New Integrated Biogeochemical/Electrochemical Method for Remediation of Contaminated Groundwater

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Background/Objectives. New technologies are desired for safe, cost-effective remediation of groundwater impacted by a wide variety of organic contaminants, including (rapidly) emerging contaminants such as perflourinated compounds, Ideally, the *in situ* technology can be effectively employed in deep aquifers and mixed lithologies to easily manage large, dilute plumes often in remote areas. Other benefits would include low cost, small footprint, minimal energy consumption (solar), low maintenance and no external chemical requirements. One such method involves integrated electro-chemical reactions under controlled conditions. Direct oxidation at semiconductor films coupled with enhanced Electro-Fenton oxidation is achieved electro-chemically and controlled remotely. Secondary effects include enhanced contaminant desorption and stimulated biogeochemical destruction. Rapid oxidation of chlorinated solvents and petroleum hydrocarbons has been observed at pilot and full scales, and future applications could address perchlorate, perflourinated compounds, 1,4-dioxane, pharmaceuticals and other challenging contaminants.

Approach/Activities. The **EBR®** (US 9,975,156 B2) system is comprised of subsurface electrodes with high catalytic activity for O_2 generation which is constantly reduced to form H_2O_2. An additional electrode is used as constant source of Fe cations via forced corrosion and effective Fe^{2+} formation from Fe^{3+}. The system radius of influence is increased by imposing an effective constant flux across the well interface due to boundary conditions effects and high chemical potential, in addition to the existing natural dispersion and advection forces. Furthermore, electro-osmosis induces groundwater flow between coupled wellbores yielding a more complete approach to aquifer remediation, especially in fine-grained, low-permeability materials that typically harbor sorbed residuals because electro-kinetics enhances the mobilization and therefore the availability of the contaminants. In terms of secondary processes to help manage contaminant rebound, the co-mobilization of nutrients and the oxidative nature of the method supports accelerated aerobic bioremediation. Here, bacterial distribution throughout an aquifer is often overlooked. But soil bacteria are like a colloid - with a surface charge – and are therefore also subjected to dynamics influenced by the effect of an applied electric field.

Results/Lessons Learned. Successful implementation of the EBR® technology at several sites has resulted in rapid site closure. The method was inspected by the water authority of Israel and its use is widely approved. For example, a study conducted by the Israeli Geological Survey and the Israeli Water Authority it was found that the electrolysis system induced rapid change in the biochemical conditions on the site (ORP levels are remotely monitored and regulated by the system). Anaerobic (low redox) wells rapidly turned aerobic. As a result, from this change, a significant decrease in the concentrations of MTBE from 68 mg/L to <0.04 mg/L was associated with a change in its isotopic composition. Assuming that the isotopic enrichment constant in the process of groundwater MTBE breakdown equals the enrichment, constant obtained from microbial experiments in the laboratory (ε = -0.7‰), then > 96% of the MTBE underwent oxidative destruction. Similar results from various full-scale remediation projects will be presented along with information on cost and processing. Lastly, we present the idea of non-uniform electro-kinetics via a polarity exchange technique to intermittently reverse electric currents to prevent significant pH changes and discuss potential applications for other contaminants under various site conditions (deep aquifer, fractured rock etc.).