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Supporting Information for:

Reducing nitrogen crossover in microbial reverse-electrodialysis cells by using ion exchange resin

Maxwell J. Wallack[1], Geoffrey M. Geise[2], Marta C. Hatzell[3], Michael A. Hickner[4] and Bruce E. Logan[1*]

[1]Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, United States
[2]Department of Chemical Engineering, University of Virginia, Charlottesville, Virginia 22904, United States
[3]George W. Woodruff School of Mechanical Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, United States
[4]Department of Materials Science and Engineering, The Pennsylvania State University, University Park, Pennsylvania 16802, United States
*Corresponding Author. Telephone: +1 814 863 7908. Fax: +1 814 863 7304.
E-mail: bel3@engr.psu.edu

Estimated Power Losses and Mitigation

The increased resistance due to the additional LC chamber and AEM will decrease the energy efficiency of an MREC. The extent of power loss can be estimated based on the increased resistance using an additional chamber and membrane. Based on net power equations for RED stacks[1], the power loss (P_{loss}) is:

$$P_{loss} = \frac{(R_{soln} + R_{mem})}{A_G} \cdot j^2 \tag{13}$$

where here j = 4 mA, R_{soln} = 25 Ω-cm^2 due to the modified width (1.3 mm) LC chamber (section 5.2), R_{mem} = 192 Ω-cm^2 due to the additional AEM, and A_G = 6.55 cm^2. The resistance due to the additional AEM was the difference between the membranes in the 3C reactor (295 Ω-cm^2) and 2C reactor (103 Ω-cm^2). This modified area-resistance took into consideration ohmic (R_{ohmic}), bulk concentration change ($R_{\Delta C}$), and boundary layer (R_{BL}) resistances for the membranes. Power loss was 0.530 mW for the additional AEM and LC NaCl solution.

Power loss can be mitigated by introducing additional membranes to the RED stack. The number of membranes necessary to mitigate power loss from the solution and membrane resistances[1] is:

$$P_{net} = N_{pairs}\, E_{OCV}\, j - P_{loss} - \frac{N_{pairs}\,(R_{soln} + R_{mem}) j^2}{A_G} \tag{14}$$

where P_{net} is the net power (set at zero), and N_{pairs} the number of membrane pairs. Based on a current of j = 4 mA, P_{loss} = 0.530 mW, E_{OCV} = 0.156 V[2, 3] for one membrane pair (one AEM and one CEM), R_{mem} = 140 Ω-cm^2 for the membrane pair[4], R_{soln} = 25 Ω-cm^2 considering HC solution is negligible, and A_G = 6.55 cm^2, three additional membrane pairs (N_m= 2.4, rounded to the highest integer) in an MREC could be used mitigate the power loss due to the use of the additional LC cell. The addition of six membranes to overcome power loss due to resistance is therefore substantial if the stack size is only a few membranes[5], but relatively insignificant if a large RED stack of several hundred membrane pairs are used.

Power losses can also arise in a stack due to the formation of bubbles when AmB is used[6]. When bubbles form, the gas prevents liquid contact with the membrane, and thus the area for ion conduction of the membranes is reduced. Altering the chamber design can minimize bubble formation[6]. However, the ion exchange resin could introduce a greater number of pores for bubbles to form in and become lodged in the resin. This inclusion of bubbles in the resin chamber could increase internal resistance, and decrease the overall energy efficiency of the system.

Power is also lost in the pumping energy that is needed to pump solutions through and to and from the stack. Pumping losses within the stack have previously been studied in RED, and they were estimated to increase the power loss by 25% in larger systems[7, 8]. When resin is added to the LC chamber, additional pumping losses are introduced. The pressure drop due to the flow in a packed bed of resin can be estimated using the Kozeny-Carman equation and available data for pressure drop based on resin size. Large resin particles (smaller mesh) will have a smaller pressure drop, so larger resins are desirable from the perspective of energy losses due to pumping.

Table S1. Reactor Setups and Programs for Background Measurements

Reactor Setup	Membranes	Test Use	BioLogic Program
HC | HC	AEM	Baseline	0-4 mA, 0.5 mA steps/10 s
HC | HC | HC	AEM	Baseline	0-4 mA, 0.5 mA steps/10 s
HC | LC | HC	AEM	Membrane resistance with dissimilar electrolytes.	0-4 mA, 0.5 mA steps/10 s
HC | LC | HC	CEM	Membrane resistance with dissimilar electrolytes. VMP3 program changed due to boundary conditions.	0-4 mA, 0.5 mA steps/2 s

High concentration (HC) and low concentration (LC) chambers in 2C and 3C reactors are separated by membranes (|).

Table S2. Ion Exchange Resin Qualities

Dowex Resin Name	Type	Abbreviation	Ion Exchange Capacity (meq/L)	Cross-Linkage (%)	Moisture Content (%)
1X2	Anion	AL	0.7	2	65-75
1X8	Anion	AH	1.2	8	43-48
50WX2	Cation	CL	0.6	2	74-82
50WX8	Cation	CH	1.7	8	50-58

Ion exchange capacity, cross-linkage, and moisture content data was gathered from Dowex technical bulletins [9]. The abbreviations indicate anion (A) or cation (C) exchange resin, as well as high IEC (H) or low IEC (L) properties.

Table S3. Membrane and Ion Exchange Resin Configurations for Resistance Tests

Membranes	Membrane Type	Dowex Resin	Resin Type	Mass Resin (g)
AEM-AEM	A	1X8	AH	1, 2, 3
AEM-AEM	A	1X2	AL	3
CEM-CEM	C	50WX8	CH	1, 2, 3
CEM-CEM	C	50WX2	CL	3
AEM-CEM	A and C	50% 1X8 50% 50WX8	AH and CH	1, 2, 3

The resin and membrane types indicate anion (A) or cation (C) exchange properties, as well as high IEC (H) or low IEC (L) resins.

Table S4. Comparison of TAN crossover and coulombs transferred after one cycle in MRECs and this study

System	AmB Concentration (M)	Coulombs Transferred	Anode TAN (mg/L)	Reference
MREC	1.8	346	590	Cusick et al.[5]
MREC	1.7	192	789	Luo et al.[10]
MREC + LC (0.023 M)	1.7 With 0.023 LC Chamber	242	311	
MREC	1.1	346	741	This study
MREC + LC (0.011 M)	1.1 With 0.011 LC Chamber	346	40.6	
MREC + LC (0.011 M) + Resin	1.1 With 0.011 LC Chamber and 50% Dowex 1X8	346	26.0	

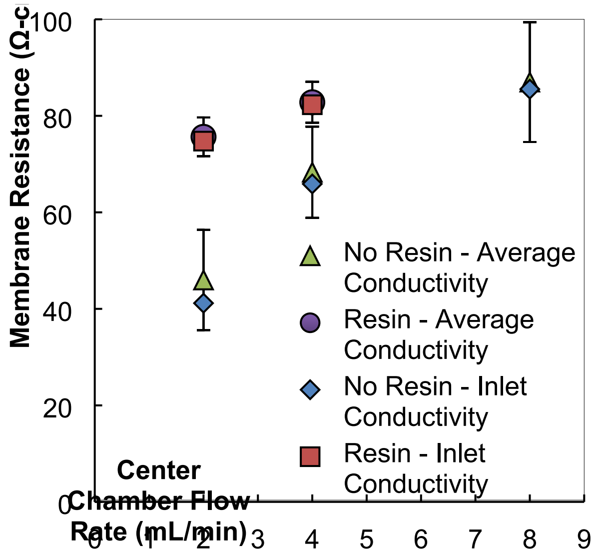

Figure S1. Calculated membrane resistance increases when using the average of the low concentration solution inlet and outlet conductivities.

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