

Field Test of a Pilot-Scale Sequential Reductive/Oxidative Bioelectrochemical Process for CAH Removal from Contaminated Groundwater

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Background/Objectives. Chlorinated aliphatic hydrocarbons (CAHs) are common groundwater contaminants due to their improper use in the past. In recent years, more sustainable remediation and cost-effective technologies involve groundwater's indigenous microorganisms such as dehalorespiring microorganisms. Dehalorespiring microorganisms are able to reduce CAHs as perchloroethylene (PCE) and tetrachloroethane (TeCA) to ethylene via reductive dechlorination (RD) while aerobic dechlorinating microorganisms oxidize low chlorinated compounds such as cis-dichloroethylene (cDCE) and vinyl chloride (VC) into nonharmful products. The integration of reductive dechlorination and aerobic dechlorination results in an efficient approach for the complete mineralization of high chlorinated compounds, which usually leads to a buildup of VC. A sequential reductive/oxidative environment can be easily created by a bioelectrochemical systems (BES) which allows the control of dechlorinating microorganisms' activity simply by an electrochemical device. The BES avoids the use of fermentable substrates or other chemicals in groundwater to stimulate the RD and it can be used to support both reductive and oxidative dichlorination reaction.

Approach/Activities. The study presents the development of a pilot-scale sequential reductive/oxidative bioelectrochemical process in which four microbial electrolysis cells (MECs) were connected in series. In the first two MECs, named reductive reactors, a graphite granular cathode was used as working electrodes while in the second two oxidative MECs, a titanium MMO anode was used as the working electrode. In the reductive reactors, the cathode chamber supplies the reducing power necessary to the dechlorinating biomass to perform the reductive dechlorination reaction, while in the oxidative reactors, the titanium-metal mixed oxide anode ensured the oxygen evolution necessary for the aerobic dechlorination. Both reactors were equipped with a graphite internal counterelectrode which allowed for a simple, flexible and cost-effective configuration of the process. The sequential bioelectrochemical process has been fed by CAH-contaminated groundwater. The reductive reactor, that performs reductive dechlorination, produced low chlorinated byproducts, the outlet of the reductive reactor, that consists in the oxidative inlet, endures the aerobic dichlorination. The hydraulic retention time has an important effect on both steps and is critical to ensure the removal of the CAHs produced by the reductive step. The process has been characterized by the evaluation of the dechlorination rates, the energy consumption, and the coulombic efficiencies, which represents the amount of electricity directly involved in the reductive and oxidative dechlorination.

Results/Lessons Learned. The pilot-scale sequential reductive/oxidative bioelectrochemical plant represents the largest attempt to scale up a bioelectrochemical process for CAHs. The pilot-scale performances were partially achieved, indeed while the removal capacity, the coulombic efficiency and the energy consumption resulted in line with the laboratory-scale performance input which resulted in the results obtained under laboratory scale, the presence of low chlorinated byproducts (i.e., cisDCE and VC) in the effluent indicated the insufficient dechlorinating capacity of the pilot. The main reason that affected the pilot plant performance was the groundwater quality; the tetrachloroethane (re-mobilized in the aquifer) resulted in recalcitrant with respect to the microbial consortium utilized for the pilot plant inoculum as

demonstrated in microcosm studies. Future inoculum selection and implementation will be crucial for an efficient process design.