Redox Stratified Controlled Biofilm Reactor for Completely Autotrophic Nitrogen Removal

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Redox Stratification Controlled Biofilm Reactors For Completely Autotrophic Nitrogen Removal

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1. Towards a novel reactor technology

Growing biofilms on oxygen permeable membranes, whereby oxygen supply to the bottom part of the biofilm can be easily controlled, can create redox stratification in the biofilm and, subsequently, micro niches for different bacterial communities which can perform simultaneous oxidation and reduction of pollutants from wastewater. These Redox-Stratified Controlled Biofilm Reactors (ReScoBiR) are a promising technology for stable completely autotrophic nitrogen removal.

Aerobic Ammonium Oxidizing Bacteria (AOB) [7]

NO2- + 1.38 O2 + 1.98 HCO3- → 0.018BC + H2O + 0.98 NO2- + 0.98 NO3- + 1.89 CO2 + 2.93 H2O

Anaerobic Ammonium Oxidizing Bacteria (AnAOB) [7]

NH4+ + 1.12 NO2- + 0.13 H2 + 0.066 HCO3- + 0.066CH4 + 2NO2- + 0.26 NO3- + 2.03 H2O

Modeling studies have confirmed that counter-diffusion biofilm (in which substrates are supplied from both sides of the biofilm) are more advantageous for completely autotrophic nitrogen removal than a conventional co-diffusion biofilm [8]. Thus, this configuration will be the object of the present study.

2. Challenges in ReScoBiR

**Advantages**

- High removal efficiencies are expected: ACOB have reported removal rates up to 26 kg N/m3/day [6].
- Oxygen demand is 65% lower than in the oxidation-denitrification process [10].
- Oxygen transfer is very effective in these systems, leading to lower power consumption [6,17,9].

**Disadvantages**

- Out competition of nitrite oxidizers is not as easy as in modeling treatment realised.
- Long start-up times until AnAOB show activity in the system [10].
- Scaling, durability and hydrodynamic behaviour of the membrane modules [4].
- No organic carbon is required: the carbon in bacteria growth is provided [11,20].
- Low CO2 and NO2 emission, causing a minor climate change impact [9].

In this study:

- Construction of the reactor system.
- Study of the nitrification in order to achieve AnAOB stoichiometry.
- Modeling of the constructed reactor.

3. Materials and methods

**Reactor monitoring**

Most of the process variables are tracked online:
- pH
- Dissolved Oxygen.
- Oxidation/Reduction Potential.
- NH4+ and NO3- concentrations.
- Air Flow.
- Reactor Temperature.

Variables tracked offline:
- Influent flow.
- Gas line pressure.
- Total Organic Carbon.
- NO3 Concentration.
- Total Suspended Solids.

These readings are accessible from any computer with an internet connection.

4. Experimental results

Operation started in February, with nitrifying biomass from the Lundtofte wastewater treatment plant (Copenhagen, Denmark). The objective was to keep the $\frac{I_{Nt}}{I_{NO}}$ ratio at the optimal level [3] for attainment of Anammox stoichiometry.

**5. Modeling**

A mathematical model for the presented Counter-diffusion ReScoBiR was built using AQUASIM [16], taking the model in [27] as guidance. A parameter estimation fit the data presented in FIGURE 11 was performed.

Bio-kinetic parameters and global mass transfer coefficient obtained were used to build a simplified MATLAB model, which accounted for the following processes in the biofilm as they are presented in [28] and [29].

Particulates:
- Growth, decay and hydrolysis processes.
- Advection due to biofilm growth.
- Diffusion (implementation improved the convergence of the model).

The model represents quite accurately the batch and the dynamics of the posterior continuous operation without aeration.

- Empirical and modeling results confirmed that the mass transfer is 10 times higher than expected.
- AOB growth rate is 3.5% higher than the expected.
- NO3 growth rate is 60% lower than the one in the literature.

The MATLAB model was extended and Anammox bacteria activity were incorporated. The model shows similar behaviour when compared to respective AQUASIM simulations.

- The model should be refined to represent better the biofilm growth and the stratification.
- A control strategy to shorten Anammox start-up time is being developed.
- The MATLAB model will provide the possibility to implement real-time control in the system.

**Figure Captions**

- FIGURE 1: Scheme of the counter-diffusion ReScobir reactor
- FIGURE 2: Flow cell with electrodes and details of the NH4+/NO3- membrane reactor
- FIGURE 3: Substrate composition
- FIGURE 4: Reactor setup
- FIGURE 5: Reactor performance during the first 10 months of operation
- FIGURE 6: Batch operating results. Evolution of parameters in the bulk liquid
- FIGURE 7: Comparison of the profiles of the NO3 removal and NO3 steady state concentrations