Remediation of TCE co-contaminated groundwater using iron electrolysis process
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Abstract
Groundwater contamination with mixtures of organic (chlorinated solvents, benzene, polycyclic aromatic compounds etc.) and inorganic contaminant (chromium, arsenic, lead etc.) is a common problem; development of innovative and high efficient technologies to target wide range of contaminant is necessary to overcome this problem. In the present study, a novel electrochemical process, iron electrolysis, is developed for the remediation of TCE co-contaminated groundwater. In the first part, the batch experiments are conducted to evaluate the role of iron electrolysis on the improved electrochemical dechlorination of TCE. In the second part, a novel electrochemically induced reactive barrier system is developed for the remediation of TCE co-contaminated groundwater. The system consists of sequentially placed electrodes, a cast iron anode, a porous copper cathode followed by mixed metal oxide (MMO) anode. The cast iron anode releases ferrous species (Fe2+) into the electrolyte and generates reducing electrolyte condition. This reducing electrolyte condition enhances the reductive TCE dechlorination on the central copper cathode. The ferrous species released from iron anode not only enhances the transformation of TCE on the cathode, but also facilitate the transformation of other contaminants including dichromate, nitrate, selenate and arsenite. The secondary anode (MMO) generates proton and oxygen to neutralize the system. Flow-through column experiments are conducted to evaluate the process and system variables (flow rate, current density, influent contaminant concentration).

Introduction
Contaminated soil and groundwater are major problems in the US and in Puerto Rico. Presence of over 150 contaminated sites, including 15 Superfund sites, results in high potential for contamination exposure and risks to public health. Trichloroethylene (TCE), often used as a metal degreaser, is one of the predominant contaminants that may contribute to serious health problems.

The Puerto Rico Testsite for Exploring Contamination Threats (PROTECT) research Center that studies the effects of environmental contamination on human health and aims to reduce the impacts on public health. As part of the Center, Project S will develop a green remedial technology to treat the TCE in groundwater. In this study we propose an electrochemically induced dual barriers for transformation of TCE co-contaminated groundwater. An example of a potential in-situ scheme of the proposed technology is shown below.

Contaminant Transformation Process

Implications for groundwater remediation
Different from the conventional electrochemical processes only using inert anodes like MMO and carbon materials, the iron anode generates ferrous species, which can serve either as electron donors for the reduction of contaminants or as adsorbents for the immobilization of contaminants. Therefore, an electrolyte-based “barrier” consisting of ferrous species was built for the cleanup of some groundwater contaminants. Unlike the zero valent iron permeable reactive barriers, the reactivity of the dual electrochemical barriers can be easily controlled by varying the applied current in term of the type and level of the contaminants. Besides, introducing iron anode and MMO anode simultaneously (or individually) provides a facile way for the in situ regulation of the redox condition of groundwater. The redox conditions can be varied based on the properties of target contaminants. Stable redox condition, in combination with the electrochemically generated gases (O2, H2), may stimulate the anaerobic or aerobic activities of the bacteria in the groundwater, facilitating the degradation of contaminants.

Conclusion
A novel electrochemical barrier consisting of iron anode and porous cathode is proposed for the remediation of synthetic groundwater with mixed contamination.
- Cast iron anode produces ferrous species, which not only creates an electrolyte-based “barrier” that enhances the reduction of TCE on cathode, but also abates other contaminants including dichromate, selenate and arsenite.
- The electrical currents passing the two anodes can be adjusted and different redox conditions of electrolytes can be controlled.
- The overall system, comprising the electrode-based and electrolyte-based barriers, can be engineered as a versatile and integrated remedial method for a relatively wide spectrum of contaminants and their mixtures.

Reference

Acknowledgements
The project described was supported by Award Number P42ES017198 from the National Institute Of Environmental Health Sciences. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute Of Environmental Health Sciences or the National Institutes of Health.