Microbial Fuel Cells and Their Way to the Future

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With decreasing water supply and increasing population growth, the need for alternative water sources and water recovery will become one of the critical problems facing humanity. At that moment microbial fuel cells (MFCs) will find the niche they belong to – the development of self-powered, sustainable “bioreactors” for wastewater purification. Until then three major steps must be undertaken in order to implement MFCs as a viable technology: i) identify and isolate the factors having the biggest impact on MFC performance; ii) scale up the technology with an emphasis on material design and interfacial biological reactions; iii) understand factors behind the variability of MFC power generation. The jump from laboratory prototype to practical device requires material and design knowledge along with the fundamental understanding of the involved processes.

In this study, the main factors contributing to the MFCs overall performance and their influence on their reproducibility are discussed. Two statistical approaches were used to create a map of MFCs components and their expanded uncertainties, *Principal Component Analysis* (PCA) and *Uncertainty of Measurement Results* (UMR)[1]. PCA was used to identify the major factors influencing MFCs and statistically determine their ascendency over MFC operational characteristics. UMR was explored to evaluate the factors’ uncertainties and estimate their portion to the final irreproducibility.

The study relies on diverse data sets collected at collaborating institutions. In order to simplify the presentation and concentrate on the MFC components, only results from *Shewanella spp*. were included[2,3]. A set of results from two identical MFC systems, differing only in the analyte content (buffer) or *Shewanella* strain[3] were processed. According to the PCA, *Principal Component* 1 (PC 1) separates the MFC responses into two major groups depending on the buffer type (Fig. 1). The MFCs with PIPES instead of phoshate buffer have thicker biofilms and higher power and current outputs.

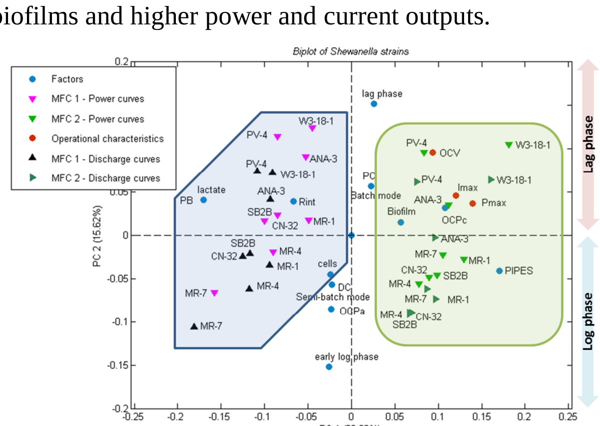

Figure 1: PCA biplot where scores (samples) and loadings (the variables) for MFCs with different *Shewanella* species are ploted on the first two components.

Principal Component 2 (PC 2) separates MFCs according to the growth phase in which bacteria are before inoculation, with the lag phase shown to have positive effect. In all cases, the generated power and current from the polarization and power curves are higher than the currents recorded via discharge measurements due to the shortness of the experiments.

There are two other important group separations based on the *Extracellular Electron Transfer* (EET) mechanism and the MFCs design. These were identified when a set of data provided from MFCs that differ in design and operation were examined. PCA shows that direct electron transfer mode is the preferential type of EET for the generation of higher current and power densities. It should be noted that design parameters such as: electrode material, electrode surface area, membrane type and/or area, the volume of the anode and / or cathode compartments and the MFC internal resistance (a cumulative result of most of the above factors) are the main design parameters affecting the MFCs performance. The membrane area and the compartment volumes have the highest impact on the maximum power, and the electrode area directly impacts the maximum current (Fig. 2).

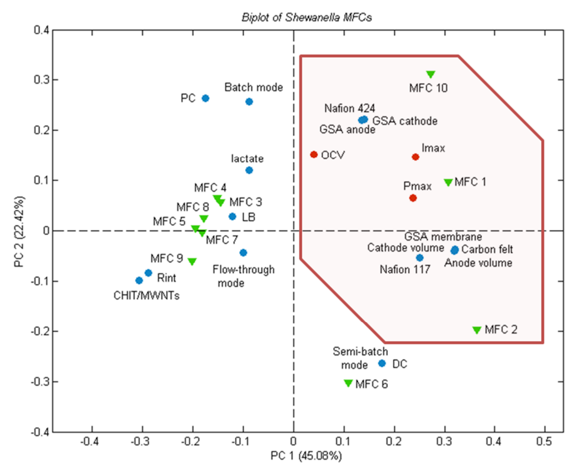

Figure 2: PCA biplot plotting loadings of the variables for different in construction *Shewanella MR-1* MFCs (scores) for the first two components

The calculated expanded uncertainties for the MFCs` operational characteristics imposed two basic conclusions: i) the maximum current and power values have sufficient uncertainties and ii) these uncertainties are due mostly to differences in the electrodes real surface area followed by the differences in the MFCs internal resistance (Fig. 3). The power uncertainty is a result of the significant current deviations.

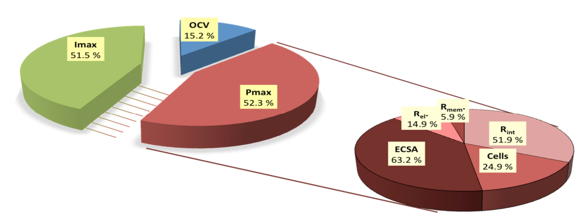

Figure 3: Uncertainties of the MFCs operational characteristics and several MFCs parameters. The uncertainty values in the pies are not normalized to 100%.

The last decade of research has made significant strides toward practical applications; however, design improvements and operational optimization cannot be realized without equally considering engineering designs and biological interfacial reactions. This PCA/UMR approach enables a predictive capability to optimize biology and engineering simultaneously. This is a powerful approach that can logically inform design and implementation of practical MFC systems.

References:

1. Babanova, S., Hubenova, Y., Mitov, M., Mandjukov, P. *Fuel Cells* **2011**, *11*, 824.
2. Higgins, S., Foerster, D., Cheung, A., Lau, C., Bretschger, O., Minteer, S., Nealson, K., Atanassov, P., Cooney, M. *Enz. Microb. Technol.* **2011**, *48*, 458.
3. Bretschger, O., Cheung, A., Mansfeld, F., Nealson, K. *Electroanalysis* **2010**, *22*, 883.