Comparison of the Biocatalytic Ability of *Shewanella* used in the Reduction of Cr (VI)

**Introduction**

Hexavalent chromium is a common contaminant in groundwater and is a byproduct of the production of dyes, paints, inks, plastics, and metal welding. Highly mobile in aqueous environments, Cr (VI) is a known carcinogen and can enter the body through skin contact.

This work explores the biomediation of hexavalent chromium in microbial fuel cells (MFCs) with strains of the *Shewanella* genus as biocatalysts for the cathodic reaction. MFCs produce electricity from biochemical energy and consist of an anode, cathode, electrolyte, ion exchange membrane, and biocatalyst (generally bacteria). As microbes oxidize substrates at the anode, electrons from this process are directed through an external circuit to the cathode. In the external circuit, electrons are passed through a load or resistor. Finally, electrons accumulate at the cathode and reduce oxidants. Aquatic Cr (VI) served as the oxidant in the MFC and was reduced to a less toxic and insoluble form, Cr (III).

*Shewanella* have been proven to function in MFCs at the anode and were used in this study as biocatalysts at the cathode. To explore differences occurring on the species-strain level the following strains were tested: *S. oneidensis* MR-1, *S. species W3-18-1*, *S. amanaites* SB2B, *S. species* ANA-3, *S. loihica* PV-4, and *S. species* MR-4. Evaluations were based on overpotentials losses, residual chromium following injection, efficiency ratings, and electron microscopy.

**Methods**

*Shewanella* strains were cultured from frozen stock under the conditions and introduced to the fuel cell as shown in the flowchart shown in Figure 2. MR-1 was utilized as the anodic biocatalyst. The fuel cell utilized in these experiments is shown in Figure 1.

During operation, sampling of the cathode for Cr (VI) was performed at regular intervals and analyzed by ion chromatography. Voltages across a 10 ohm external resistance were recorded every minute by a digital multimeter. Nitrogen was purged through each chamber to maintain anaerobic conditions for the duration of operation.

**Results**

Differences in observed voltage from theoretical voltages from the Nernst equation can be characterized as overpotentials.

\[ E_{OCV} = E_{elec} + (\frac{RT}{F} \ln (P_{anode} / P_{cathode})) \]

These losses can be grouped into three categories: (1) activation losses, (2) bacterial metabolic losses, and (3) mass transport or concentration losses. Overpotentials under open circuit conditions are displayed in Figure 3.

**Discussion**

Statistically similar overpotentials in Figure 3 suggest similar internal resistances between cells populated with different strains. Any differences in performance can be attributed to differences associated with the strains rather than internal losses.

Figure 4 compares final Cr (VI) concentrations after three consecutive exposures. Consecutive exposures saw a decrease in Cr (VI) reduction for all strains. All species, Cr (VI) was reduced to negligible concentrations after the first exposure, however, this was not true for exposure 2. Figure 5 compares efficiencies between strains calculated by the ratio of electrons transferred in the reduction of Cr (VI) to the electrons transferred across the external resistance. Surprisingly, all strains produced efficiency ratings greater than one. This implies oxidation and electron production within the cathodic compartment of each MFC. This may occur by several methods including oxidation of inactive biomass and unintentional lactate transport through the cation exchange membrane.

Strains vary in their efficiencies between exposures, however, *S. species* W3-18-1 and *S. loihica* PV-4 show a consistent increase between exposures.

**Future Work**

Future work will include further analysis of *S. oneidensis* MR-1, *S. species* MR-7, and *S. putrefaciens* CN-32. Data from the eight strains will be compared to determine the greatest Cr (VI) reduction capabilities. The system will be optimized by mixed microbial population studies and the analysis of additional strains at the anode in terms of colomic efficiency.

**Acknowledgements**

Financial assistance was provided through a WiSE undergraduate research fellowship and NSF award 0826198. Additional assistance was given by the members of the Nealson lab and the Water Quality Engineering Science and Technology Research Lab.

**USC Undergraduate Research Symposium**

April 15, 2009