Suppression of nitrite-oxidizing bacteria in intermittently aerated biofilms: a model-based explanation

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Suppression of nitrite-oxidizing bacteria in intermittently aerated biofilms: a model-based explanation

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Introduction & Aims

- Short-cut ammonium (NH_4^+) removal via nitrite (NO_2^-) is energy- and cost- efficient. The challenge is to suppress nitrite-oxidizing bacteria (NOB).
- Despite successful NOB suppression versus ammonium-oxidizing bacteria (AOB) in activated sludge based on differential growth kinetics, maintaining long-term nitritation in biofilms can be challenging[1].
- Pellicer-Nàcher[2] observed that fully nitratation membrane-aerated biofilm reactors accumulated NO_2^- immediately after switching from continuous to intermittent aeration.
- The purpose of this study was to develop and calibrate an improved biofilm model incorporating pH calculation, systematically evaluate potential causes for NOB suppression associated with intermittent aeration.

Model development & Model calibration

The multi-species nitrifying biofilm model is a one-dimensional model based on Terada[3], incorporating explicit pH calculation.

- A physical gas diffusion link between compartments

$$A \cdot k_{M,i}\left(\frac{1}{H_i} C_{i,air} - C_{i,base}\right)$$

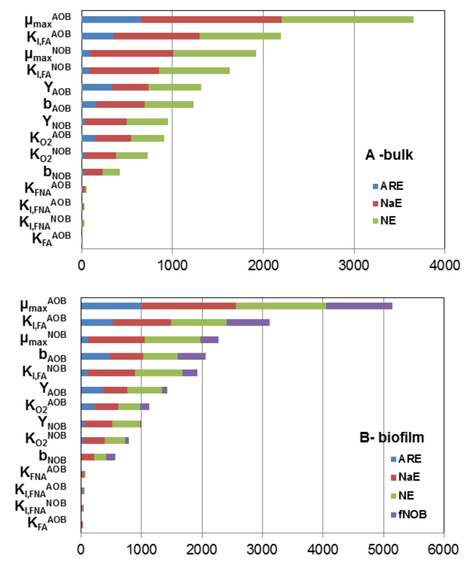
- Biological process, e.g. AOB

$$\mu_{AOB,f(pH)^4} \cdot X \cdot \frac{S_{O2}}{K_{O2} + S_{O2}} \cdot \frac{S_{FA}}{K_{FA}^{AOB} + S_{FA} + S_{FA} \cdot S_{FA}/K_{I,FA}^{AOB}} \cdot \frac{K_{I,FNA}^{AOB}}{K_{I,FNA}^{AOB} + S_{FNA}}$$

- Chemical process: pH calculation

$$H^+ + HCO_3^- \leftrightarrow H_2CO_3\ (CO_2)$$

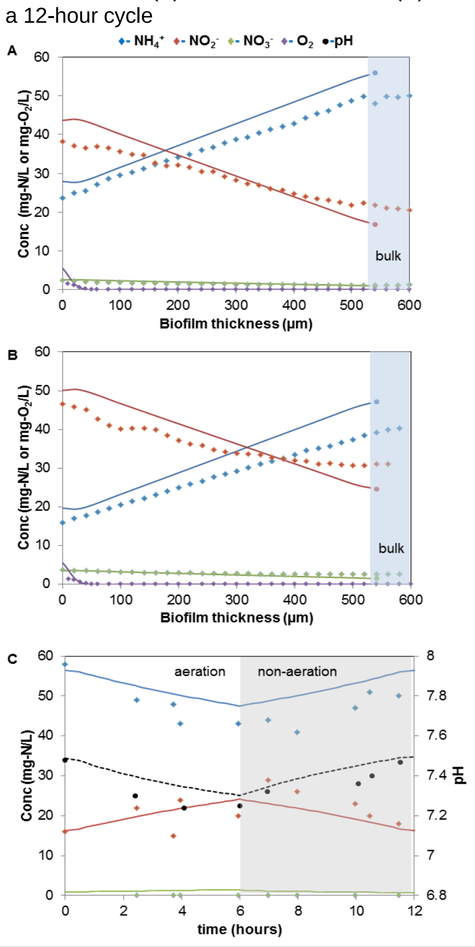
Sensitivity ranking of kinetic parameters with default ASMN values



- μ_{max}- the most determinant kinetic parameter in N conversion simulation.
- In-situ microprofiling data is more informative than bulk measurements.

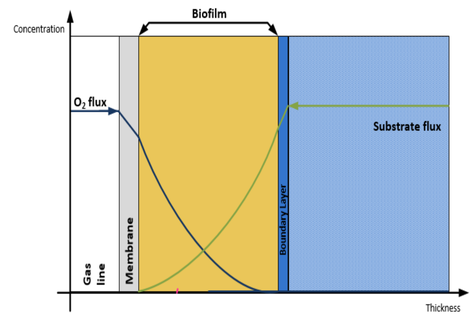
Experimental (symbols) and predicted (lines) concentrations

(A) the first aeration hour (B) the last aeration hour (C) bulk profiles in a 12-hour cycle



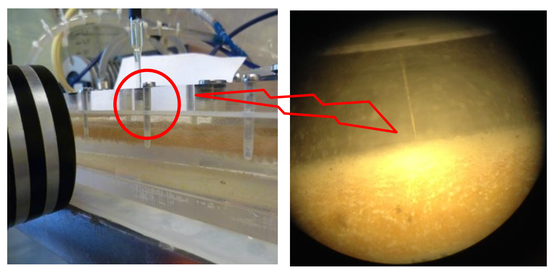
Counter diffusion biofilm system

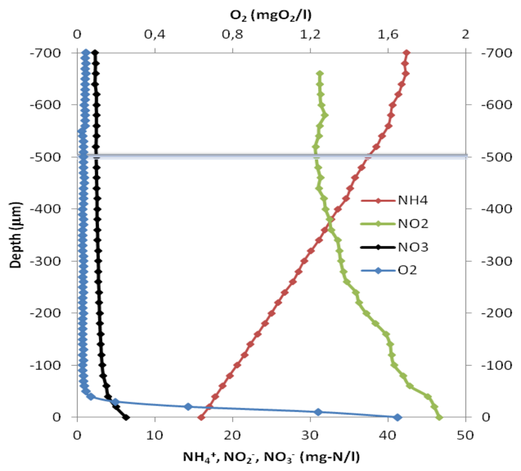
NOB suppression challenges



- Long solids retention times
- Strong spatial chemial gradients
- Multiple simultaneous chemical gradients
- Spatial protection of bacteria at the biofilm base

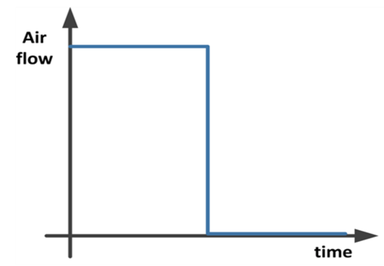
Microsensor setup





Microprofiles measured within the biofilm in the aeration periods at steady state

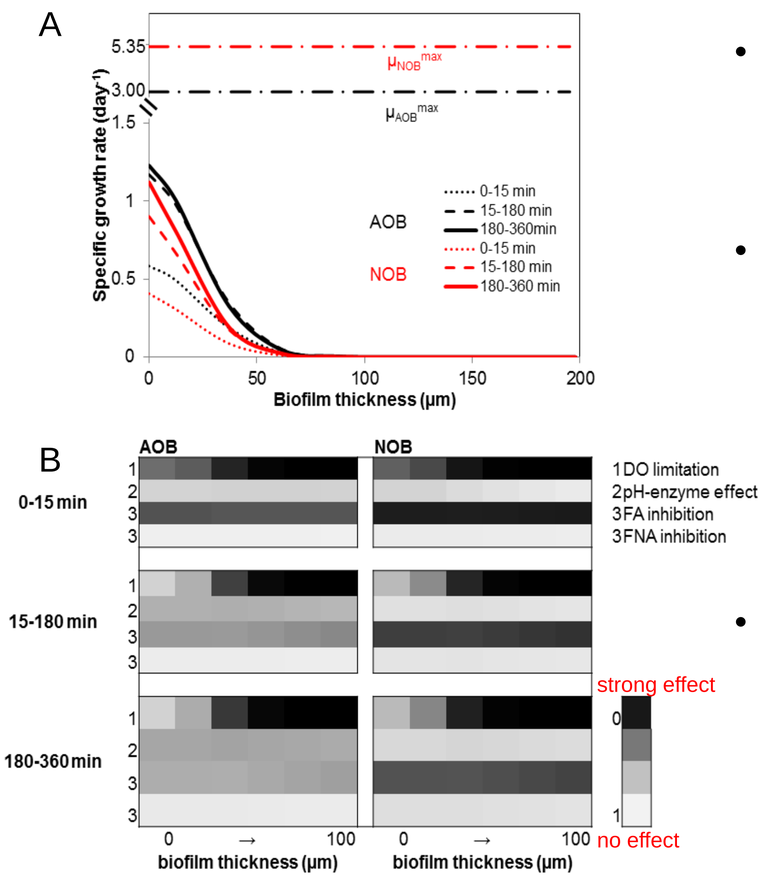
Intermittent aeration



An intermittent aeration:

6-hour aeration period (100% air) + 6-hour non-aeration period (100% N_2)

NOB suppression exploration



(A) Specific growth rate of AOB and NOB within the biofilm in a 6-hour aeration period at day 15 (B) individual effect on AOB and NOB within the 100 μm-aerated biofilm base (0- strong limitation/inhibition effect, 1- no limitation/inhibition effect)

- AOB preferentially utilize oxygen and outcompete NOB.
- FA inhibition caused by pH substrate-speciation is the crucial factor in suppressing NOB in intermittently aerated biofilms.
- Strong FA inhibition at the onset of aeration causes lag phase of NOB activity over AOB.

Conclusions

- Intermittent aeration supports efficient nitritation in membrane aerated biofilm reactors.
- A pH-explicit 1-D multispecies nitrifying biofilm model reveals that NOB suppression- associated with intermittent aeration- is primarily governed by periodic FA inhibition, which is the consequence of transient pH upshifts. These pH upshifts caused by alkalinity increases during non-aeration are mainly due to carbon dioxide stripping to the membrane lumen.
- In counter diffusion biofilms pH effects appear more important than DO effects on NOB suppression.

References:
1 PMID: 15303723
2 DOI: 10.1021/es1013467
3 DOI: 10.1002/bit.21213
4 DOI: 10.1016/j.procbio.2007.09.010

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