**BACKGROUND:**

- Hexavalent Chromium (Cr\(\text{VI}\)) is an EPA priority groundwater pollutant due to its high toxicity and prevalence in natural waters.
- Exposure to Cr\(\text{VI}\) can cause lung cancer, kidney and liver damage, respiratory problems, ulcers, and skin irritation.
- A 2011 study by the Environmental Working Group found Cr\(\text{VI}\) present in 31 of 35 major cities in the United States.
- Traditional ex-situ remediation (pump and treat) of aquifers contaminated with Cr\(\text{VI}\) is energy intensive, slow, and highly invasive.
- This research proposes a sustainable and green remediation approach utilizing the integration of electrokinetic and microbial fuel cell (MFC) technologies in low permeability aquifers.

**ELECTROKINETIC TECHNOLOGY**

- Heavy metals (such as chromium) are one of the main contaminants that can be removed by electrokinetic processes in groundwater.
- One of the advantages of electrokinetic transport is to mobilize contaminants in low permeability zones of aquifers, such as clayey sand.
- Electrokinetic system is comprised of the following components:
  1. External direct current source
  2. A positively charged electrode (anode)
  3. A negatively charged electrode (cathode)

**MICROBIAL FUEL CELL TECHNOLOGY**

- Microbial Fuel Cells exploit bacteria’s natural ability to break down organic matter in order to generate energy. *Shewanella Oneidensis* strain MR-1 was used in these experiments.
- Carbon dioxide, electrons, and protons are generated in the anode.
- The electrons generated in the MFC redox reaction can be used to reduce heavy metals found in groundwater.
- Electrons and protons are used in the cathode to reduce Cr\(\text{VI}\) to Cr\(\text{III}\).
- A Proton Exchange Membrane (PEM) allows for the passage of protons across compartments.
- Anaerobic conditions are required in anode and cathode compartments.

**RESEARCH OBJECTIVE:** To investigate the remediation potential of the integrated electrokinetic and microbial fuel cell technologies in the reduction of Cr\(\text{VI}\) present in groundwater sources.

**RESEARCH RESULTS:**

- Voltage produced during the EK-MFC semi-batch experiment
- Current measured within the electrokinetic cell for aquifer soil
- Continuous Flow EK-MFC System
- Experimental set-up for the semi-batch EK-MFC System
- Experimental set-up for the continuous flow EK-MFC System
- CV\(\text{III}\) and total chromium concentrations in the anode reservoir during electric potential application for aquifer soil
- CV\(\text{III}\) and total chromium concentration in the center of the clay column during electric potential application for aquifer soil
- CV\(\text{III}\) and total chromium concentrations in the cathode reservoir during electric potential application for aquifer soil
- Scanning electron micrographs of a Proton Exchange Membrane with MR-1 Biomass
- Scanning electron micrographs of the anode electrode with MR-1 Biomass

**SUMMARY AND DISCUSSION:**

- CV\(\text{III}\) concentration was significantly decreased in the MFC system using *Shewanella oneidensis* strain MR-1.
- Significant reductions of Cr\(\text{VI}\) and total chromium occurred in the continuous flow EK-MFC system.
- pH decreased in the anode and increased in the cathode during the continuous flow experiment.
- MFCs can be successfully used to remediate polluted groundwater in a cost-effective manner.
- Electrokinetic technology was demonstrated to be effective in mobilizing Cr\(\text{VI}\) in bench-scale column simulating aquifer.
- The remediation process discussed in this study has low carbon footprint.

**FUTURE RESEARCH:**

- Design and implementation of a pilot-scale process according to the following conceptual rendering:
- Investigate the limitation of electrokinetic transport and MFC technologies for Cr\(\text{VI}\) reduction.
- Investigate the effectiveness of electrokinetic and MFC technologies for the reduction of other toxic metals (i.e. U\(\text{VI}\)).

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