OxyMem, The Flexiable MABR.

Eoin Syron, Barry Heffernan
Oxymem Ltd, Blyry, Athlone Co Westmeath, Ireland
Esyron@oxymem.com

Abstract

The Membrane Aerated Biofilm Reactor (MABR) has moved from the pilot stage through the demonstration stage and is now a commercial available technology for the biological treatment of wastewater. The MABR is carrying on with the current trend of engineering reactors to provide specific conditions which take advantage of non-sterile environmental bio-technology processes. The counter diffusion of the oxygen and substrate in the membrane attached biofilm provid a unique and controllable environment for processes such as simultaneous nitrification/denitrification as well as high rate systems utilising pure Oxygen. The OxyMem MABR which utilised PDMS hollow fibre Membranes can be used in various configurations to achieve efficient and economical treatment outcomes

Keywords
MABR, Biofilm, Membranes.wastewater

Introduction

The treatment of wastewater by biofilm systems is older than the activated sludge process, with the first Trickling Filters being installed in the late 1800's. The process characteristics that made biofilm systems attractive initially, such as biomass retention, decoupling of SRT and HRT, low solids production and ability to withstand shock loads are still valued today. But thanks to improvements in reactor design it has been possible to improve the processes. Today biofilm systems have very high rate of reaction, can be used to encourage the growth of specific bacterial such as Anammox and by controlling parameters such as DO and pH even achieve multiple processes in one reactor. The MABR is next stage in this reactor development and because of the counter diffusion of Oxygen and the pollutants the MABR allows for another level of control in a Biofilm Reactor. While initially the MABR was seen as simple a more efficient aeration system (Onishi, 1980) (Yeh and Jenkins, 1978) it is now being used to provide specific treatment requirement, increased treatment capacity along all the time utilising the efficient aeration system. The OxyMem MABR system utilises dense hollow fibre silicone membranes to supply oxygen to a biofilm that grows on the membranes and treats the pollution in the wastewater. The membranes thus have a dual function, they provide oxygen to the system and act as a support for the bacteria to grow on. The OxyMem MABR combines biological treatment for carbon and nitrogen removal which brings effluent to required discharge standards, all incorporated into a compact structure. The OxyMem MABR creates an ideal environment to support a robust biofilm which absorbs and consumes carbon and nitrogen based pollutants. The OxyMem System has been demonstrated at various sites across the world and with the results being discussed in this paper.

Methodology

In all cases the OxyMem MABR uses silicone hollow fibre membrane with an outer diameter of >510um and an inner diameter of 300um. Air or Oxygen is supplied at pressures <200mBar, with a continuous flow through the hollow fibres. This is to remove any gasses or water vapour that diffuse back into the hollow fibre membrane.

Figure 1: images of the OxyMem hollow fibre membrane.

The membranes are placed into a module containing over 2100m2 of surface area available for biofilm growth and oxygen transfer occupying a volume of 4.5m3. Mixing around the membranes is carried out by creating a flow pattern that encourages the wastewater to flow parallel to the membranes. Biofilm grows naturally when the membranes are place in municipal wastewater, or a seed can be used to speed up the biofilm development. The Oxymem system can be operated as a biofilm system, where all the nutrient removal is carried out in the membrane attached biofilm. In this case, the only suspended solids leaving the system are detached biomass. The OxyMem can also be operated as a combination Fixed Film-Activated Sludge process, where the treatment is carried out by both the attached Growth and the suspended growth at the same time. This allows for differences in microbiological populations between attached and suspended growth (Downing & Nerenberg, 2008). For example, due to Oxygen being supplied directly to the membrane attached biofilm, Ammonia Oxidising Bacteria AOB can grow in the biofilm without the need to provide dissolved oxygen in the bulk liquid. This allows for simultaneous nitrificiaton and denitrificiation with the easily biodegradable COD being available for the de-nitrifying micro-organisms in suspension

Figure 2: OxyMem MABR installed in Aruja Brazil

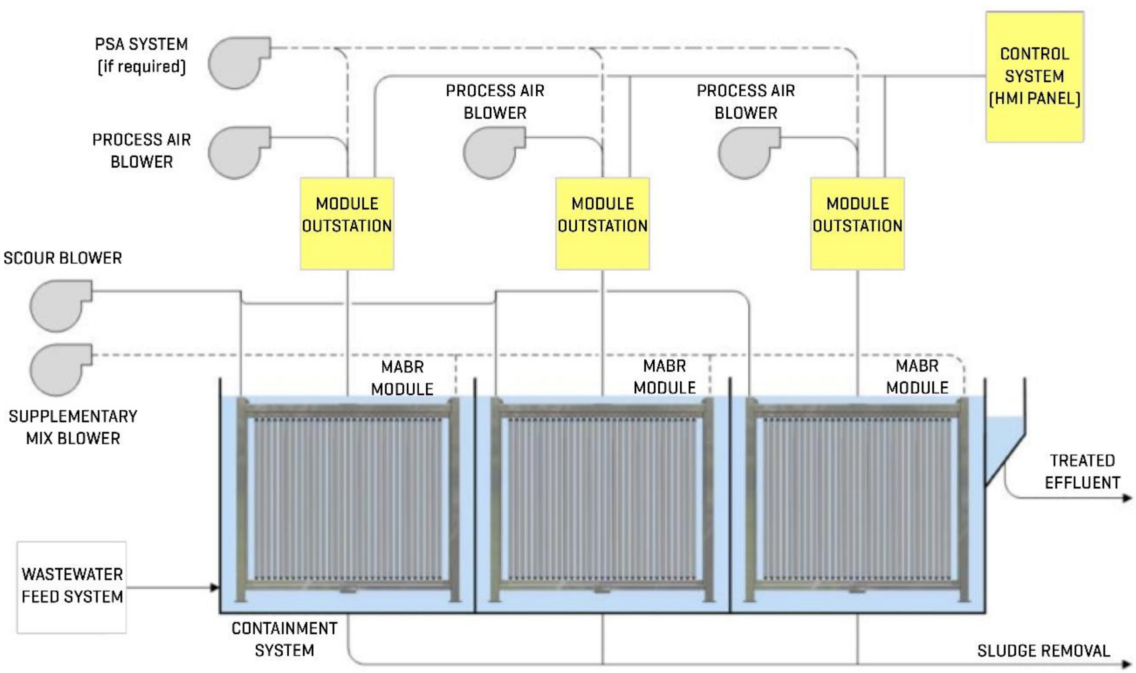

Figure 3: Schematic of an OxyMem System operating as a pure biofilm treatment system.

OxyMem MABR systems are operated will low air pressure inside the hollow fibre membranes typically 200mBar, with air being exhausted constantly from the membranes. This air can be analyse to calculate the Oxygen transfer rate and provide real time feedback on the activity of the micro-organisms attached to the membranes (respirometery). Along with the online calculation of the OTR when operating as a pure Biofilm system the Oxygen Uptake Rate OUR can be calculated by analysing the influent and effluent samples for COD, BOD, N-NH4 and NO3.

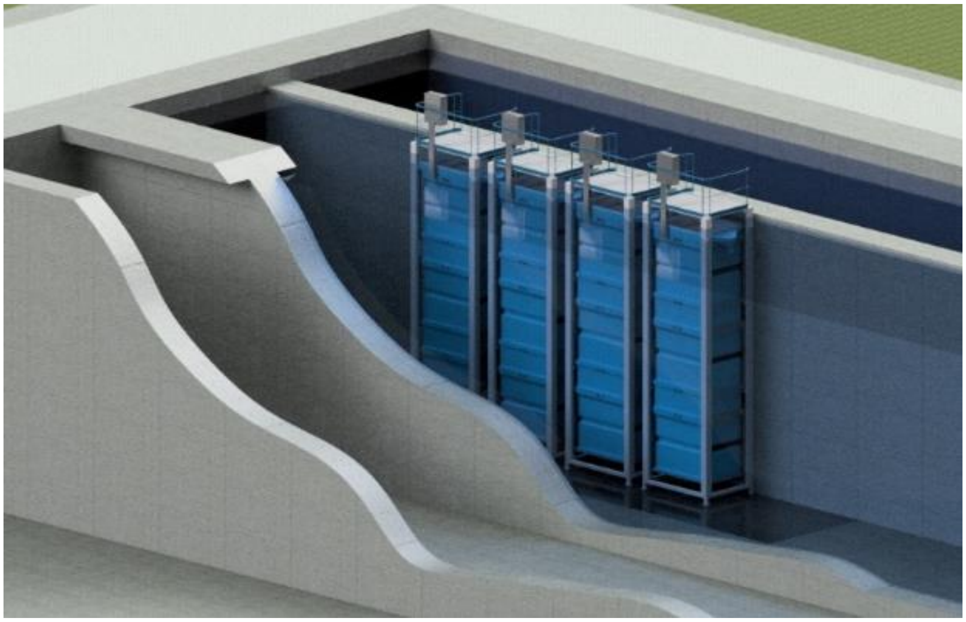

Figure 4: Schematic of OxyMem MABR Retrofitted into an existing Activated Sludge Lane.

Results,

To date Oxymem systems have been installed to treat both Municipal and Industrial wastewaters and has achieved both high loading rates as well as low energy utilisation in both types of installation. A summary of the results achieve is shown in Table 1.

	Country	Type of Wastewater	Flowrate (m^3/day)	Vol (m^3)	Performance				Modules
					Inlet	Removal	Effluent	Energy/ Sludge	
GEN 3	Algeria	Domestic/ Municipal	100	15m^3					2
	Brazil	Municipal (Lagoon)	90	27m^3	COD 300-400mg/l BOD 100-170mg/l sCOD 150-200mg/l N-NH4 35-55mg/l TSS 70-130mg/l	COD>80% BOD>90% N-NH4>80% TSS>90%	COD<80mg/l N-NH4<10mg/l TSS<10mg/l BOD<10mg/l	0.15 kWh/m3	3 (Air)
			170			COD>70% BOD>90% N-NH4>50% TSS>90%	COD<100mg/l N-NH4<20mg/l TSS<15mg/l BOD<20mg/l		
	Netherland	Industrial (Food Manufactur er)	6	9	COD 10,000-12,000mg/l sCOD 4,000-6,000mg/l N-NH4 50mg/l TSS 6,000-9,000mg/l	COD>50% sCOD>80%	TCOD ≈ 5000 sCOD ≈ 1000		1 (O_2)
	Spain	Municipal (Post primary Clarifiers)	130	Bio-24 Total-27	COD 400-500mg/l sCOD 150-260 mg/l BOD 180-260mg/l N-NH4 40-60mg/l TSS 70-120mg/l	COD 60% N-NH4 50%	COD 180mg/l sCOD <100mg/l N-NH4 22mg/l	0.2 KWH/m3 8 kgO2/kwh (blower only) 0.5 kWh/kgCOD	3
			65			COD 80% N-NH4>85%	COD <100mg/l sCOD <50mg/l N-NH4 <10mg/l		
GEN 2	UK	Municipal Post Primary Clarifiers	24	Bio-9 Total 11.4		BOD>95% TN>60% NH4>99%	NH4<1mg/l BOD< 10mg/l COD< 40mg/l TSS <30mg/l	0.2 kWh/m^3 0.5 kWh/kgCOD 0.15 kgTSS/kgCOD	6
			72			BOD > 50% COD 66% NH450%			
	Spain	Pharma	12	Bio-4.5 Total 5.7		COD≈ 75%	COD<200mg/l		3
			24			COD ≈ 57%	COD<400mg/l TSS<50mg/l	0.35 kWh/KgCOD 0.1 kgSS/kgCOD	
	Sweden	Municipal, 3mm screens	14.4	Bio-4.5 Total 5.7		COD 70% TN 50-60% NH4 70-80%	BOD 10mg/l COD 200mg/l sCOD 50-100mg/l NH4 10mg/l	0.35kWh/m3 0.6kgTSS/kgCOD	3
			7.2				BOD 3mg/l COD 130mg/l sCOD 85 mg/l N-NH4 5mg/l		
	Ireland	Leachate	2	1.4	(Low strength) ($NH4_{in}$=200mg/l)	NH4>99%	N-NH4<1mg/l	0.0045 kWh/gNNH4 1.80 gNaOH/gNNH4 0.06 gTSS/gNNH4	1
					(High strength) ($NH4_{in}$=2000mg/l)	NH4>90%	N-NH4≈200mg/l		

An example of the flexibility of the Oxymem System was during the Installation in Brazil where the installed reactor was operated as both a simulated drop in solution where the wastewater from the onsite lagoon was pumped directly to the OxyMem. This was to demonstrate how the MABR could increase the capacity of an existing overloaded plant. Ideally the MABR modules would have been dropped directly into the lagoon; however, it would be impossible to quantify the impact of three MABR modules on the total plant. Therefore, the three modules were housed in a side stream tank and fed with water taken from the lagoon. Following on from this period the OxyMem MABR was fed directly with raw water and to evaluate the MABR as a standalone biofilm solution capable of achieving discharge standard effluent in terms of COD, nitrogen and solids.

Discussion

The MABR significantly reduces the energy requirement for the aerobic treatment of wastewaters because of its unique approach to the supply of Oxygen. Considering both the energy required for aeration and the energy required for mixing, the OxyMem MABR achieved energy requirements of 0.2 kWh per m^3 of municipal wastewater treated and 0.35kWh per kg sCOD removed. Though the MABR can achieve very high Oxygen Transfer Efficiencies >50% with air, or >90% with pure oxygen. A major energy saving is also because the system can be operated with very low air pressures. The pressure loss due to air flow in the hollow fibre membranes is <20mBar and because the membranes are dense water does not permeate back into the hollow fibre membrane even though the external hydrostatic pressure is much greater than the internal pressure. Oxygen will continue to be transferred across the membrane even when there is a higher external pressure, as it is the difference in concentration (Partial Pressure) which is the driving force for the mass transfer across the membrane wall. While high OTE is desirable to minimise the quantity of Oxygen wasted, it also results in lower Oxygen Transfer Rates, OTR and an increased membrane requirement. Therefore, as with other biological aerobic treatment system there is a trade-off between operation and capital costs. While the OxyMem MABR has been demonstrated from the treatment of several types and strengths of wastewater. One of the most interesting things it the future potential which this approach to biofilm and environmental biotechnology allows. The independent control and direction of supply of the pollutant and the reactant allow for much higher levels of control of rates of reaction and locations of zones of reaction that was possible previously. Additionally, the ability to supply other gasses or substrates through the membrane opens the possibility for the supply of specific eletron donors such as H2 or CH4 directly to a biofilm, the fact that these expensive gasses are retain in the membrane means that they are not wasted. Continuously monitoring the off gas coming from the membranes expands the possibilities for online feedback and give almost realtime feed back on the performance of the treatment system. This close to real time feedback is a novelty in an industry that is more used to waiting 5 days for sample analysis.

Conclusions

The MABR is another tool in the environmental engineers ability to control and manipulate the micro environment in a biological treatment reactor to achieve desired process outcomes. The MABR has been deployed as a Fixed Film treatment system where all of the degradation takes place in the biofilm, along with in a side stream situation where the waste water from an operating lagoon was recirculated through the OxyMem Reactor, in both case the MABR provided treatment for the wastewater proving its flexible nature.

References

Downing, L.S., Nerenberg, R., 2008a. Effect of bulk liquid BOD concentration on activity and microbial community structure of a nitrifying, membrane-aerated biofilm. Applied Microbiology and Biotechnology 81 (1), 153–162.

Onishi, H., Numazawa, R. and Takeda, H. (1980) Process and apparatus for wastewater treatment. Patent, U.S. (ed).

Yeh, S.J. and Jenkins, C. (1978) Pure oxygen fixed film reactor. journal of the enviromental engineering division,ASCE 104 4, 611-623.