Quantifying the Thermal Desorption Effect Resulting from the Exothermic Fenton's Reaction

Gary Cronk (gary@jagconsultinggroup.com)
(JAG Consulting Group, Santa Ana, CA, USA)
Greg Sounhein (greg@sounpacific.com)
(SounPacific Environmental Services, Las Vegas, NV, USA)

Background/Objectives. The heat given off during the exothermic Fenton's ISCO reaction has seldom been quantified or recognized as a significant contributor in VOC destruction. This is likely due to hydrogen peroxide's reputation as a generator of high strength hydroxyl radicals that provide excellent VOC destruction without consideration of the thermal desorption effect. Considering the large number of ISCO sites that experience VOC rebound from matrix diffusion, there is a significant need to quantify the effectiveness of thermal desorption during the Fenton's ISCO reaction.

Approach/Activities. Hydrogen peroxide possesses tremendous exothermic potential. In the field, groundwater temperatures generated by the Fenton's reaction have been measured in the range of 110º to 160º Fahrenheit while injecting 10% to 12% stabilized peroxide (using a carboxylate chelating agent). Unfortunately, this exothermic temperature increase cannot be satisfactorily duplicated in the lab environment, due to the small size of the testing vessels typically used. The exothermic Fenton's reaction is most evident and measurable during a field injection, where heterogeneous soils create semi-confining conditions which trap the heat released by the Fenton's reaction while simultaneously increasing subsurface pressures due the rapid release of oxygen gas. A Bench Scale Treatability Test was designed to simulate the thermal effect from the Fenton's reaction in the field. Separate peroxide reactor vessels (containing high levels of PCE, TCE, and 1,1,1-TCA in both soil and groundwater) were tested by heating the vessels to 130º and 110º Fahrenheit, respectively. Control samples (without peroxide) and unheated peroxide vessels were also included in the bench test design.

Results/Lessons Learned. Using a mass balance approach, it was determined that the sorbed mass in the control sample was significant at this site, with the soil mass being over 7 times higher than the dissolved phase mass (31,010 µg vs. 4,120 µg Total VOCs). The bench testing confirmed that 49% more thermal desorption (VOCs removed from soil) occurs at 130º F when compared to an unheated peroxide vessel. And up to 33% more desorption occurs at 110º F than an unheated vessel. Equally important, the bench testing determined that 130º heat also increases the destruction rate of dissolved phase VOCs by 90% and the 110º heat increased the dissolved phase VOC destruction rate by 89% compared to unheated vessels. The increased VOC removal and destruction rates at higher temperatures are primarily due to faster reaction times and increased VOC solubility. Peroxide oxidation is a two-step process that involves initial desorption of VOCs from the soil and subsequent destruction of dissolved phase VOCs. Overall, this bench testing confirmed that the heat given off (or simulated) from the Fenton's reaction provides a huge increase in destruction of dissolved phase VOCs while also enhancing the desorption of VOCs from the soil. The combined thermal effect of the Fenton's reaction provides a significantly improved VOC treatment effectiveness as compared to other ISCO technologies (that don't produce a thermal influence). Capitalizing on this thermal effect, a Fenton's injection event can be engineered to provide maximize VOC desorption and destruction and thereby minimize the matrix diffusion rebound effect.