(A) Highly Sustainable Active Remedial Tool for Degrading Petroleum and Chlorinated Contaminants, Even in Clay Formation

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Bioelectrochemical technologies (trademarked "E-Redox®"-O [oxidation] and -I [reduction]) have been respectively applied at dozens of sites to treat petroleum and chlorinated solvent (CVOC)-contaminated soil and groundwater and successfully achieved site closures. The two E-Redox® tools are applicable to tight formations such as clay, thanks to their working mechanism of electron transport. These remediation technologies are featured by the use low-cost non-consumable materials, rapid installation, and low frequency O&M, and Zero to minimum energy input. Sustainability analyses by using the SiteWise (version 3.2) indicate that the operational carbon emission of the E-Redox® technologies is orders of magnitudes lower than contemporary remediation technologies, especially for UST and chlorinated solvents impacted sites with tight formations such as clay, silts, and bedrock fractures.

In the case study of petroleum contaminants remediation, E-Redox-O (oxidation) units were installed in groundwater wells at an active fuel station in Littleton, Colorado, with a total area of approximately 37,500 ft^2. The units were installed in an array throughout the contaminant plumes within the property and operated with ZERO energy input. After 4 months of operation, approximately 93% of benzene was degraded throughout the site. After the benzene was degraded to below or near the detection limits in majority of the site, three E-Redox units were moved from "clean" locations to new locations to address the newly identified plume area. Electrical voltage was generated in all E-Redox units since installation, ranging from 30 to 180 mV. The voltage profiles served as a convenient tool for real-time monitoring of the E-Redox units performance and biodegradative activity in groundwater in general without the use of groundwater sampling. The 2-yr operation the E-Redox-O technology at this site has achieved a substantial reduction of overall benzene concentrations in the groundwater (below detection limit of 0.001 mg/L). The site is currently under post-remediation monitoring for closure.

In the case study of CVOC remediation, the E-Redox® system initiates reductive reactions that are dominated by abiotic beta elimination, and desorption of CVOC compounds from solid into aqueous phase. The rapid abiotic dichlorination process results in the production of ethene and ethane without accumulation of dichloroethenes and vinyl chloride. The E-Redox®- I (reduction) units was implemented at a former dry cleaner Brownfield site in Denver, CO. Tetrachloroethene (PCE) was the main constituent of concern in the groundwater. The subsurface formation is clayey with low permeability, obstructing the performance of other remediation efforts, including injections of permanganate, with limited dispersion and persistence in wells. The E-Redox®- I (reduction) units were installed. Monitoring data showed a rapid reduction of PCE from 169 mg/L to approximately 50 mg/L within 30 days; however, PCE concentrations fluctuated around 50-60 mg/L over 13 months. The cause was presumed to be the presence of residual permanganate in the groundwater, which interfered with the reduction of PCE by the E-Redox® units. After raising the intensity of the E-Redox® units, permanganate was reductively depleted, and PCE reduction resumed in most areas of the site.

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