Economic Evaluation Of Commercial Applications For Electrogenic Bioreactors Based On Experimental Results

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Abstract: Electrogenic bioreactors, including microbial fuel cells (MFC) and electrolysis cells (MEC), have been characterized and evaluated on lab and large bench scale over long time periods in search of economic feasibility. In view of the results, life cycle cost calculations show there exists a range for which MFC are advantageous. MEC systems are being validated as means for retrofitting and upgrading anaerobic digesters.

Keywords: electrogenic bioreactors; microbial electrolysis cells anaerobic digestion

Session: Bio-electrochemical systems / Microbial fuel cells

Introduction

Electrogenic Bio Reactors (EBRs) is a wastewater treatment technology based on the activity of electrogenic bacteria, which can transfer electrons to electrodes as part of their metabolism (Logan et al., 2006). That can be used for current generation in microbial fuel cells (MFCs) or synthesis of different products such as hydrogen and methane gases in microbial electrolysis cells (MECs). Although wastewater treatment process-oriented research is performed for over 30 years in the field, commercial processes are not yet available in the market, as the systems' complexity results in costs which make it less competitive comparing to existing solutions.

In MFCs, the efficiency is sensitive to ohmic losses, which are minimized by means such as using a cathodic catalyst, minimizing the distance between electrodes and by using as highly conductive materials as applicable, which is derived from cost considerations. In that view, the research presented demonstrates the range of wastewater which treatment using MFCs would be competitive comparing to the existing technologies, and that is based on thorough study and optimization of the MFCs. For MECs, the extraction of the product requires purification processes which make the entire process less feasible. Therefore, the study focuses on coupling to anaerobic digesters (AD) producing biogas to upgrade their performance. It was demonstrated (De Vrieze et al., 2014, Yin et al., 2015) that the positive influence of such coupling on the AD is higher methane concentration in the gas and higher tolerance to load variations that would otherwise cause volatile fatty acids accumulation and consequently a process failure a decline in biogas production.

Materials and methods

The MFC was of a spirally wound design (fig. 1). The spiral is comprised of a carbon cloth electrode for the anode, and an elongated oxygen permeable membrane sleeve attached to another carbon cloth electrode for the cathode. The electrodes are rolled into a spiral together with a flow spacer and an insulating separator. 200 mL up to bench-scale
reactors with a volume of several liters were operated for long terms of up to several months to optimize the performance and the materials. Feed solution was synthetic wastewater, with acetate as carbon source. The cells were characterized following standard methods and process parameters were recorded regularly.

The MECs tested had a similar spirally wound design. However, the structure only included two carbon cloth electrodes, separated by a porous layer and rolled together with a flow spacer (fig. 2A). The electrodes were connected to a power supply, through which the required working voltage was applied, in the range of 0.6-1.2 V. Following inoculation, a MEC was coupled to a UASB type AD of ten times larger volume (fig. 2B) and to a system of two AD reactors working in series, in which the MEC was circulated with the second AD. The coupled systems were fed with glucose based synthetic medium and the performance was compared to that before the addition. Samples were taken from the suspended biomass for community analyses.

Results and conclusions

All performance parameters of MFCs operating continuously for a length of time was shown to depend on the organic loading. The power output and COD removal rate increase with increasing organic loading, as does effluent COD. On the other hand, the coulombic efficiency and removal rate increase with decreasing load (fig. 3). Based on laboratory and bench scale results, an economic analysis was performed to compare the life cycle value of MFC to the most common alternatives of activate sludge and anaerobic treatment, and a feasibility map was drawn, demonstrating the conditions of flow and concentration for which MFCs offer the lowest life cycle cost (fig. 4). This zone is relatively small, and the research is focused on expanding it by improving performance in combination with lower cost materials of construction.

The MEC coupling to the AD has resulted in very quick improvement in the biogas quality, which CO2 concentration has dropped by 50% (fig. 5). In the two AD reactors system, a significant increase in the presence of electrogens in the anaerobic reactors was observed following the coupling of the MEC (fig. 6). The enrichment is indicative of a significant influence of the MEC on the microbiological population in the reactors system, which has a potential to lead to significant improvement in the performance parameters.

References:
**Figure 1** Picture of a spirally wound bench scale MFC test unit

**Figure 2** A) Schematic illustration of the MEC spiral layers, B) Block diagram of the AD-MEC coupled process

**Figure 3** MFC performance as function of the COD loading.
Figure 4 EBR technology feasibility map

Figure 5 Biogas production before MEC addition (blue), the intermediate time after the MEC addition (yellow) and after the change in gas quality (red)

Figure 6 Bar graphs of electrogenic microbial community composition of the reactors before the coupling (A) and after (B).