Metal Removal from Acid Mine Drainage using Microbial Electrolysis Cells

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Introduction

Acid Mine Drainage (AMD) occurs when sulfide-based soil and rocks are exposed to water and air due to natural weathering, abandoned coal mines, targeted ores, and construction sites [1]. The process releases metal ions, sulfates, and other cations such as Mg and Ca into surface water bodies, groundwater, and soil [1-3]. AMD has been a significant environmental and economic issue in Pennsylvania, impacting the water quality and aquatic life of over 5000 miles of water streams from abandoned mines [4].

Microbial Electrolysis Cell (MEC) is an emerging platform in various biotechnology and wastewater treatment fields. It utilizes microbes as catalysts to degrade organic matter and produce valuable products such as hydrogen. This project aims to utilize the MEC process, focusing on metal removal and hydrogen production simultaneously, as an AMD treatment, to reduce high chemical and energy consumption. By improving this system, we aim to contribute to more sustainable and efficient AMD treatment methods with low impacts.

Objectives

1. Evaluate the efficiency of Transition Metal Removal (Fe, Mn, Cu, Co, Zn, Ni, Cd, and Cr) from AMD.
2. Optimize Cathodic Conditions (pH, Voltage) to enhance selective metal reduction efficiency.
3. Investigate the role of an Anion Exchange Membrane (AEM) in facilitating ion transport between anode and cathode compartments.

Materials and Methods

- **Reactor Setup:**

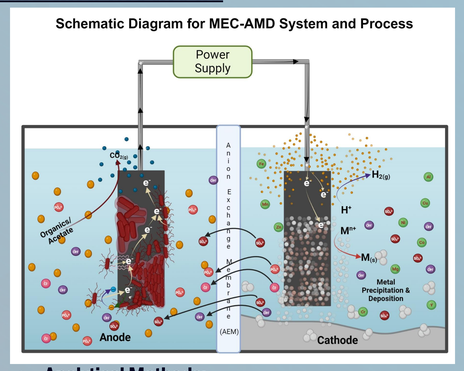
MEC is constructed with two compartments (Anode and cathode) separated by an AEM. The anode contained 30 mM Acetate as the Electron Donor, while the cathode was filled with AMD as the electrolyte for the metal reduction.

- **Electrode Configuration:**

Graphite electrodes were used in both compartments. An Ag/AgCl reference electrode was placed in the anode to control the anodic voltage.

- **Experimental Conditions:**

-0.3 V was applied to the anode to drive microbial activity and metal reduction in the cathode.



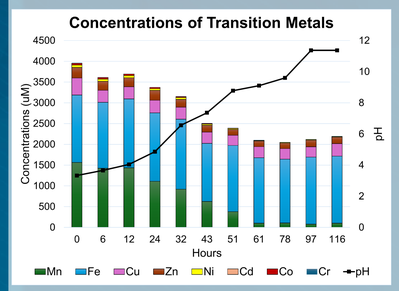
- **Analytical Methods:**

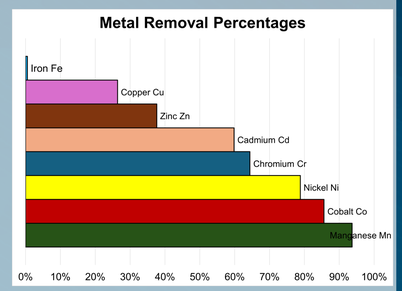
Chemical Oxygen Demand (COD) was measured using Standard HACH COD kits to monitor organic matter degradation in the anode. Metal concentrations in the cathode compartment were measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and anion concentrations were measured using Ion Chromatography (IC).

- **Hydrogen Gas & Precipitation Collection:**

105 mL of H_2 gas and 44 mg of Precipitation were collected at the end of the experiment.

Results



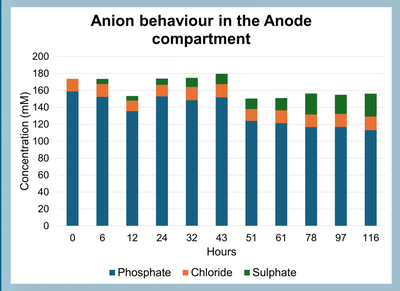


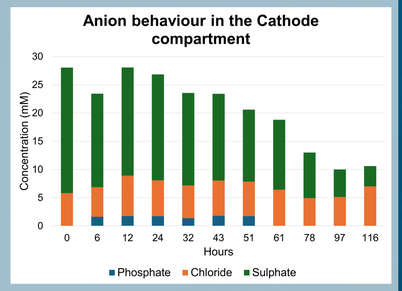
- **Transition Metal Removal:**

Mn, Co and Ni showed the highest removal rates, reaching over **70%**, while Fe and Cu had lower efficiencies.

- **pH Impact on Metal Reduction:**

The increase in cathodic pH from 6 to 11.5 was correlated with higher metal removal, indicating the role of pH in enhancing metal precipitation.



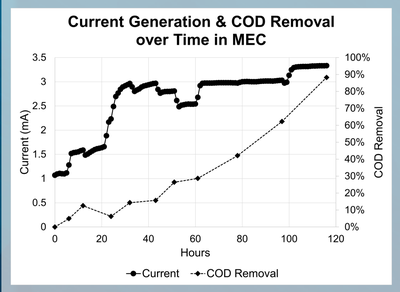


- **Anion Behavior:**

Due to AEM, sulfate concentrations in the cathode decreased significantly over time, while phosphate and chloride levels remained stable in the anode and cathode compartments, respectively.

- **Ion Transfer in AEM:**

The AEM facilitated anion movement, particularly sulfate transfer from cathode to anode, supporting the overall charge balance in the MEC system.



- **Current & COD Removal:**

Current generation increased from 1 mA to over 3 mA within 100 hours, with COD removal rates reaching over 90%, demonstrating efficient organic matter degradation.

Conclusions

- **Effective Metal Removal:**

The MEC system demonstrated significant removal of transition metals, including Mn and Co, with a total precipitation weight of **43.82 mg**, indicating successful metal reduction.

- **Role of Microbial Activity:**

Microbial electrolysis effectively facilitated the reduction of transition metals from acid mine drainage, highlighting the potential of MECs for environmental remediation.

- **Impact of Cathodic Conditions:**

Optimizing cathodic pH and voltage played a critical role in enhancing metal reduction efficiency, showing that precise control of these parameters is essential for improving system performance to do selective metal removal.

- **Ion Transport Through AEM:**

The AEM effectively facilitated ion transfer between the anode and cathode, contributing to charge balance and overall system stability.

- **Future Implications for Metal Removal:**

With further optimization, the MEC system can potentially improve metal removal efficiency, especially for rare earth elements (REEs), making it a valuable tool for the sustainable treatment of acid mine drainage.

References

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