In Situ Bioremediation at Port Hueneme, California

Site Name: U.S. Navy Construction Battalion Center

Site Location: Port Hueneme, California

Contaminants: MTBE, TBA

Media: Groundwater

Technology: *In situ* bioremediation

Technology Scale: Pilot

Period of Operation: August 1998 through ongoing (information available for first 18 months)

Technology Provider:
Joseph P. Salanitro
Environmental Technology
Westhollow Technology Center
3333 S. Highway 6 (P.O. Box 1380)
Houston, TX 77251-1380
Telephone: (281) 544-7552
Fax: (281) 544-8727
E-mail: *jpsalanitro@shellus.com*

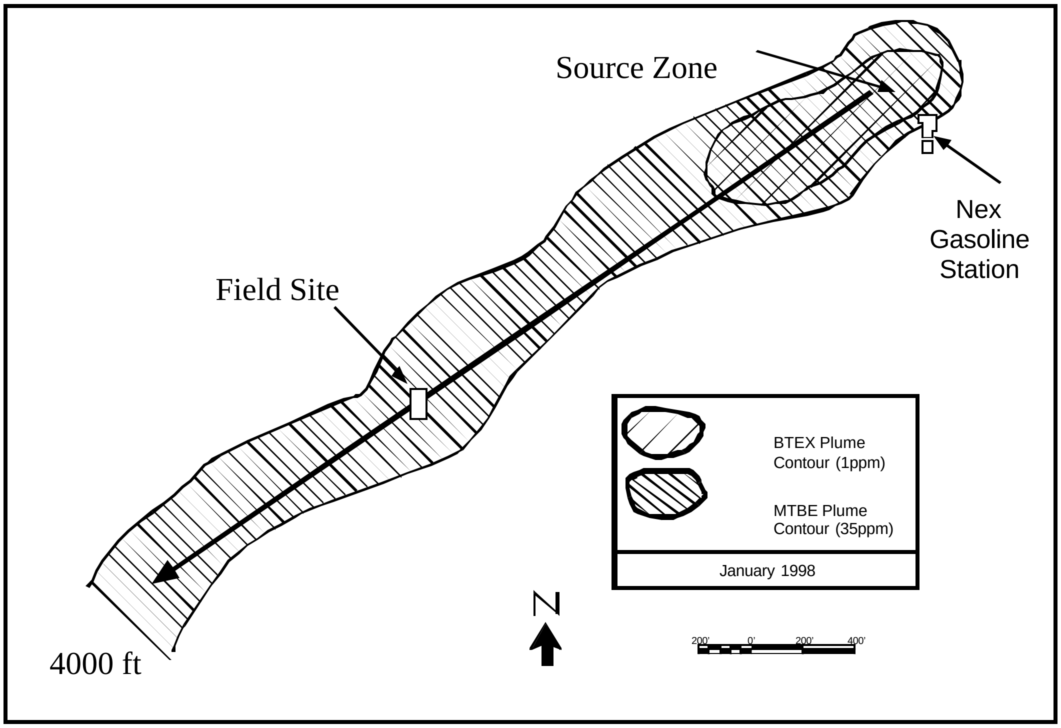
Technology Researcher:
Paul C. Johnson
Department of Civil and Environmental Engineering
Engineering Center, G-wing, Room 252
Tempe, AZ 85287-5306
Telephone: (480) 965-9115
Fax: (480) 965-0557
E-mail: paul.c.johnson@asu.edu

Site History [1]:

From 1984-1985, several thousand gallons of leaded gasoline containing MTBE were released from storage tanks at the Naval exchange (NEX) gasoline station of the naval base at Port Hueneme, California, resulting in MTBE and benzene, toluene, ethylbenzene, and xylene (BTEX) plumes. As shown in Figure 1, by January 1998, the MTBE plume was more than 4,000 feet (ft) long and 400 ft wide. The BTEX plume, located within the MTBE plume, was about 1,000 ft long and about 300 ft. Levels of TBA measured in the plume ranged from 50-250 ug/L.

The water table is approximately 13 ft below ground surface (bgs) and the upper aquifer is 10 ft thick. Cone penetrometer testing showed that the upper and lower portions of the upper aquifer sediments consist of silty loam and fine-medium sandy soils, respectively. The apparent groundwater velocity in the upper and lower portions of the upper aquifer varied from approximately 0.1-0.3 ft/day and 0.3-0.5 ft/day, respectively.

Figure 1. Site Map [7,9]



Technology Description [1, 2, 4, 8, 9]:

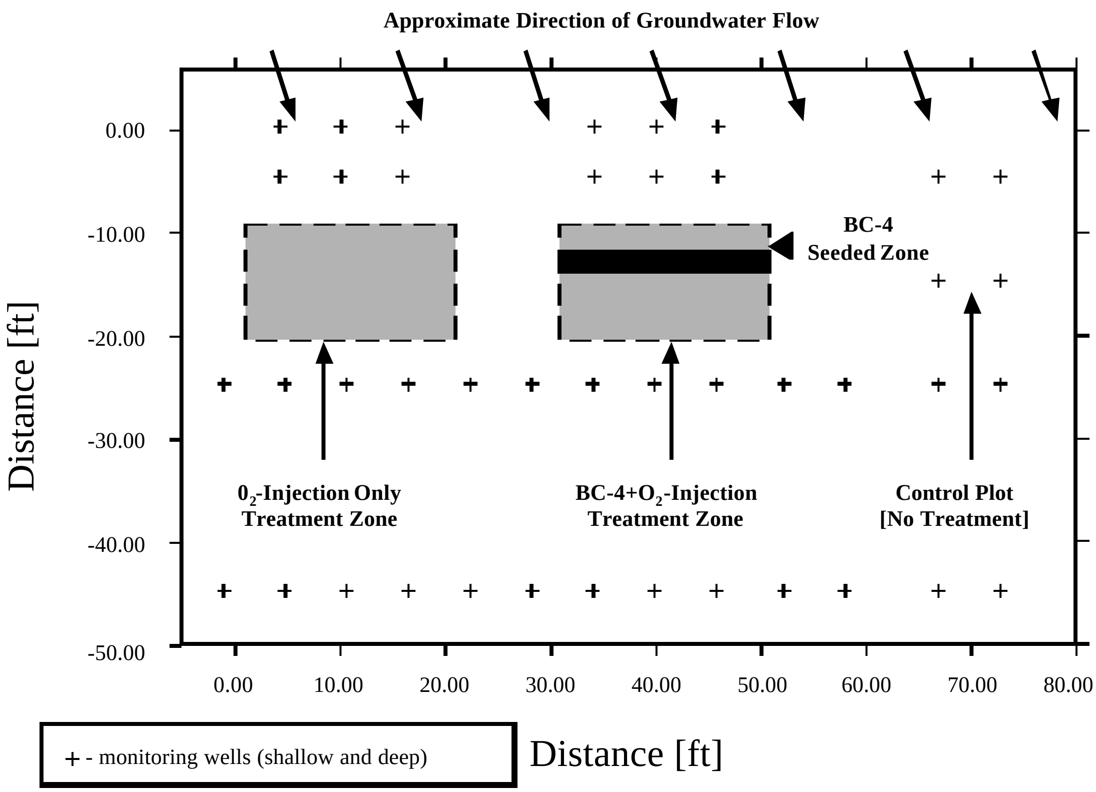
Laboratory and field experiments of in situ bioremediation using addition of oxygen and select microbial cultures were conducted at Port Hueneme.

In April 1998, laboratory testing of the microbial culture MC-100 (previously referred to as BC-4) was conducted at Westhollow Technology Center using well water taken from the Port Hueneme aquifer. Testing was conducted in microcosms under anoxic conditions and oxygenated conditions (see results below). These data indicated that MTBE and BTEX could be degraded with oxygen in soils augmented with specific ether degraders.

The MC-100 culture is part of the patented "BioRemedy" process developed at the Westhollow Technology Center, and marketed by Shell Global Solutions. Equilon Enterprises LLC designs and implements the process, which is expected to be commercially available in early 2000. The BioRemedy process can be used to control the leading edge of a MTBE plume or to degrade the source.

Field experiments conducted at Port Hueneme from June to August 1998 were designed to implant high densities of MC-100 in an oxygenated biobarrier and to compare the results with those for an oxygenated zone and a control zone. Figure 2 shows a layout for the field test site. The test site was located approximately midway down the advancing MTBE plume. In this region, MTBE is the only soluble fuel constituent, and is present at concentrations ranging from 2,000-8,000 ug/L. The concentrations of dissolved oxygen (DO) were <1 mg/L prior to the test.

Figure 2. Layout for Field Test [1]



Each test plot was aligned parallel to the initial estimated groundwater flow direction, and had dimensions of 20 ft wide and 40 ft long. The spacing between test plots was 10 ft. The MC-100 microbial consortium was grown with MTBE as the sole carbon source, and had a specific MTBE removal rate of 20-30 mg/gm cells/hr. MC-100 was injected at points across and throughout the depth of the target treatment zone. The oxygen delivery system consisted of an oxygen generating system and injection wells for intermittent oxygen sparging. The oxygen delivery system was started approximately 6 weeks prior to MC-100 seeding to increase levels of DO. Oxygen gas was generated on site with an Air-Aep AS-80 pressure swing adsorption system and was used to periodically fill 15, 76L pressure storage vessels. Oxygen delivery was intermittent with a total of 1700L gas delivered to each plot from 4-8 times/day.

Monitoring wells were installed using a direct push soil coring system, and were screened over 5 ft intervals, either from 10-15 ft bgs (shallow) or 15-20 ft bgs (deep). Groundwater samples collected from the wells were analyzed for MTBE, TBA, and numbers of MTBE degraders.

Technology Performance [1, 2, 9]:

Cleanup goals for MTBE and TBA are 5 and 10-15 ug/L, respectively, as stated in State of California MCL directives.

Laboratory Results [2]

The laboratory tests conducted with sulfate or no added electron acceptor showed that MTBE was not degraded. Unamended oxygenated water samples degraded 10-12 mg/L of MTBE to <5 ug/L over a period of 4-9 weeks, indicating the presence of naturally-occurring ether degraders. The inoculation of 50 mg cells/L groundwater with a microbial mixed culture, MC-100, showed significant enhancement of MTBE degradation. Addition of MC-100 reduced MTBE to non-detectable levels within two weeks. Microcosms prepared with soil and oxygenated groundwater from the Port Hueneme site containing gasoline (700 mg/L) also degraded MTBE (70-80 mg/L) and BTEX (45 mg/L) to non-detect levels in 16 weeks when seeded with MC-100 at 50 and 250 mg cells/kg soil.

MC-100 Field Results [1, 2]

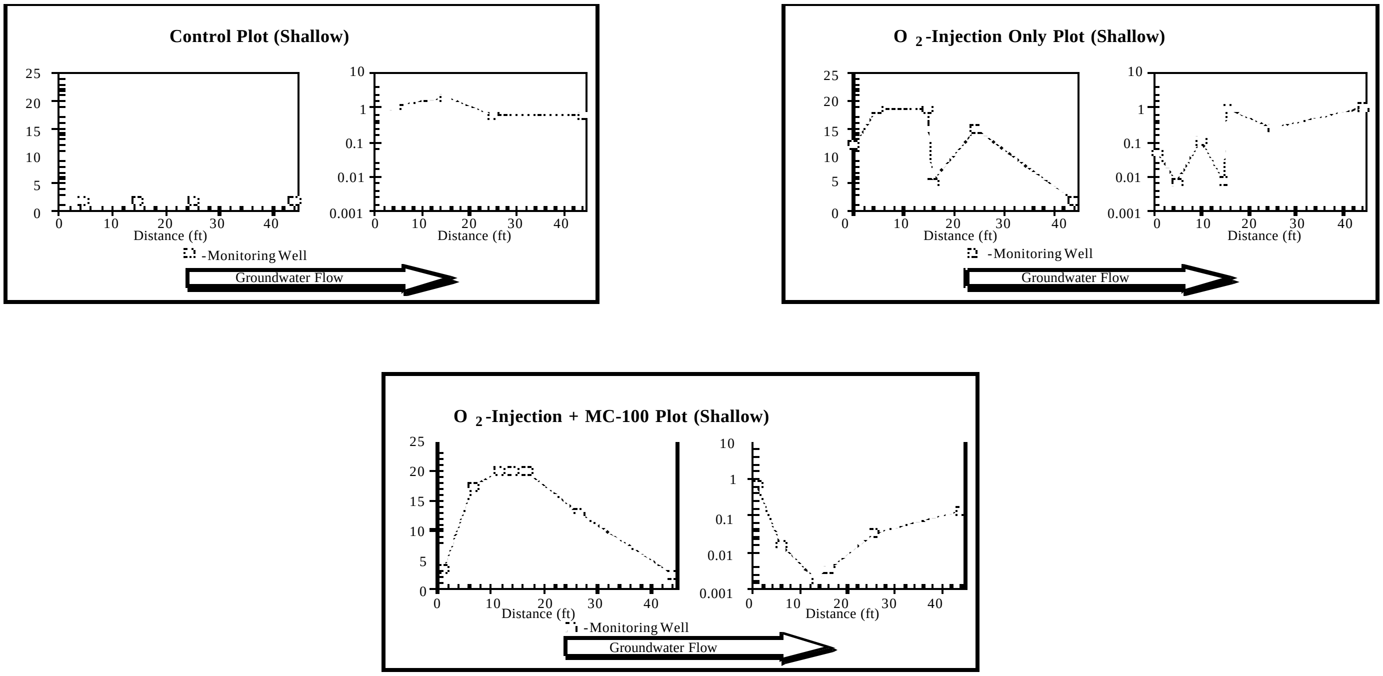
The field experiments first evaluated levels of DO in the groundwater. Throughout the target treatment zones the DO level was generally >10 mg/L and in many cases >20 mg/L. Oxygen levels also increased in areas up-gradient, down-gradient, and cross-gradient to the target treatment zones, some areas of the control plot were affected by oxygen injection.

Figure 3 shows the average DO and MTBE concentrations (mg/L) in shallow well water samples collected along the groundwater flow path in the control, oxygen only, and oxygen plus MC-100 plots. Only data from Day 261 are shown on Figure 3. This figure shows that the addition of oxygen plus MC-100 had a greater affect at reducing the concentration of MTBE in the groundwater than either the control plot or the oxygen only plot. The oxygen plus MC-100 plot reduced the concentration of MTBE from approximately 1 mg/L (1,000 ug/L) to <0.001 mg/L (<1 ug/L) at a point just down-gradient of the seeded zone, after 260 days. Although not shown on Figure 2, TBA levels also declined from 50-250 ug/L to <10 ug/L in the seeded plot.

The concentration of MTBE in the oxygen only plot declined to 10 ug/L at points 5 ft and 15 ft from the edge of the plot, after 260 days. These distances correspond to where the concentration of DO was approximately 20 mg/L. This decline indicated that indigenous degraders present in the groundwater were able to degrade MTBE in the presence of high oxygen levels after a lag time of several months. The concentration of TBA in the MTBE plume (50-250 ug/L) was not degraded in the oxygen only plot.

The concentration of MTBE in the control plot remained at approximately 1 mg/L (1,000 ug/L) at all sampling locations within 40 ft of the edge of the plot. No information was provided about the concentration of TBA in the control plot.

Figure 3. Average DO and MTBE Concentrations (mg/L) in Shallow Well Water Samples at Day 261 [2]



Technology Cost [9]:

The in situ bioremediation of MTBE using the oxygenated biobarrier was estimated by the technology provider to cost about $150,000 for a full-scale application, depending on site-specific conditions.

Observations and Lessons Learned [1,9]:

The intermittent operating mode was found to be an efficient alternative to continuous oxygen injection, with sufficient oxygen remaining in the aquifer between injection cycles.

According to the technology provider, inoculation of subsoils with specific MTBE-degraders and maintaining adequate oxygenation of the aquifer will enhance MTBE biodegradation in situ and control the MTBE plume mass from reaching potential downstream receptors. Additional benefits of inoculated barriers over oxygen-only sparged aquifers is that MTBE-degraders may not be present in many aquifers or are present in insufficient numbers to sustain MTBE degradation in plumes over long periods.

References:

1. J.P. Salanitro, G.E. Spinnler, C.C. Neaville, P.M. Maner, S.M. Stearns, Equilon Enterprises LLC, and P.C. Johnson and C. Bruce, Arizona State University. "Demonstration of the Enhanced MTBE Bioremediation (EMB) In Situ Process". In In Situ Bioremediation of Petroleum Hydrocarbon and Other Organic Compounds, Editors Bruce C. Alleman and Andrea Leeson. The Fifth International In Situ and On-Site Bioremediation Symposium, San Diego, California, April 19-22, 1999.

2. Joseph Salanitro, Gerard Spinnler, Paul Maner, and Halina Wisniewski, Equilon Enterprises, and Paul Johnson, Arizona State University. "Potential for MTBE Bioremediation In Situ Inoculation of Specialized Cultures". Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation Conference. Houston, Texas. November 17-20, 1999.

3. "MTBE Biodegradation and BC-1". Underground Tank Technology Update. University of Wisconsin-Madison, Department of Engineering Professional Development. Vol. 13, No. 6. November/December 1999.

4. "Engineered In-situ MTBE Biodegradation". Underground Tank Technology Update. University of Wisconsin-Madison, Department of Engineering Professional Development. Vol. 13, No. 6. November/December 1999.

5. Joseph Salanitro and Paul Johnson. "Using In Situ Biobarriers to Rapidly Degrade MTBE in Subsoils and Groundwater". L.U.S.T.Line, New England Interstate Water Pollution Control Commission. Bulletin 33. October 1999.

6. J.P. Salanitro, L.A. Diaz, M.P. Williams, and H.L. Wisniewski, Shell Development Company. "Isolation of a Bacterial Culture that Degrades Methyl t-Butyl Ether". Applied and Environmental Microbiology. Vol. 60, No. 7. July 1994.

7. Equilon Enterprises LLC. In Situ Enhanced MTBE Bioremediation, Westhollow Technology Center Technical Bulletin. Not Dated.

8. Shell Global Solutions (U.S.). "Bioremedy A Proven Solution for MTBE". Brochure. Not Dated.

9. J.P. Salanitro, Environmental Technology. E-mail to Linda Fielder, EPA/TIO. Comments on Draft Case Study on BC-4 Demonstrations. February 17, 2000.