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Microbial Fuel Cell Technologies for Remediation of Hexavalent Chromium in Groundwater

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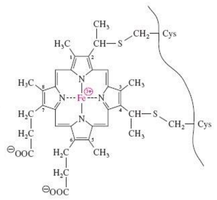
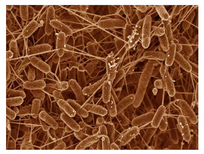
Introduction

- A typical fuel cell converts chemical energy to electrical energy but requires the use of expensive catalysts to drive the reaction.
- Microbial Fuel Cells (MFCs) make use of bacteria as a biocatalyst eliminating the need for expensive catalysts.
- MFCs have a wide range of applications including wastewater treatment, ground water remediation, leachate treatment, bio-sensing, as well as deep ocean and space exploration.
- The electrons generated in the MFC redox reaction can be used to reduce metals found in groundwater



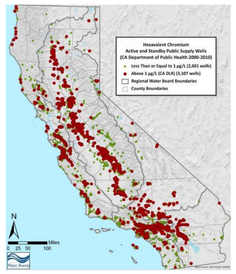
An example of a membrane bound protein responsible for extracellular electron transfer.



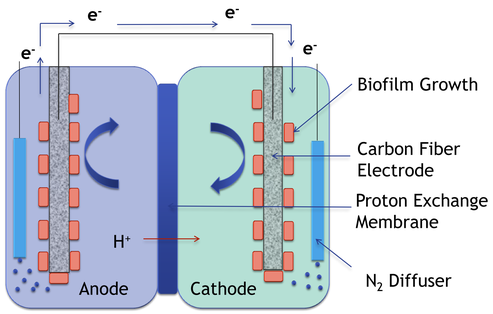
Nanowires connecting MR-1 Bacteria

Background

- Approximately 30% of California's drinking water comes directly from groundwater.
- Cr^{VI} is an EPA priority pollutant and a known carcinogen.
- Cr^{VI} is prevalent in California's aquifers
- MFCs can treat polluted groundwater by reducing Cr^{VI} (highly toxic and highly soluble) to Cr^{III} (less toxic and less soluble).
- Cr^{VI} is a waste product from the leather tanning, and electroplating industries.



Public Water Supply Wells in California with Cr^{VI} presence



Anode Reaction $C_3H_6O_3 + 3H_2O \rightarrow 3CO_2 + 12e^- + 12H^+$
Cathode Reaction: $HCrO_4^- + 7H^+ + 3e^- \rightarrow Cr^{3+} + 4H_2O$

- Carbon dioxide, electrons, and protons are generated in the anode.
- Electrons and protons are used in the cathode to reduce Cr^{VI} to Cr^{III}
- Proton exchange membrane (PEM) allows for the passage of protons across compartments.
- Anaerobic conditions are required.

Research Objective: To investigate the capabilities of Shewanella MR-1 bacteria in the reduction of Cr^{VI} present in groundwater sources. Humic Acid was included in one of the MFCs in order to accurately model the ubiquitous presence of natural organic matter within groundwater sources.

Research Results

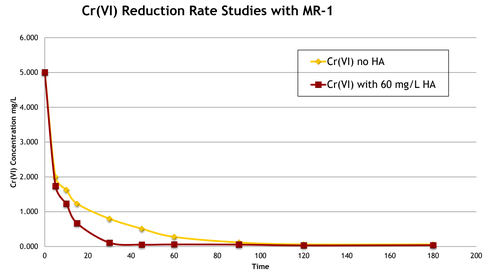
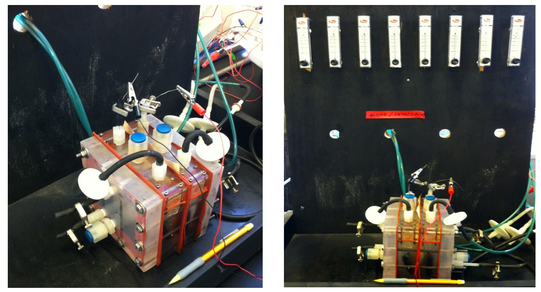


Figure 1. Chromium rate studies with Shewanella MR-1 bacteria showing the effect of natural organic matter (NOM) in chromium reduction.



Dual chambered microbial fuel cell

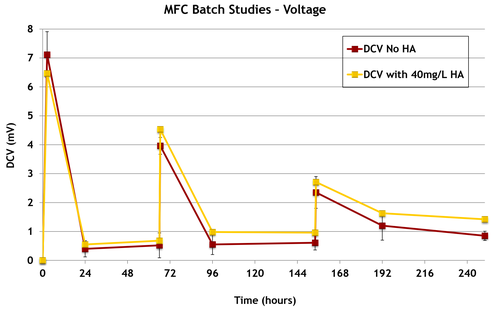


Figure 2. MFC Voltage output during Chromium reduction batch studies This studies took place in dual-chambered microbial fuel cells pictured above. As in the rate reduction studies 40 mg/L of HA were used in one of the samples. Voltage change was tracked every 5 minutes for over 240 hours and periodic injections of a chromium solution took place.

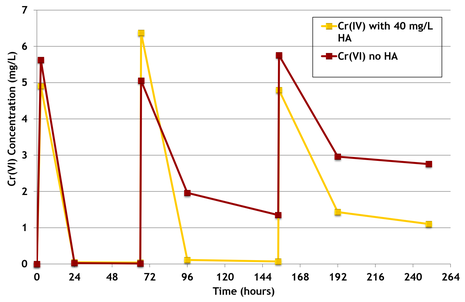


Figure 3. MFC chromium reduction batch studies.
Cr^{VI} concentrations were periodically recorded over the time length of the studies.

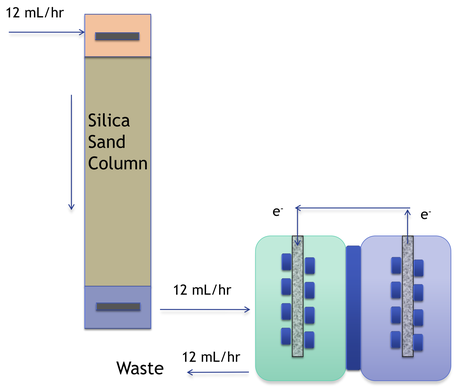


Diagram of continuous flow dynamic system

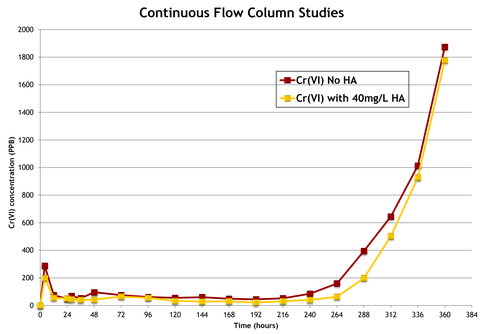
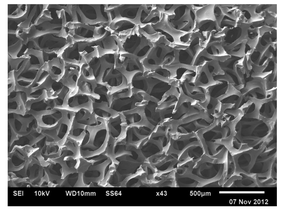


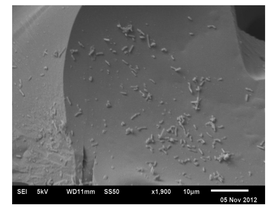
Figure 4. Chromium removal profiles in a dynamic continuous flow system.

Discussion

- Cr^{VI} concentration was significantly decreased in the presence of MR-1 bacteria.
- The MFCs retained a greater concentration of Cr^{VI} as the experiment progressed attesting to the reduction capabilities of the MFC.
- In the continuous flow dynamic studies the MFCs were able to effectively reduce Cr^{VI} below the current national MCL standard for an extended period of time.
- Experiments with NOM present resulted in better chromium removal in all cases.



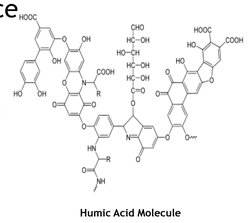
Micrograph of a Carbon Sponge Electrode



Micrograph of an electrode with MR-1 Biomass

Summary

- The ability of an MFC to reduce Cr decreases with increased amounts.
- MFCs can be successfully used to remediate polluted ground water in a cost-effective manner.
- Humic acids aid in the electron transport process.



Humic Acid Molecule

Future Research

- Wastewater as a fuel source
- Optimize MFC design to increase columbic efficiency
- Investigate the reduction of other toxic metals (i.e. U(VI))
- Address MFC system scale-up issues
- Optimize use of newly designed and fabricated MFCs

Acknowledgements

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