Energy Issues in Bioelectrochemical Treatment of Water and Wastewater

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Water is a vital resource to human health and societal development. Consumption of clean water and release of wastewater is an important human activity that significantly affects the environment. Due to the lack of sufficient freshwater source and increasing pollution of natural water body, proper treatment of water and wastewater at a reasonable cost is critical to a sustainable society. A significant port of the cost during water/wastewater treatment is associated with energy consumption. Therefore, it is of strong interest to develop energy-efficient treatment approaches [1].

Bioelectrochemical systems (BES) are receiving more attention as a promising approach for energy-efficient treatment of water and wastewater. BES is not a new concept, and it can be traced back to one century ago when the bioelectricity was first reported [2], which led to the research of microbial fuel cells (MFCs). MFCs take advantage of microbial metabolism of organic compounds with a solid electron acceptor (an electrode), and can convert organic wastes directly into electric energy [3]. MFCs hold great promise in recovering bioenergy from wastewater; unlike anaerobic digestion, the direct electricity generation in MFCs avoids the collection, treatment and conversion of biogas into electricity, thereby potentially saving the cost associated with biogas generators. Further development of MFCs discovers that with an externally applied potential, a modified MFC can produce hydrogen gas, instead of electricity, and this device is called microbial electrolysis cell (MEC) [4]. When an additional chamber is installed between the anode and the cathode, an MFC is converted into a microbial desalination cell (MDC) that achieves desalination without much requirement of external energy [5]. The schematics of MFCs, MECs, and MDCs are shown in Figure 1.

The potential benefit of BES application in water and wastewater treatment is related to energy; however, despite intensive research of BES in the past decade, energy issue has not been well addressed:

- First, energy data are not properly presented in the published materials [6]. A common parameter that is used to represent "electricity generation" in an MFC is power (density). However, power is not energy. Water/wastewater industries usually use "kWh/m^3" to represent energy consumption. The research community should present energy data using the same parameter for a better dialogue between academia and industry. In addition, due to the variation of organic concentration in different wastewaters, energy density can also be expressed in "kWh/kg COD", in which "kg COD" is the removed chemical oxygen demand.
- Second, energy benefit of BES is not clearly recognized. Previously, energy production is claimed as the most important advantage of BES. However, our studies revealed that MFCs do not produce much energy, and cannot outcompete anaerobic digestion in terms of energy production from organic compounds [7]. Through a long-term study of MFCs installed in a municipal wastewater treatment facility, we concluded that the primary benefit of MFC technology is energy saving, followed by reduced sludge production and energy recovery [8]. Our MDC study demonstrates that MDC operation should be conducted under a high current zone, instead of a high power zone for energy production [9].

Proper understanding of energy issues in bioelectrochemical treatment of water and wastewater is crucial to identifying suitable application niches, and further development of those technologies.

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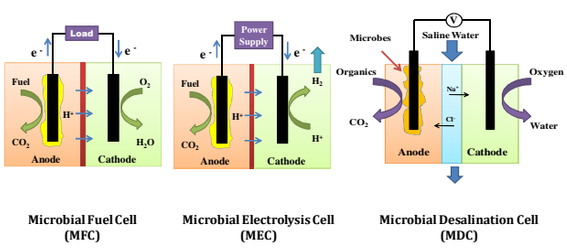

Microbial Fuel Cell (MFC) | Microbial Electrolysis Cell (MEC) | Microbial Desalination Cell (MDC)