Potential and Limits of Aerobic and Anaerobic BTEX Biodegradation in Aquifers

by Joseph P. Salanitro, Ph.D.

It is now well established that a major factor of the intrinsic containment and mass decline of plumes of the aromatic hydrocarbons benzene, toluene, ethylbenzene, and xylene (BTEX) from fuel spills to subsurface aquifers is the inherent and ubiquitous degradative activity of soil microbes on these compounds. The availability of dissolved oxygen (DO) through the processes of aquifer reaeration (groundwater flow, rainfall events, capillary fringe aeration) is also essential for stimulating aerobic biodegradation of BTEX.

In recent years, laboratory experiments with aquifer sediments have shown that BTEX may be biodegraded at significant rates by anaerobic bacteria utilizing alternate electron acceptors (EA), e.g., NO_3^-, Fe^{+3}, SO_4^{-2}, and CO_2. These findings have prompted us to investigate three laboratory soil/groundwater systems (aerobic, anaerobic, and chronic low DO) which may represent field plume conditions. When aquifer sediments were equilibrated with sufficient DO, hydrocarbons (BTEX) were also degraded at high rates with no lag phase. Experimental simulations of chronic low DO, a condition common in low permeability aquifers, were performed in a pressure-transducer-controlled respirometer in which the DO was maintained at constant low levels (less than 1 to 2 mg/L). BTEX also degraded rapidly at all DO levels.

These results suggest that plumes that appear to have low DO but continuous oxygen infiltration significantly bioattenuate BTEX. In addition, this model for an O_2-diffusion-limited aquifer may not be anaerobic, but may represent stable, slowly degrading aerobic plumes. The anaerobic biotransformation potential of BTEX was also determined in microcosms prepared with subsoil or groundwater amended with NO_3^-, Fe^{+3}, SO_4^{-2}, or no EA. Groundwater from the "aerobic" and "anaerobic" portions of one site plume showed losses in BTEX, but no correlation existed between the presence of reduced EA and biodegradation. Anaerobic slurries of subsoil from another site showed significant BTEX declines, but reduced gases (CH_4, H_2S, H_2) were not formed. In these microcosms, however, high concentrations of soil-bound (not dissolved) Fe^{+2} formed, suggesting that Fe^{+3} may have been a predominant anaerobic EA. Our data indicate that the presumed consumption/reduction of anaerobic EA may not always be coupled to BTEX losses in groundwater plumes. Finally, these results suggest a more critical evaluation of natural attenuation in aquifers is needed regarding O_2 transport mechanisms and the extent of anaerobic BTEX biodegradation.

Biographical Sketch

Joseph P. Salanitro is a senior staff research microbiologist in Environmental Technology at Shell Development Company's Westhollow Technology Center (P.O. Box 1380, Houston, TX 77251). He received his Ph.D. in microbiology from Indiana University. During his 25-year career with Shell, he has been involved in both the chemical and oil sectors of environmental research, including the aerobic and anaerobic biodegradability testing of surfactants, chemicals, pesticides, and petrochemical waste effluents and the role of microbes in sour gas formation in oilfield waterfloods. His current interests are biodegradation testing in environmental media and defining the potential and limits of aerobic and anaerobic biodegradability of crude oil and fuel components in the remediation of soil and ground water.