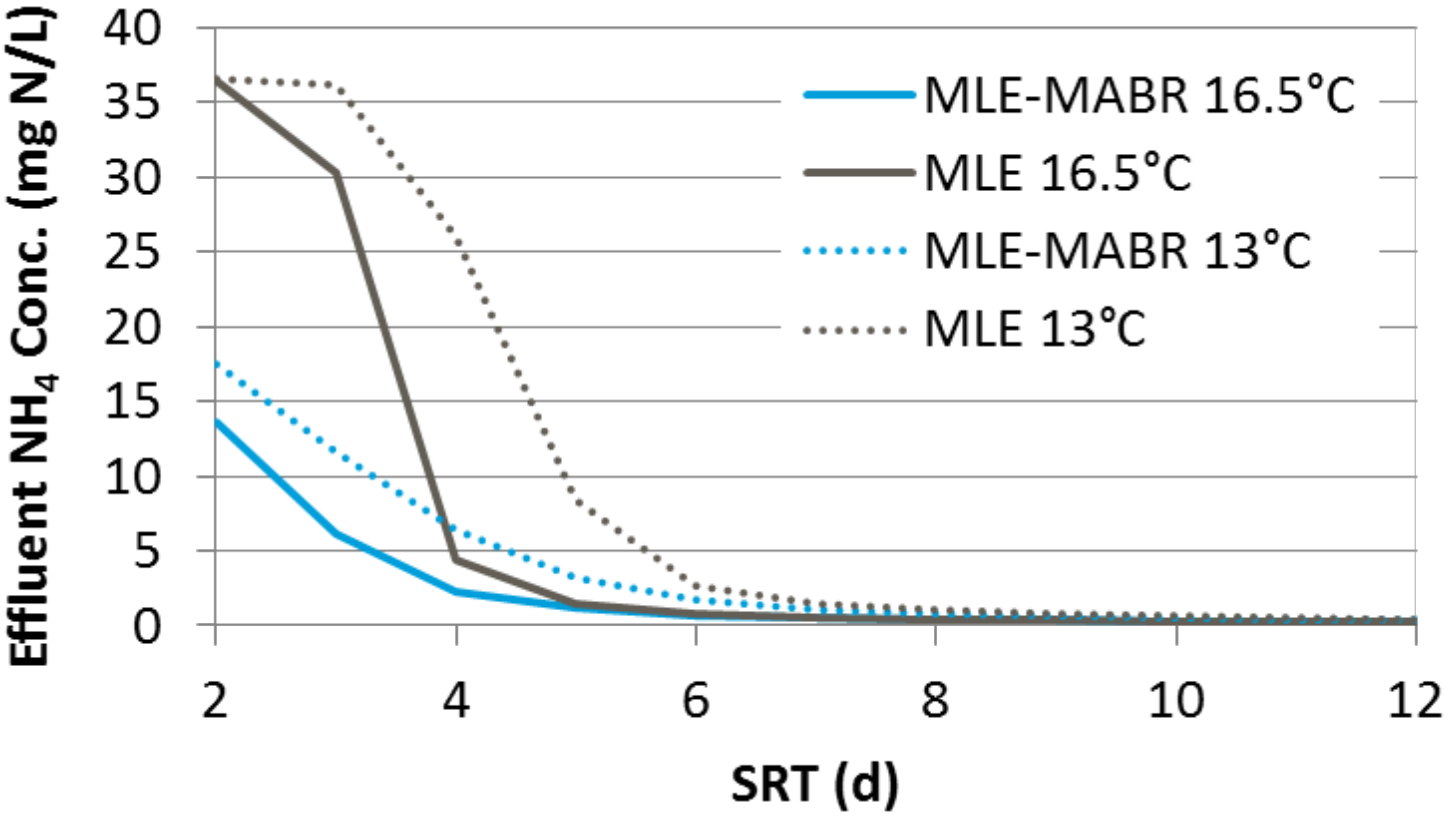


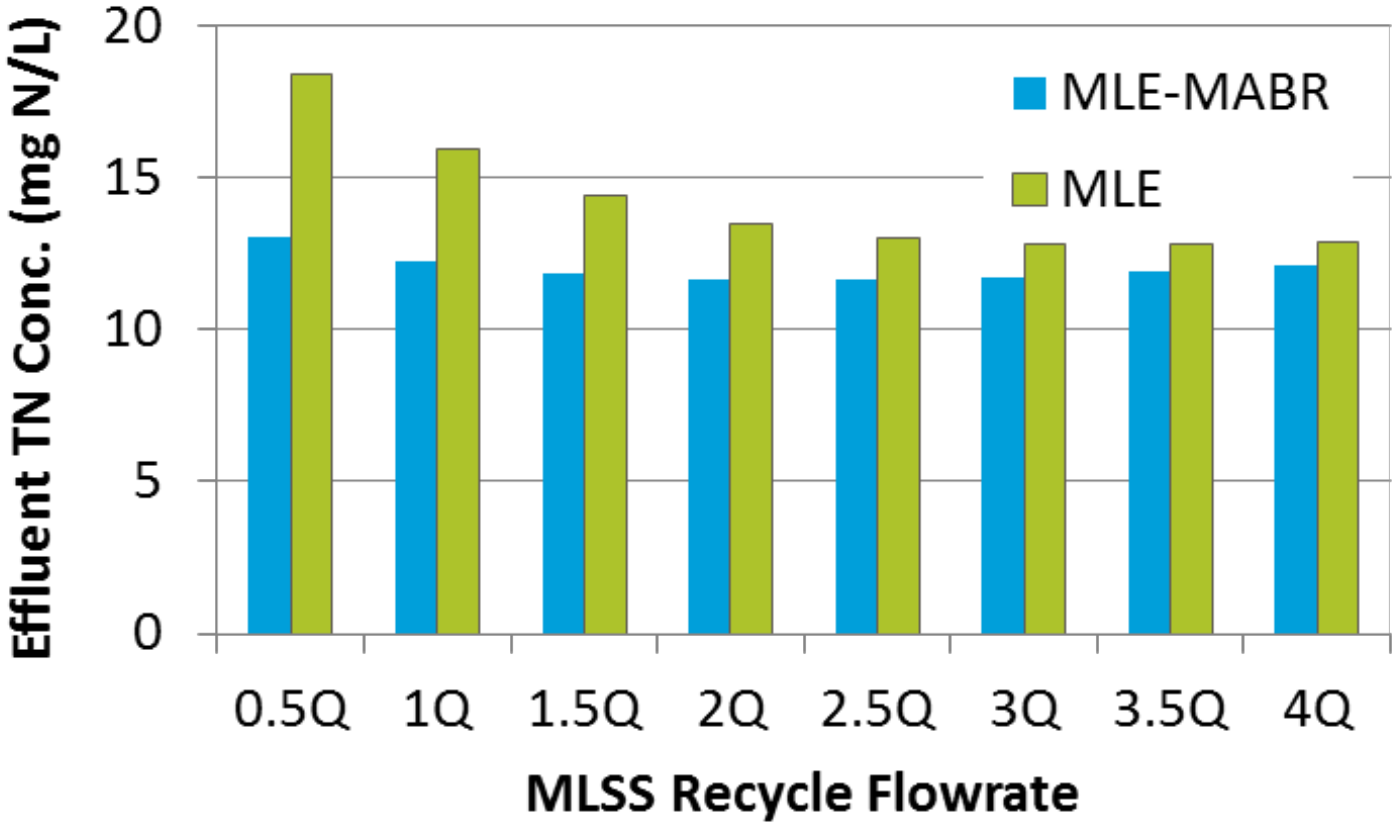
AOB and NOB reside primarily in the inner regions of the biofilm where oxygen is abundant.

NITRIFICATION CAPACITY



The MLE-MABR intensifies treatment and increases nitrification capacity.

DENITRIFICATION CAPACITY



The MLE-MABR requires a lower rate of internal recycle.

COST CONSIDERATIONS

Capital Costs

- Intensified treatment
- Required fine screens
- Limited blower addition
- Membrane life of 20 years

Operating Costs

- Decreased airflow requirements
- Lower pumping requirements
- Lower chemical costs

MABR PILOT STUDY –SUNNYVALE, CALIFORNIA

Start-Up February 2017

BLACK & VEATCH

THE CITY OF SUNNYVALE WATER POLLUTION CONTROL PLANT

KU THE UNIVERSITY OF KANSAS

GE ZeeLung™

CONCLUSIONS

CONCLUSIONS

- The MABR offers the advantage of a biofilm reactor while offering energy savings.
- There are three commercialized MABRs available for municipal wastewater treatment retrofit and decentralized systems.
- The MABR offers energy savings due to increased aeration efficiency and potentially less pumping requirements.
- The MABR may also reduce chemical requirements due to efficient use of carbon for denitrification.

Questions?

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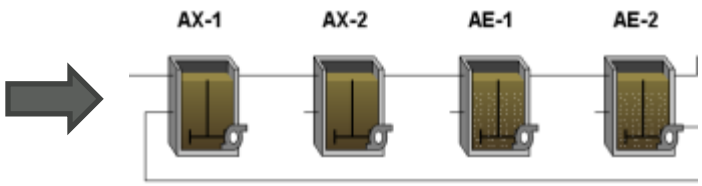
Kansas City, MO 64114

CASE STUDY: MLE-MABR

MLE



MLE-MBBR