# MABR Workshop Breakout Session Notes

## Imagining the Future – Exploring New Applications for MABR; Jeff Peeters, Suez Water Technologies & Solutions

1. Main commercial application today is process intensification – increasing capacity and/or improving nutrient removal in existing tanks
2. Benefits of MABR compared to MBBR/IFAS incude:
	1. Much more energy-efficient
	2. Ability to direct oxygen directly to location in process
3. MABR mimics biology – transfer of O2 and nutrients from the inside rather than outside
4. New/future application ideas:
	1. Improving current application
		1. MABR in aerobic (or swing) reactors
		2. Integration with EBPR (in biofilm or in suspension)
		3. Shifting share of biofilm in hybrid process from 25-50% of treatment to 80%+…  is there a limit wrt biofilm thickness control?
		4. Peak trimming
	2. New applications in wastewater treatment
		1. MABR enabled AMX – mainstream & sidestream
		2. N2O mitigation and/or recovery
		3. MABR in a water reuse system, e.g.; in combination with MBR
		4. Effluent ammonia polishing, e.g.; overcome high energy costs for MBBR (mixing limited)
	3. New applications outside wastewater treatment
		1. Transfer of H2, e.g.; biogas
		2. Transfer of CO2, e.g.; algae, alkalinity

## MABR Process Engineering: What We Know for Sure, What we are Still Contemplating; Ronen Shechter, Fluence

**Discussion subjects**

1. Process staging and IFAS mode: what happens downstream at low loading rate / low concentration? How does MABR influence nitrifiers fraction in the ML? How does MABR operate at low ammonia – is it just low rate by Monod or lower?
2. Mixing frequency – not just scouring, also influences mass transfer. We know that (see last slide on my flash presentation Tue). How is it or how should it be considered in process design –and how can it be modeled?
3. Challenges or Suggestions of the design of MABR reactor: (1) Seasonal community change - how to balance it? and (2) Advection based supply of electron donor or acceptor through the membrane.
4. Phosphate removal with MABR? - With a single stage of MABR might be challenging, but hybridization with other techniques would work
5. How operate MABR? especially advection and diffusion. Flux by advection is vulnerable to detachment. So, Advection based MABR is very challenging
6. Hybridization process with MABR in Anoxic tank - Employ Air as a circulating and mixing forc
7. What is the tips for the starting-up MABR? Answer) (1) Having heterotroph base layer is not ideal if you plan to enrich nitrifying biofilm.
8. Treat higher rates in anoxic tanks where ammonia concentrations are highest
9. How much air is needed for internal mixing and for helping advection?

**Notes from Jamboard**

*< Session 1 >*

1. Treat higher rates in anoxic tanks where ammonia concentrations are highest
2. Super selection of different communities using different approaches and nitrifiers are best for MABR
3. How operate MABR? especially advection and diffusion.. Flux by advection is vulnerable to detachment. So, Advection based MABR is very challenging
4. Regarding process staging, the MABR + polishing for biofilm is logical.
5. Challenges or suggestions of the design of MABR reactor: (1) Seasonal community change - how to balance it? and (2) Advection based supply of electron donor and acceptor through the membrane
6. How to design for TN removal - internal ciculation into the MABR or a downstream anoxic volume

*< Session 2 >*

1. Hybridization process with MABR in Anoxic tank - Employ Air as a circulating and mixing force.
2. What is the tips for the starting-up MABR? Answer) (1) Having heterotroph base layer is not ideal if you plan to enrich nitrifying biofilm...........................
3. Phosphate removal with MABR? - With a single stage of MABR might be challenging, but hybridization with other techniques would work How much air is needed for internal mixing and for helping advection?

## MABR Biofilm Thickness Control; Barry Heffernan, Oxymem

**Round 1:**

1. Difference between pure biofilm and IFAS biofilm with AS in terms of biofilm control and importance:
	1. Carbon process differently: in pure biofilms all carbon is processed in the biofilm, in IFAS with AS carbon is processed by both biofilms and suspended growth
2. Carbon concentrations or loads, which is more important in terms of impact on biofilm growth
	1. Load gets into the biofilm
	2. High concentration of COD is not a problem for system of treating COD
	3. Low concentration of COD may cause a problem of biofilm thickness for systems doing nitrification because of the potential massive carbon loading for biofilm growth
3. Lessons learned from trickling filters:
	1. Hydraulic application rate to prevent excess biofilm
	2. For MABR biofilms: when is necessary to exert biofilm control and when is not?
4. What problems are caused by excessive biofilms?
	1. Substrate diffusion limitations
	2. Clogging and channeling
	3. the challenge is to let massive flows enter membrane
	4. Mass transfer resistance
	5. Too thick biofilm results in structural problems and biomass loss, need time for its rebuild
	6. Temperature related issues: not seen
5. Can system be less susceptible to the temperature variation due to hot air seeding biofilm & can hot air keep the biofilm temperature:
	1. Hot air cannot change much temperature of system because of the massive thermo mass of water
	2. Heat generated by biodegradation of COD keeps the temperature of liquid
6. Will too thick biofilm cause massive structural loss?
	1. A gas scouring system is used to prevent and unclog too thick biofilm
	2. Exhausted gas is collected to scour air bubbles onto the biofilm continuously (Suez) or intermittently (OxyMem), also for mixing
	3. Oxymem biofilm control: 2-3 mins/day scouring for energy saving, use inert gas to measure biofilm thickness

**Round 2:**

1. Oxymem biofilm thickness control:
	1. One blower for process air for aeration, and another for large bubbles scouring for thickness control
	2. biofilm thickness indicator, scouring decision processor
	3. Use inert gas (Argon) and pressure decay test to measure relative biofilm thickness, which is used to control the scouring blower
2. Oxymem findings:
	1. For municipal system with pure biofilm: control scouring can increase nitrification rates (more than doubled)
	2. The amount of oxygen transferring the membrane is not changing: too low COD-over aeration-no denitrification
3. Suez biofilm thickness control:
	1. Bubble generators underneath the membrane
	2. Process air collected to generate bubbles for biofilm thickness control and mixing
4. Do you control thickness in hybrid biofilms?
	1. Yes, use the same control system
	2. Self-control: winter-higher SRT-thicker biofilm, summer-lower SRT-thinner biofilm
5. Hybrid MBBR vs. MABR:
	1. MBBR: cannot be placed at the beginning of the plant for nitrification due to outcompete of nitrifiers, no active biofilm thickness control but rely on the shear
	2. MABR: cannot stop nitrification
6. Pure biofilm system:
	1. Nitrifiers are close to membrane
	2. Heterotrophs near bulk liquid
	3. SND
	4. Loading rate controls the thickness is more important than active controls
	5. Biofilm density more important
	6. Enough COD loadings result in no DO in the bulk liquid and SND with no flocs
7. Hybrid biofilm system:
	1. Prefer nitrifiers in the biofilm but heterotrophs in the bulk liquid (never happen)
	2. Competition is always there
	3. MABR cannot be put in an anaerobic tank because O2 and nitrate will consume VFA and inhibit bio-P
8. EPS production in pure and hybrid biofilms:
	1. Differences are expected but more research is needed

## Modeling MABR’s; Kelly Gordon, Black & Veatch

**Session 1:**

1. Question: What MABR question are you trying to answer through modeling, and what type of MABR model do you use to answer it? Why do you choose this model?
	1. **What model complexity is required?**
		1. **Speed is important** in terms of number of layers
		2. **15-20 layers could be an optimum but could be impractical**
		3. What is a reasonable **oxygen concentration within the membrane**? This can create super-saturation and potential voids in the biofilm.
	2. What is the number of layers, and how does it relate to solving ODEs?
		1. How important is hydrolysis? **Rate of attachment and solids transfer** of particulates is important, since it makes the top layer appear similar to the bulk liquid sludge
	3. How complex do the models have to be?
2. Sticky notes: (stickies are grouped by theme)
	1. How to model MABRs with regard to complexity:
		1. “How do we include **variable density** in the **layered biofilm models** and still maintain the mass transfer between layers?”
		2. “I am most interested in **spatial/continuum models**. My background is in fluid/structural interactions. Is it more realistic to have **layered biofilms**? The layers must be dynamic?
		3. “My background is to use biofilm models to model granules. My question is that does anyone observe the phenomena that except for oxygen, other substrates (like ammonia, nitrite, nitrate, and phosphorus have a small change in concentration?” - could be caused by number of **layers**, fully **penetrated biofilm**, or insufficient biomass (**density/thickness**)
		4. “Few years from now how **complex** are we looking to make our models? Will a “**simplified mode**l” be able to still answer our questions?” practicality tradeoff between time and accuracy (think of goal of model and question being asked). Can machine learning be incorporated to make faster, more efficient models?
	2. Metabolisms:
		1. “Anammox + MABR”
3. Overall summary of breakout room themes:
	1. Model complexity in terms of runtime and accuracy
		1. Layers vs. continuum
		2. Biomass density
		3. Solids attachment and detachment
		4. Simplified model and machine learning

**Session 2:**

1. Will **void space** disturb modeling?
2. How is **aeration modeled** and what is the impact of **scouring**? How does this result with modeling biofilm thickness – it makes everything complicated!
3. Do you have continuous vs. discontinuous scouring?
4. **How do you measure attachment and detachment?**
	1. **Biofilm thickness** is the key user input and will control the attachment and detachment rate
	2. Need to think about “nitrifier SRT”
	3. Concept of **interlayer mixing** is important
	4. Not just the outer layer is detached
	5. Impact of **seeding**?
		1. How is this **validated with experimental models**?
	6. Are most of the practitioner models using detachment as proportional to thickness?
	7. For **anammox** MABRs, how important is detachment?
5. For **initial conditions** for MABR modeling, how important is the starting community? (depends on the question/goal and type of model)
	1. How long is process performance increased for a membrane that is pre-seeded?
	2. Growth rates are important here!
	3. How were the initial conditions in literature chosen?
6. Overall summary of breakout room themes:
	1. Importance of attachment/detachment
		1. interlayer mixing
		2. Seeding
		3. Biofilm thickness
		4. scouring
	2. Seeding and initial conditions