Comparative Evaluation of Oxygen Diffusion & H_2O Electrolysis Technology:

In-Situ Oxygen Enhanced Bioremediation of MTBE at a California bulk fuel terminal

A side-by-side comparative evaluation of two in-situ enhanced bioremediation technologies designed to increase dissolved oxygen (DO) levels in a contaminated groundwater plume was recently initiated at a bulk fuel terminal site in California. The groundwater at the site is contaminated with MTBE and TPH resulting from leaks\spills from above ground bulk fuel storage tanks. A pilot study was initiated by the site owner to evaluate two different technologies for increasing DO levels in the impacted groundwater to stimulate in-situ bioremediation of the contaminants, with a particular interest in remediating the more recalcitrant MTBE contamination.

Over an eight month test period the Waterloo Emitter™ oxygen diffusive in-situ bioremediation system was found to perform significantly better as compared to a water electrolysis system.

Technology and Operating Conditions

<u>Diffusive oxygen release</u>

The Waterloo Emitter™ used in this study was comprised of a 5 foot cylindrical PVC frame (3.88 inch diameter) around which ¼" diameter silicone diffusive tubing is coiled (Figure 1). The silicone tubing allows controlled and uniform diffusive release of a wide range of liquid or gaseous bio-enhancing amendment materials, in this case oxygen gas. The Waterloo Emitters™ were connected to a standard pure oxygen (99.99%) tank and pressured to 20 psi. The operation of the Waterloo Emitter™ is based on Fick's Laws of diffusion whereby the difference in oxygen concentration within the Waterloo Emitter™ diffusive silicone tubing and the groundwater establishes a controlled and predictable diffusion gradient that drives molecular oxygen through the tubing where it is immediately dissolved in the surrounding groundwater. The diffusion of molecular oxygen without any intermediary bubble-gas or solids dissolution phase transfer commonly associated with conventional air sparging, micro bubbler, or oxygen release compound techniques, results in achieving the maximum DO solubility for any given site geology conditions.

Figure 1 – Waterloo Emitter

<u>Water Electrolysis</u>

The other oxygen release technology evaluated in this project utilized down-well electrolysis units to generate in-situ oxygen by applying an electrical current to the electrolysis cell which in turn splits water molecules into oxygen and hydrogen gas. The electrolysis cell and the pump draw 5 amps of current and approximately half of this current is used to operate the pump. One oxygen atom is produced for every two electrons of current that actually is fed to the electrolytic cell. Below the electrolysis cell sits a pump which pumps the oxygen enriched water up through a vertical pipe (electrolysis cell and pump being isolated by a packer) to the upper region of the treatment well in order to attempt to push the oxygenated water out into the surrounding formation.

Site Conditions

The groundwater flow at the site is extremely slow due to a shallow gradient (0.03 ft/ft to 0.04 ft/ft) and low permeability sediments. The MTBE concentration in the treatment wells for each of the two oxygen addition technologies typically ranged between 150-400 ug/L (ppb).

This case study prepared by the University of Waterloo with editorial input provided by both the bulk fuel terminal site owner and the site consultant.

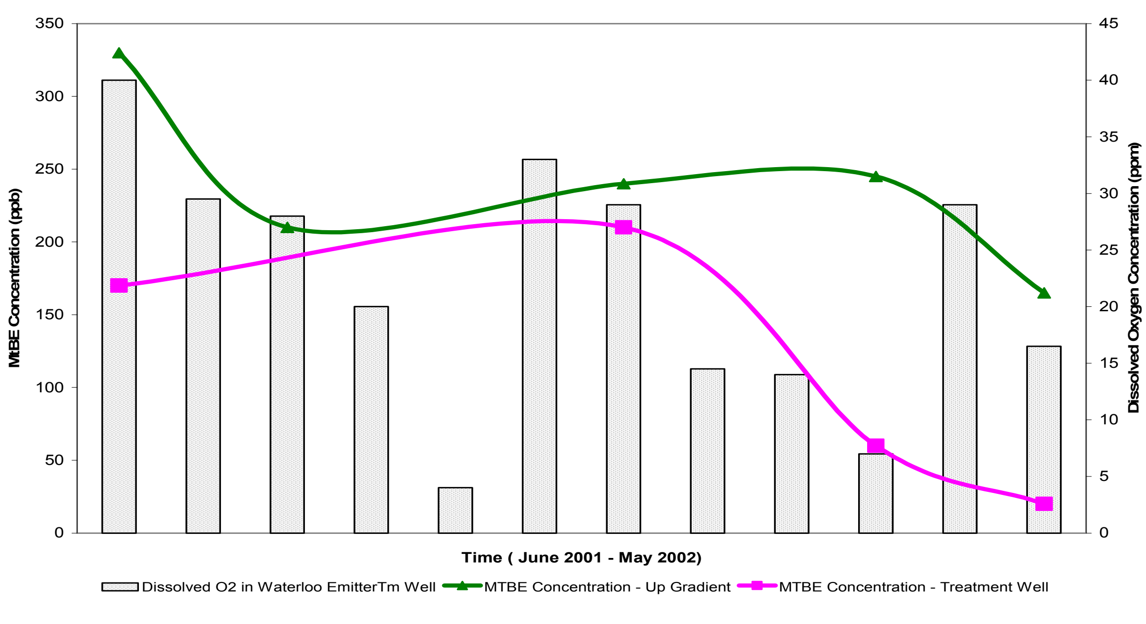
Installation Layout

A plume transect containing twenty (20), four (4) inch technology treatment wells, and forty five (45) up and down gradient monitoring wells was installed. There were nine (9) electrolysis treatment wells installed on ten (10) foot centers, and immediately adjacent to the electrolysis wells, eleven (11) Waterloo Emitter™ technology wells installed on five (5) foot centers. The up and down gradient monitoring wells were installed approximately five (5) feet from the treatment wells to measure changes in the flux of DO and contaminants as the groundwater moved through the treatment wells.

Results and Performance

Over an eight (8) month test period (October 2001-May 2002), the wells were periodically sampled and tested for MTBE, TBA, and DO concentrations. The DO levels measured in both technology treatment wells varied significantly over the test period. This observed variation was largely attributed to changing contamination concentrations that resulted in varying levels of dissolved oxygen demand and consumption in the treatment wells. The DO levels in the Waterloo Emitter™ treatment wells were approximately on average around twenty (20) mg/l (ppm) whereas the DO levels in the electrolysis treatment wells were approximately on average around five (5) mg/L (ppm). A preliminary evaluation of collected data from the electrolysis technology side of the pilot installation indicated that there was no apparent reduction in contaminant mass flux through either the treatment wells or down gradient monitoring wells. On a comparative basis, the Waterloo Emitter™ technology was observed to decrease MTBE concentrations in the treatment wells (Figure 2). However, there was little MTBE reduction observed in the down gradient monitoring wells. The lack of observed downgradient remediation might indicate that more time is required to allow the aerobic treatment zone to expand through the highly consolidated site soil formation. Also, a calculation of theoretical dissolved oxygen demand (DOD) for the concentration of hydrocarbons flowing through the treatment zone suggested that the DO supply almost equals the theoretical DOD. If a DO supply and demand imbalance does exist, there might be a requirement to install additional treatment wells should the treatment goal require a complete remediation. Based on the limited performance of the electrolysis technology, the site owners decided not to continue collecting data on the system or to further consider the technology for further full scale use at the site. The Waterloo Emitter™ technology will continue to be monitored for a subsequent 6-12 month period to collect downgradient performance data in order to assess the applicability of the technology..

Figure 2: MTBE and Dissolved Oxygen Concentrations in Waterloo Emitter Treatment Well



This case study prepared by the University of Waterloo with editorial input provided by both the bulk fuel terminal site owner and the site consultant.