Design and Performance of a Biobarrier for Perchlorate Treatment

Richard Royer (rich.royer@arcadis.com) (Arcadis, Clifton Park, NY)
John Wood (John.Wood@sabic.com) (SABIC, Selkirk, NY)
Bettina Longino (BLL@jcomail.com) (The Johnson Company, Montpelier, VT)
Greg Hamer (greg.hamer@woodplc.com) (Wood PLC, Irvine, CA)
Frank Szerdy (frank.szerdy@woodplc.com) (Wood PLC, Oakland, CA)
Nick Amini (Nick.Amini@waterboards.ca.gov) and Mona Behrooz (Mehrnoosh.Behrooz@waterboards.ca.gov) (Santa Ana Regional Water Quality Control Board, Riverside, CA)

Background/Objectives. An emulsified vegetable oil (EVO) biobarrier was installed and is presently operating to treat a perchlorate plume at a site in southern California. The site subsurface is composed of fine-grained sediments with irregularly occurring, laterally discontinuous coarse-grained silt and sand interbeds. The biobarrier was designed to treat dissolved perchlorate with minimal consumption of amendment by alternate electron acceptors, primarily sulfate. Perchlorate-impacted groundwater also contained naturally-occurring elevated levels of sulfate (thousands of mg/L) and chlorinated volatile organic compounds (CVOCs) whose biodegradation was undesirable.

Approach/Activities. The estimated retention time in the biobarrier was determined from a pilot scale packed-bed trench reactor. A residence time of approximately two days was established as the desired minimum for complete perchlorate degradation with minimal potential for impact to CVOCs. The combination of desired residence time and estimated groundwater velocity resulted in a nominal minimum biobarrier thickness of one foot. Direct push injection was selected as the most practical installation method. The biobarrier was installed between approximately 60 feet depth and the water table (approximately 30 feet below ground surface) to treat two water bearing zones separated by a more continuous and consistently fine-grained layer. The amount of EVO applied was calculated using site-specific EVO retention data and a saturated thickness modified to reflect only the more transmissive zones within the generally fine-grained subsurface. The resultant design used a substantially lower EVO loading than might typically be employed for CVOC treatment. During installation of the biobarrier, visual breakthrough of EVO at intermediate monitoring points confirmed that the target radius of influence was met or exceeded at the injection volumes used.

Results/Lessons Learned. Two years of monitoring data for wells upgradient, within and downgradient of the biobarrier demonstrate that the biobarrier is effectively destroying perchlorate. Water quality improvements in increasingly distal wells are observed as clean water exits the biobarrier and reduces concentrations in those wells by clean water flushing. Monitoring of perchlorate, nitrate, sulfate, and total organic carbon (TOC) over time allowed for evaluation of biobarrier dynamics and determination of the redox regime within the biobarrier. Following installation the biobarrier almost immediately went into a sulfate reducing regime. As the biobarrier matured TOC concentrations in groundwater samples decreased to background (or near background) levels and sulfate reduction greatly decreased, eventually to levels where sulfate reduction was minimal or not occurring. Thus, for this biobarrier, TOC is not a useful primary indicator of biobarrier longevity. Monitoring of terminal electron acceptor concentrations (sulfate, nitrate, and perchlorate) is being used to determine when the biobarrier will need to be reamended. An EVO-based biobarrier was designed and implemented to successfully treat perchlorate using a design and monitoring approach that differs in significant ways from biobarrier designs for CVOC treatment.