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Editorial: Microbial Fuel Cells: From Fundamentals to Applications

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Editorial on the Research Topic

Microbial Fuel Cells: From Fundamentals to Applications

The global strategy for the next few decades is to achieve a smart and sustainable economy based on knowledge, innovation, and efficient use of resources, especially those that are environmentally friendly. Among the different cutting-edge technologies that have emerged in the last decade, bioelectrochemical systems (BES) are part of a portfolio of technologies that aim to accelerate the development of low-carbon technologies and contribute to a sustainable and secure energy system supply. These systems have the ability to treat wastes that contain substrates and microorganisms and simultaneously produce energy. Therefore, in the last few years, BES such as microbial fuel cells (MFCs) and microbial electrolysis cells (MECs) have been the focus of many studies and much research due to their potential to address two global problems: waste materials and energy demand. In addition, these systems can be adapted to a wide range of applications, since they can be used for the production of energy, hydrogen, and chemicals of high value, wastewater treatment, and metal and nutrient removal/recovery. Furthermore, using this technology in industry is very attractive since the wastes produced by that industry can be converted into energy, reducing waste disposal costs and increasing company profit.

Wastewater streams that contain heavy metals require further treatment as they are typically non-biodegradable pollutants with a toxic effect on the environment and human health. Moreover, there is an economic interest in the recovery of the heavy metals since they are non-renewable and expensive raw materials. Therefore, metal recovery is a very interesting application for BES, since most of the commonly used methods to perform this recovery (chemical, physical, or biological) require energy input and sludge disposal. Ezziat et al. provided a review regarding the metal removal/recovery from different effluents using an MFC in which its main principles and fundamentals are summarized. The different studies on metal removal/recovery in single-chamber (SCMFCs) and double-chamber MFCs (DCMFCs), as well as the major challenges that this technology needs to face before its application, such as thermodynamic limits, heavy metal biotoxicity, pH imbalance, and membrane biofouling, are also presented.

Despite the promising prospects of BES, they can suffer from reduced power output since their performance relies on different phenomena and processes, such as microorganism activity, biofilm formation, the electron transfer mechanism, the interaction between the biofilm and the electrode, and the electrochemical reactions, and their high costs also remain challenging. Moreover, until now, a consensus has not been reached regarding the optimal design or the best electrodes and separator materials to use to scale up this technology.

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In pursuit of the improvement of the power output and reduction of the costs of the scaled-up systems, Gajda et al. developed a MFC stack using a cost-effective ceramic as a membrane/chassis for the reactor architecture by compacting the design and exploring the use of the ceramic support as the building block for small-scale modular multi-unit systems. The results showed that the small reactors outperformed the large ones in terms of power output due to an increase in the surface area–volume ratio of the ceramic membrane, more efficient mass transport, and a decrease in the electrode distance. It was also found that the power output was influenced by the type and thickness of the ceramic separator as well as the anode electrode surface area. Higher areas improved the power output of the individual units, increasing the overall system power output. An MFC stack composed of 560 small-scale units showed a power output of up to 245 mW. As electrochemically active biofilms are critical to the function of BES, Cotterill et al. studied the formation and composition of anodic biofilms on two pilot-scale MECs operated for over 6 months in continuous mode with domestic wastewater and inoculated with that same wastewater. The major goals of this work were identifying the bacterial community through Illumina 16S rDNA sequencing, determining, with an NCM (neutral community model), the dominant processes behind the community assembly, and comparing the spatial variation of the community composition and the biofilm distribution within and across the anode surface with increased scale-up. The results from these investigations were used to provide suggestions for design, start-up, and operating conditions toward the optimization of the biofilm in pilot-scale MEC. It was found that the community composition was mainly governed by stochastic processes, that the technology can be used on most domestic wastewaters as long as the anodes are seeded with the target wastewater, and that deterministic factors, such as the applied voltage and flow rate, may also play a role in establishing the anodic community.

Kocatürk-Schumacher et al. tested the concept of combining a bioelectrochemical system with an anaerobic membrane bioreactor (AnMBR) to produce electricity, reducing the overall energy consumption of wastewater treatment. Therefore, a microbial anode was integrated into an AnMBR under two different configurations, and this system was used for the treatment of synthetic brewery wastewater. As fouling is a drawback in AnMBRs, the authors investigated the effect of two fouling mitigation methods on the permeate fluxes and current densities. The results revealed that permeate fluxes were influenced by the membrane pore size and that the cathode position does not influence the permeate fluxes and current densities but has a clear influence on the permeate pH. Using a turbulence promotor increased the permeate fluxes and the current densities in the filtering anode, and the hybrid anode resulted in similar current densities but higher permeate fluxes than the filtering anode. The hybrid anode configuration is a very promising design, since it combines high permeate fluxes on conventional non-conductive filters with current generation on an inexpensive conductive material.

In summary, this Research Topic intends to make a difference among the few similar titles available in the bioelectrochemical systems field, since it discusses the key work done in order to improve BES performance based on its limitations with regard to both fundamental and technological issues.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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