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Unisense Application Note

The use of oxygen microelectrodes to study nitritation biofilms with different geometries

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Introduction

Nitrogen removal via nitrite has gained increasing attention due to its potential cost savings. Membrane aerated biofilm reactors (MABRs) are one potential technology suitable to achieve nitritation. In this study we compared lab scale MABRs (counter-diffusion) with conventional (co-diffusion) biofilm reactors to evaluate the influence of environmental conditions and operational parameters on nitritation performance. Oxygen mass transfer rates are postulated as a crucial parameter to control nitritation in the MABR.

Experimental Setup

Four reactor systems were operated for growth and in situ inspection of co- and counter-diffusion biofilms. The liquid phase compartment was separated from the gas compartment by a flat sheet silicone membrane which also served as the growth surface for the biofilm. The counter-diffusion biofilm (Fig. 1A) reactors were aerated by providing constant air flow through the gas compartment allowing oxygen to diffuse through the flat sheet silicone membrane into the base of the biofilm. In the co-diffusion (Fig. 1B) reactors the air compartment was flushed with N_2 gas and sealed to prevent oxygen from entering the system through the bottom of the biofilm. Aeration was provided in the bulk liquid. The reactor systems were operated under similar conditions with the aim to achieve partial nitrification for subsequent Anammox inoculation. Feed was composed of a synthetic wastewater leading ammonium-N concentration of 200 g NH_4-N m^{-3}.

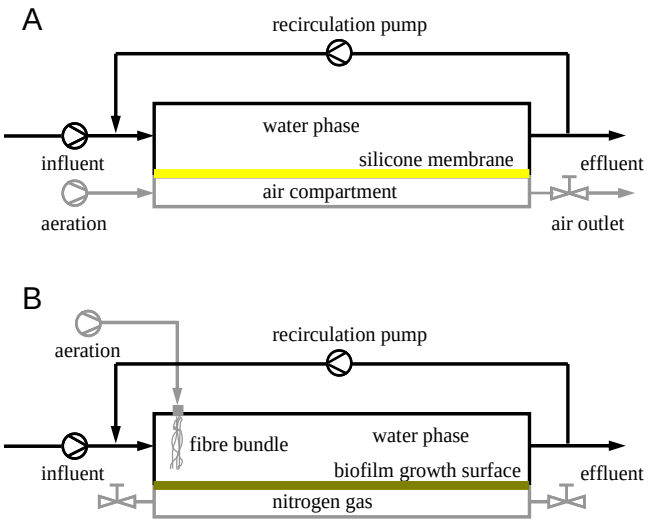

Figure 1: Schematics of the reactor systems. A: Counter diffusion Biofilm Reactor; B: Co-diffusion Biofilm Reactor

Oxygen microsensor measurements in the biofilms were conducted with a 10 µm Clark-type oxygen microsensor (OX10, Unisense A/S). The sensor was inserted directly into the biofilm from the bulk liquid through a small hole in the reactor lid for in-situ profiling using the

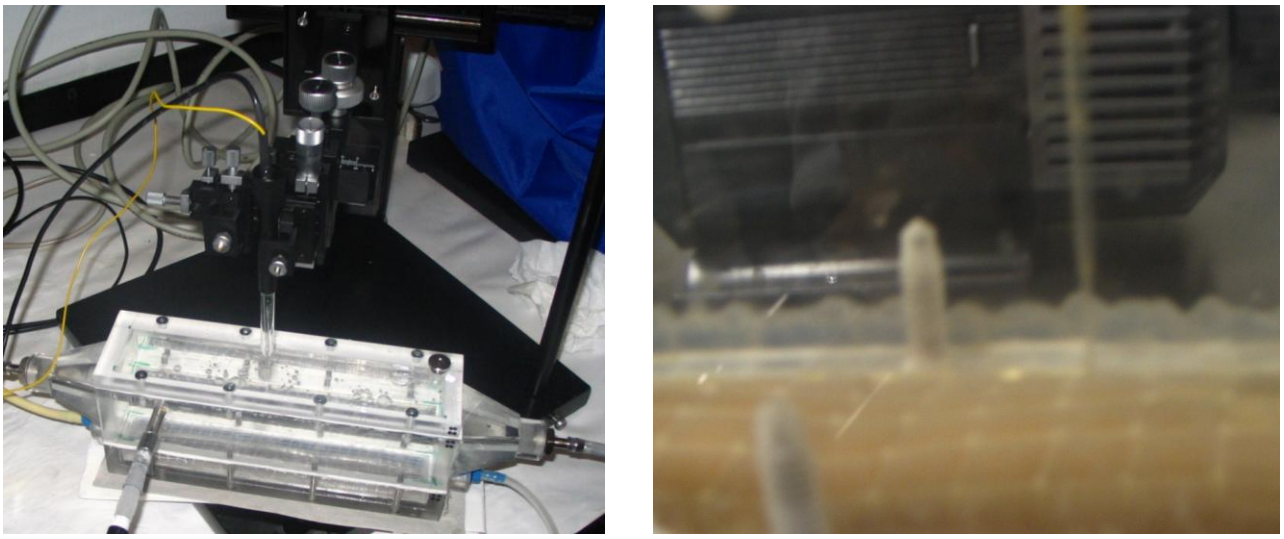

Figure 2: Pictures of the experimental setup for microelectrode measurements

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Unisense MicroProfiling System (Figure 3).

Figure 3: Unisense MicroProfiling System

Results and Conclusions

The nitritation efficiencies in the Counter diffusion biofilm did not vary significantly for the applied pressure range even though oxygen concentrations at the membrane base and oxygen fluxes were different. Examples of typical profiles at the different pressures are shown in Figure 4 with the respective fluxes ($J_{O2} = D_{O2,eff} \frac{\Delta S_{O2}}{\Delta z}$) and nitritation efficiencies (Table 1).

Oxygen profiles in the different biofilm geometries are shown in Figure 5. The oxygen penetration depth in the counter-diffusion system (Fig. 5, right) was approximately 125 µm in all profiles with a biofilm thickness estimated between 650-800 µm. Oxygen concentrations at the biofilm membrane interface were above 5 g-O m^{-3} in all experiments.

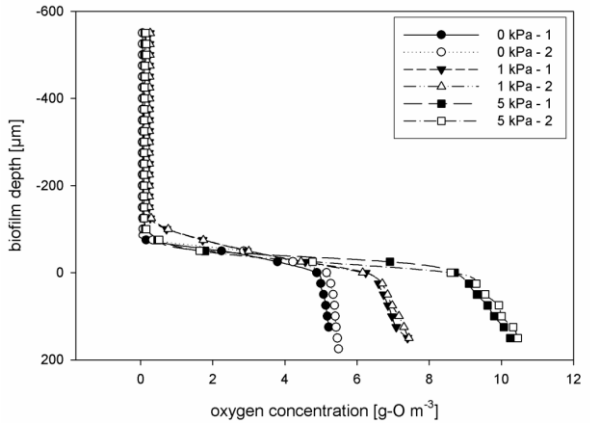

Figure 4: Microsensor profiles at 30 h of the batch tests at different relative gas pressures. Biofilm base at depth 0 µm (below oxygen concentrations in the silicone membrane); biofilm liquid interface at approximately -550 µm.

kPa	0	1	5
Nitritation [%]	13.5 ± 30.0	19.2 ± 1.3	21.9 ± 3.5
$J_{O2,m}$ [g-O m^{-2} d^{-1}]	9.7 ± 0.6	10.9 ± 0.6	14.8 ± 1.4

Table 1: Nitritation efficiencies (ΔNO_2^- produced /ΔNH_4^+ removed) for batch runs at 200 g-NH_4-N m^{-3} (N-biomass) at different relative gas pressures and the corresponding oxygen fluxes calculated from observed microsensor oxygen profiles ($J_{O2,m}$).

The profile of the co-diffusion system (Fig. 5, left) revealed a less steep oxygen gradient in the biofilm (oxygen penetration depth of 300-400 µm). Biofilm thickness was approximated to 600-800 µm and the oxygen concentration in the bulk liquid was between 0.4-0.8 g-O m^{-3}.

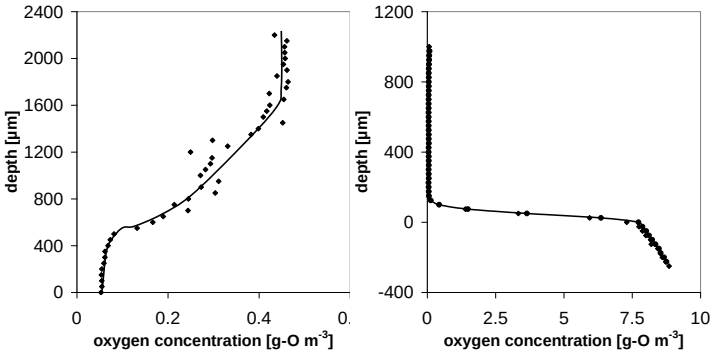

Figure 5: Examples of oxygen microsensor profile in the Co- (left) and the Counter-Diffusion reactor (right). Biofilm/bulk interface at approximately 1200 µm (left) and 800 µm (right). It was not possible to define the exact base of the Co-Diffusion biofilm as the oxygen reading in the silicone layer at the bottom was also around 0 g-O m^{-3} and could not be distinguished from readings in the biofilm.

This study demonstrated the challenges in achieving nitritation in MABRs and the importance of careful determination, adjustment, and monitoring of oxygen and ammonium fluxes and their respective absolute concentrations. Further research should focus on finding the optimal biofilm thickness and oxygen penetration depth for nitritation MABRs taking into account the impact of absolute concentrations of oxygen and the nitrogen species.

Results published in:

Lackner S., Terada A., Horn H., Henze M., and Smets B.F. (2010) *Nitritation Performance in Membrane Aerated Biofilm Reactors differs from conventional Biofilm Systems.* Water Research, 44(20), 6073-6084

Unisense Product List:

OX-10 Microsensor
OXY-Meter
LS18 laboratory stand
MM-33 micromanipulator and MC-232 motor controller
SensorTrace Pro software