In Situ Bioremediation at Vandenberg Air Force Base

Site Name: Vandenberg Air Force Base

Site Location: Lompoc, California

Contaminant: MTBE

Media: Groundwater

Technology: *In situ* bioremediation

Technology Scale: Field Demonstration

Period of Operation: 1999 to ongoing (data available through December 1999)

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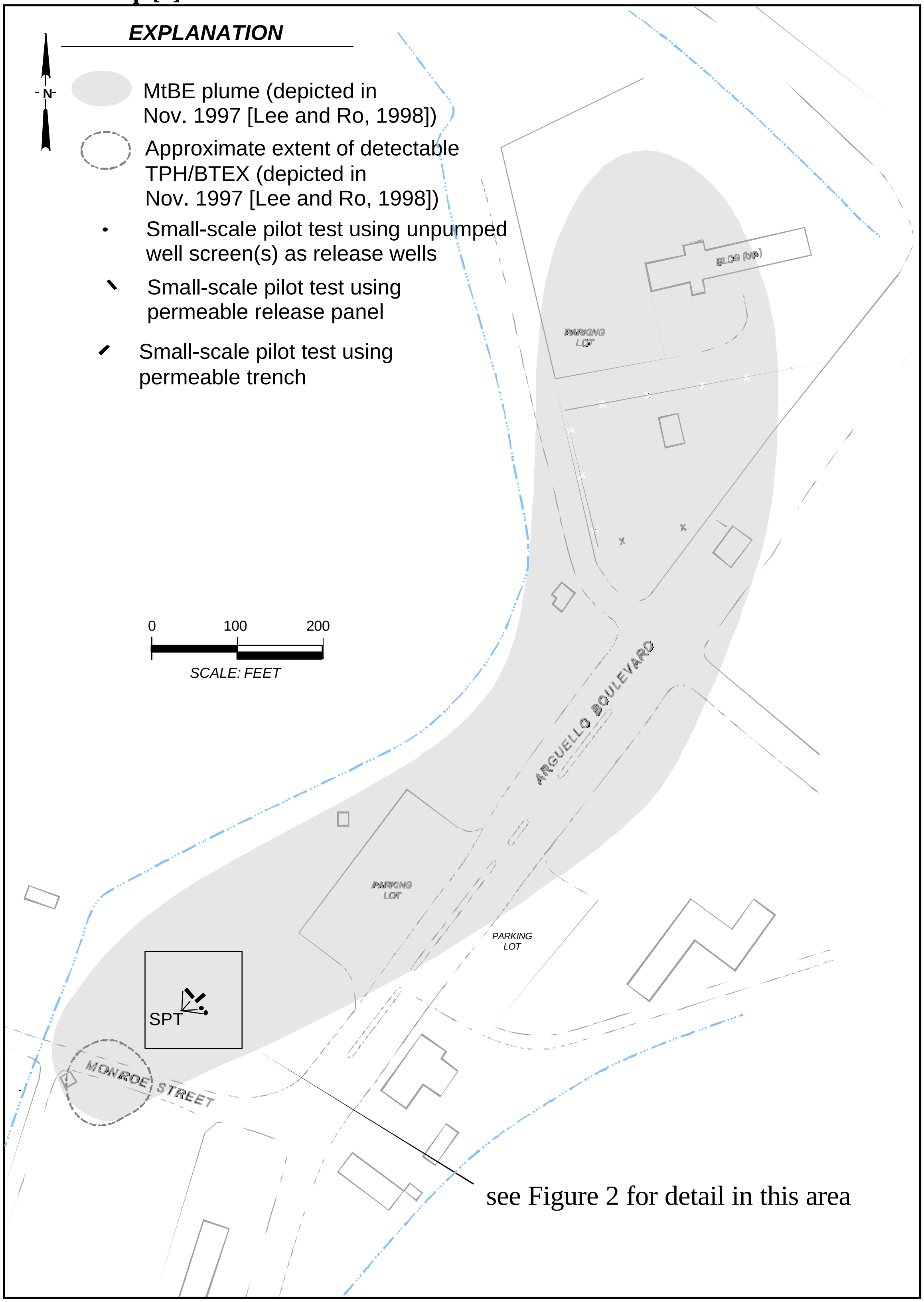
Site History [1]:

Site 60 at Vandenberg Air Force Base (AFB) is the location of an abandoned service station. Leaks from gasoline tanks resulted in contamination of the groundwater with MTBE, BTEX, and other petroleum hydrocarbons. As shown in Figure 1, data from November 1997 showed the MTBE plume extended approximately 1,700 feet downgradient from the source area, and the smaller BTEX/TPH plume, located within the MTBE plume, extended approximately 100 feet downgradient of the source area. The BTEX/TPH plume appears to have degraded relatively rapidly, while the MTBE plume appears to have continued to migrate.

A research project to study in situ bioremediation of MTBE has been underway at Vandenberg AFB since 1998. As part of this project, Site 60 is being used to study possible methods for stimulating aerobic in situ biodegradation of MTBE using native and non-native microbes. To achieve aerobic conditions in an otherwise anaerobic plume, researchers studied the use of diffusive emitters to introduce oxygen into the subsurface. The field pilot studies are being conducted near the apparent centerline of the existing MTBE plume, approximately 200 feet downgradient of the source area. At this location, MTBE is the only VOC detected at significant concentrations on a regular basis.

Figure 1. Site Map [1]



This report addresses three pilot tests being performed at the site. Two of the tests involve evaluating different configurations of oxygen emitters - cylindrical and rectilinear in terms of their ability to create aerobic conditions in the subsurface and to enhance intrinsic degradation of MTBE. The third test involves evaluating the effects of adding an emplaced MTBE degrader (strain PM1) under aerobic conditions on the degradation of MTBE.

Technology Description [1, 2, 5]:

The three pilot tests being conducted at Site 60 are:

1. Release wells
2. Release panel (permeable panel)
3. Emplaced MTBE degraders (strain PM1) (permeable trench)

Figure 1 shows the location of the pilot test areas with respect to the MTBE and TPH/BTEX plumes. Figure 2 shows the general layout of the three pilot tests. The tests are being conducted in the same general area to increase the probability that each technology is treating groundwater with similar characteristics, allowing for comparison of results. Sulfur hexafluoride (SF_6) is being used as a tracer in each of the tests to verify that the injection and monitoring systems were working properly.

<u>Release Wells</u>

The objectives of this pilot test include evaluating release wells that house cylindrical oxygen emitters to create aerobic conditions in the aquifer and evaluating the growth and activity of native microbes for oxidizing MTBE.

Figure 3 is a plan view of the release well test. Two 8 inch diameter wells (RW1 and RW2), screened to a depth of 8 ft, were installed at the site using standard auger drilling techniques, and seven multi-level wells (T1 through T7) were installed up- and down-gradient of the release wells. As shown in Figure 4, the multi-level wells were multi-chambered (7 “levels”), screened at locations above, within, and below the screened interval of the release wells.

Each release well contained an oxygen emitter. The emitters consist of continuous coils of low density polyethylene (LDPE) tubing looped around a PVC frame; each emitter contained two tubes – one inner and one outer. The length of the inner and outer tubes on the RW1 emitter are 41.4 and 54 meters, respectively. On the RW2 emitter, the length of the inner and outer tubes are 39.5 and 55.9 meters, respectively. The tubing is connected to a gas cylinder (oxygen or oxygen/ SF_6) and is pressurized (50 psi) to force the oxygen to diffuse from inside the tubing into the water flowing through the well screen. During the first 60 days of operation, oxygen only was released into the groundwater. After 60 days of operation, SF_6 was added to the gas as a tracer .

<u>Release Panel</u>

The objectives of this test include evaluating a flat panel approach for housing rectilinear emitters to create aerobic conditions in the aquifer, and evaluating the growth and activity of native microbes for oxidizing MTBE.

Figure 2. General Layout of Three Pilot Tests [1]

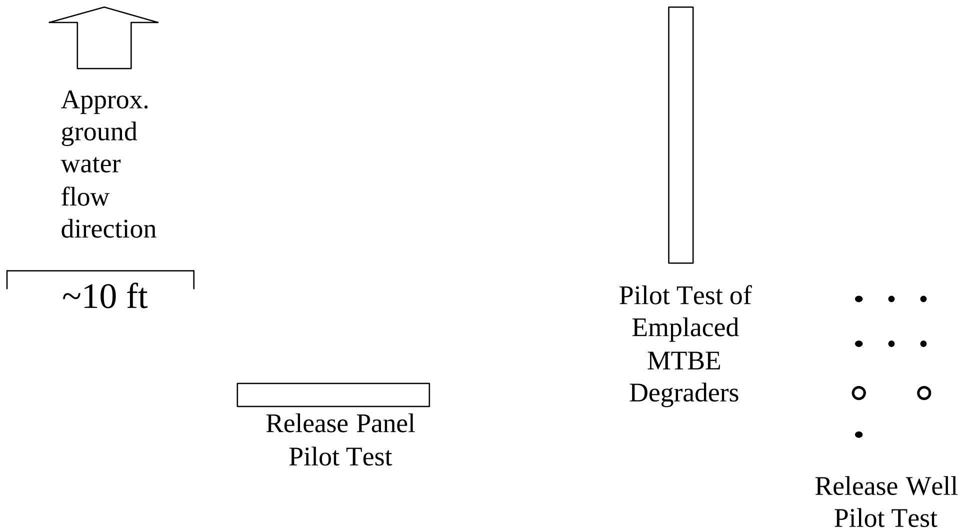


Figure 3. Plan View of the Release Well Test [1]

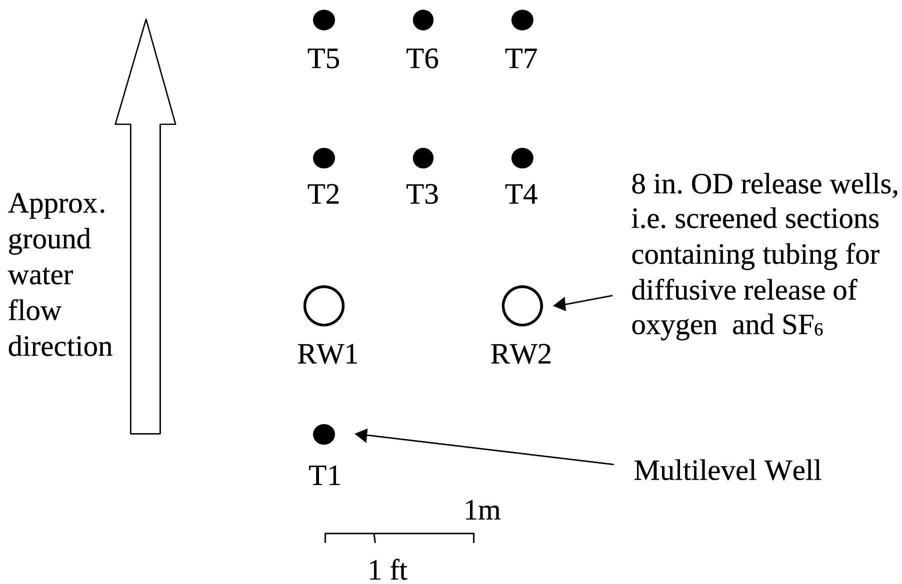


Figure 4. Plan View of the Multi-Level Wells [1]

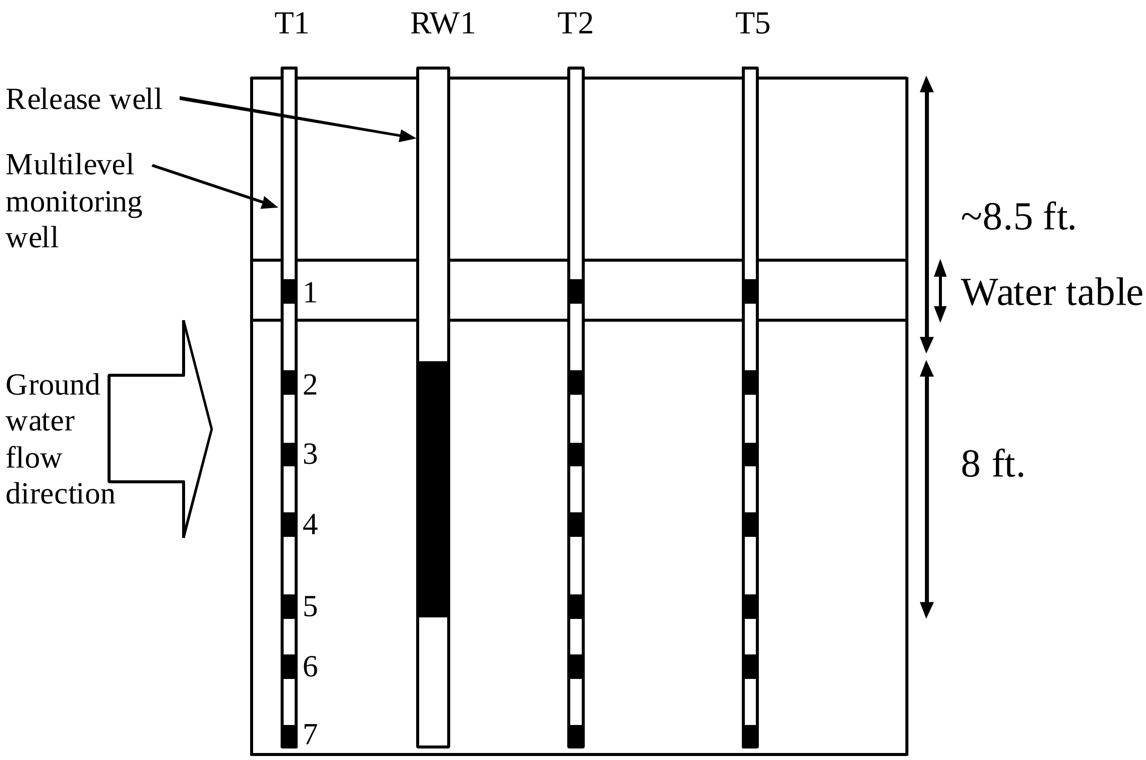
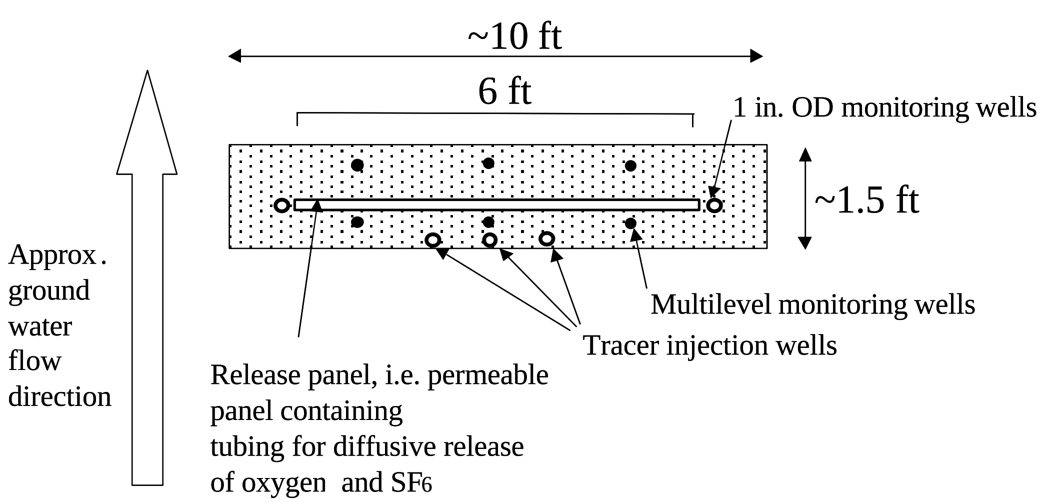


Figure 5 is a plan view of the release panel test. According to the researchers, the use of flat panels oriented orthogonal to the groundwater flow offer the potential for relatively uniform solute release over considerable cross-sectional areas. The panel consists of three layers of prefabricated stripdrain material, each 6 ft by 6 ft by approximately 1 inch. Continuous lengths of ¼ inch LDPE tubing are woven around the internal supports of the stripdrain and the panel is covered with a high permeability geotextile designed for subsurface drainage applications.

Figure 5. Plan View of the Release Panel Test [1]



The panel and monitoring wells (described below) were placed in a trench (10 ft wide and 12.7 ft deep) and secured by backfilling with pea gravel. Native materials, with relatively low permeability, were used to fill the trench to ground surface.

As shown in Figure 5, the wells installed for the pilot test included three injection wells for use in bromide tracer studies of the groundwater flow through the panel; multi-level monitoring wells, three up-gradient and three down-gradient of the panel to monitor oxygen and SF_6, and monitoring wellson the side and bottom of the panel for bromide tracer monitoring.

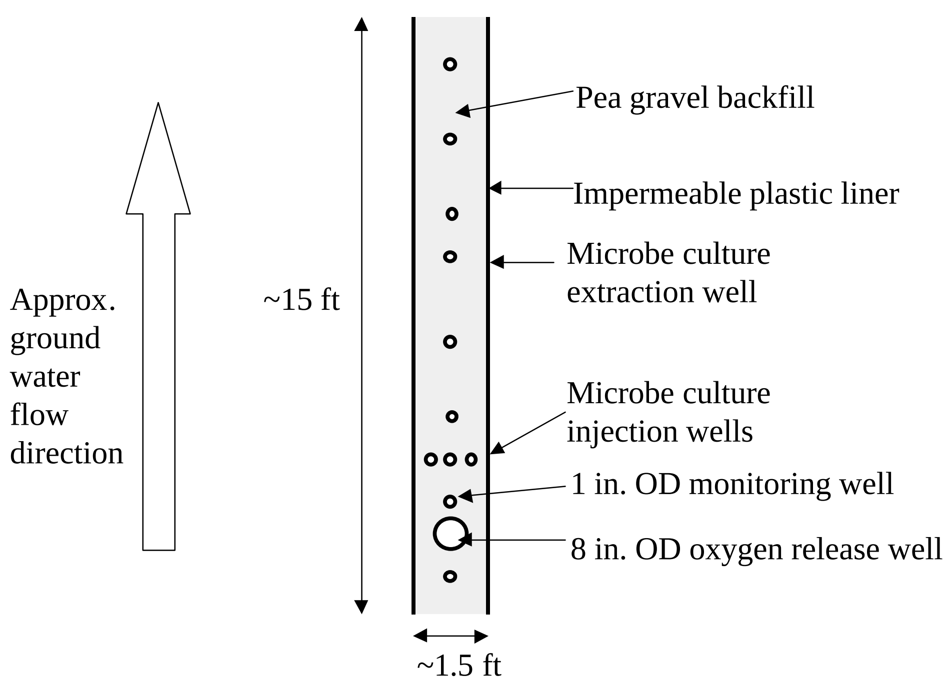
Emplaced MTBE Degraders

In addition to evaluating intrinsic bioremediation of MTBE, a test was conducted to study the addition of emplaced MTBE degraders and evaluate the performance of microbes under “the best possible field circumstances”. This study used strain PM1, which laboratory tests have shown is capable of colonizing the pea gravel and then metabolizing MTBE.

Figure 6 is a plan view of the emplaced MTBE degraders test. The test area consisted of a pea gravel section, approximately 1.5 ft wide, 15 ft long, and 12 ft deep, surrounded on the sides and bottom by an impermeable plastic (geotextile) liner. The test area was designed to allow groundwater to flow through the pea gravel without contact with the surrounding, native media. As shown in Figure 5, an oxygen releasing well is located just inside the entrance to the test area, followed by three microbe culture injection wells, and one microbe culture extraction well. The equipment was installed in a trench similar to that used for construction of the release panel test.

The treatment zone is to be established by injection of a slurry of microbes in the three injection wells, and extraction of solution from one of the wells further down-gradient.

Figure 6. Plan View of the Emplaced MTBE Degraders Test [1]



Technology Performance [1, 2, 3, 5]:

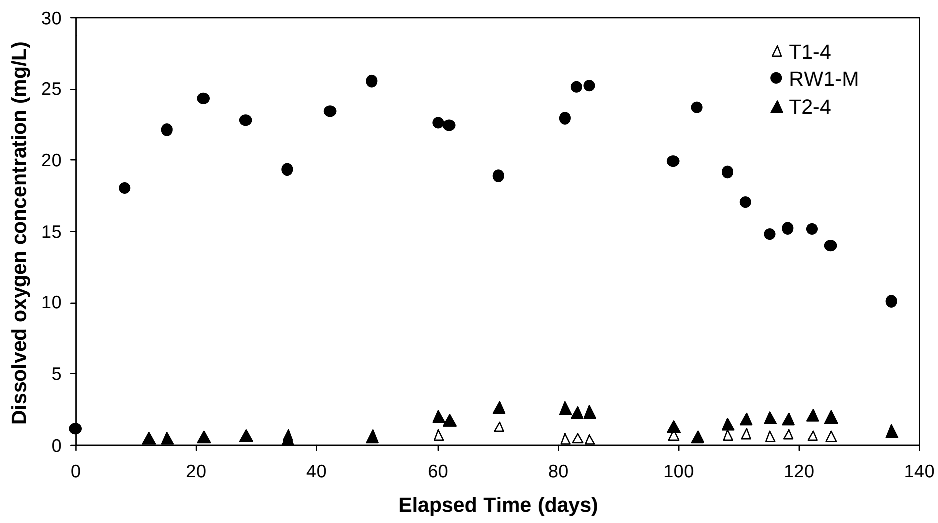
Release Wells

Data on concentrations of dissolved oxygen (DO) and SF_6 in and around the release wells is available for the first 140 days of operation (no data on MTBE concentrations were available at the time of this report). After 140 days, a gradual buildup of SF_6 was observed in the release wells, and SF_6 was observed in all the T-series monitoring wells. According to the researchers, this indicates that the emitters are working as expected. In addition, the highest concentrations of SF_6 were found in level 4 of the T-series multilevel monitoring wells, suggesting that a particularly conductive stratum is sampled by level 4 of the multilevels.

Figure 7 shows the concentration of DO for a flowpath along the conductive stratum from T1 (up-gradient) through RW1 to T2 (down-gradient). Upgradient of the release well (well T-1), the concentration of DO was negligible throughout the 140 days of operation. In the release well itself, the initial DO concentration was approximately 1 mg/L before increasing to 20-25 mg/L after approximately 20 days. From day 20 to day 100, the DO concentration remained relatively constant, then decreased. According to the researchers, the reasons for the decrease are not known at this time.

Downgradient of the release well (well T-2), the DO concentration was initially negligible, then increased to approximately 2.5 mg/L after about 60 days of operation. The DO concentration remained at that level through day 140. The researchers indicated that the oxygen demand of the groundwater and/or aquifer material is significant, and may be slowing the rate of progress of DO into the aquifer.

Figure 7. Concentration of DO for a Flowpath Along Conductive Stratum [1]



Release Panel

The operation of the release panel began in mid-August 1999 and data are available through December 1999. During this time, oxygen was cycled on and off to test the system according to the following schedule:

August 15, 1999 – Oxygen release started – "ON"
December 1, 1999 – Oxygen release stopped – "OFF"
December 14, 1999 – Oxygen release started – "ON"

At the start of operations, a bromide test was conducted that confirmed groundwater flow through the panel and backfill. Figures 8, 9 and 10 show the analytical data for DO, MTBE, and TBA on 10/21/99 (during the first "on" cycle), 12/14/99 (at end of "off" cycle), and 12/29/99 (during second "on cycle"), respectively.

As shown in Figure 8, during the first "on" cycle, the DO concentrations downgradient of the panel were approximately 10 ug/L on the left and middle sections the panel and about 4 ug/L on the right of the panel. The SF_6 tracer was observed at concentrations proportional to the DO, indicating that the emitter was working as expected. The downgradient MTBE concentrations during this cycle were <5 ug/L to 23 ug/L on the left and middle sections of the panel and about 90 ug/L on the right section of the panel. TBA was below the detection limit in the upgradient well and was detected at 36 ug/L downgradient of the middle section of the panel. The DO and MTBE data suggested that the flow of groundwater through the panel was not perfectly orthogonal as expected, but was angling to the left, resulting in partial bypass of the right edge of the panel. Therefore, in evaluating the results from the October 1999 sampling event, the researchers used the data from the left and middle sections only. These data showed that the panel reduced concentrations of MTBE in the groundwater from levels as high as 417 ug/L to below the detection limit. Along with the TBA data, the researchers indicated that the data suggest that MTBE concentrations are being reduced by native aerobic MTBE-degrading bacteria whose activity has been stimulated and sustained by the oxygen release panel.

Data from the end of the first "off" cycle (Figure 9) showed that once the oxygen supply was turned off, the DO concentrations decreased to low levels (1.1 to 1.2 ug/L) both upgradient and downgradient of the panel. MTBE concentrations in the downgradient wells increased to levels ranging from 85 ug/L to 427 ug/L, and in some cases, the levels of MTBE in the downgradient wells were higher than in the upgradient wells. According to the researchers, these data indicated that when the oxygen was turned off, the groundwater conditions returned to those found at the site before operation of the panel.

The oxygen was then turned back on and data collected after about two weeks of restarting the oxygen supply (Figure 10) show an increase in DO concentrations and a decrease in MTBE concentrations in the downgradient wells. According to the researchers, these data suggest that degradation of MTBE is dependent on oxygen release in the groundwater and also that treatment may easily be reestablished after there has been an interruption in the supply of oxygen to the groundwater.

TBA was not detected during the December sampling events. The researchers indicated that these data may suggest that the microorganisms are capable of degrading MTBE with only transient appearance and subsequent rapid degradation of TBA.

Future work on the panel research is expected to focus on confirming the capabilities and limits of the native aerobic MTBE metabolizers.

Figure 8. Analytical Results from Release Panel Tests – 10/21/99 [2, 3]

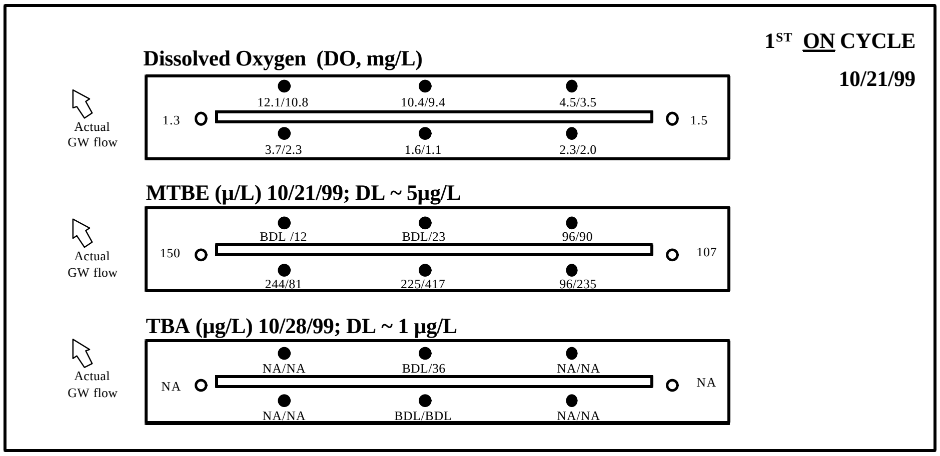


Figure 9. Analytical Results from Release Panel Tests – 12/14/99 [2, 3]

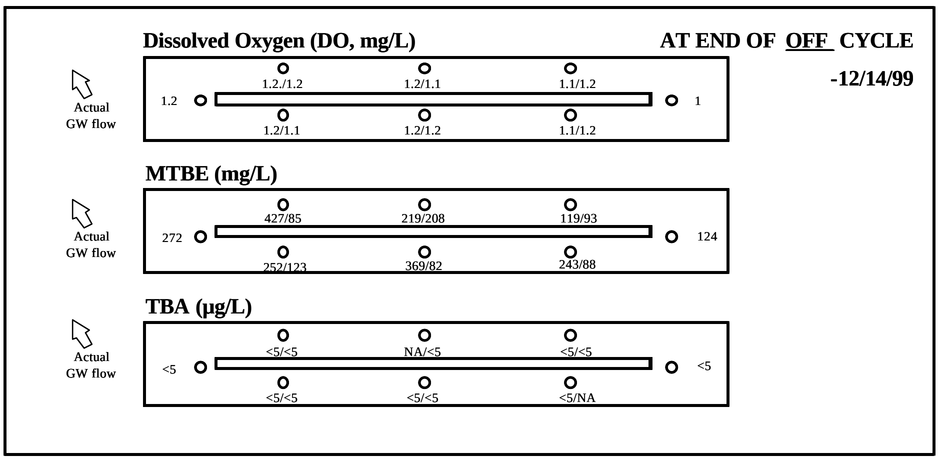
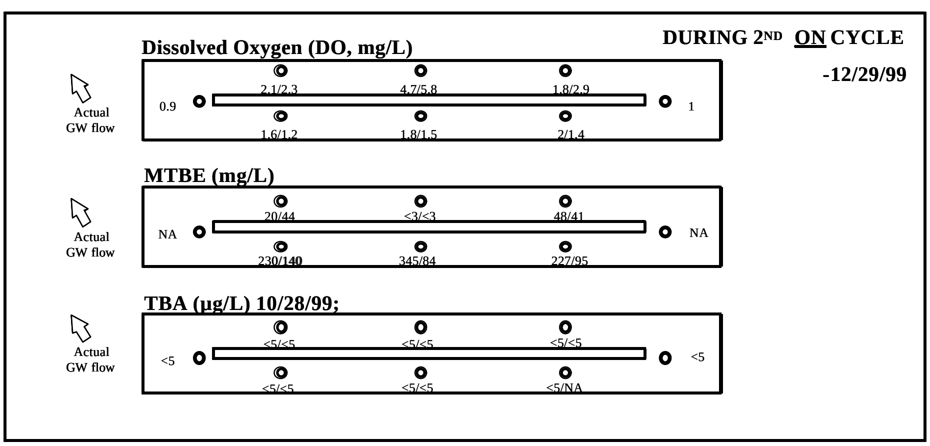
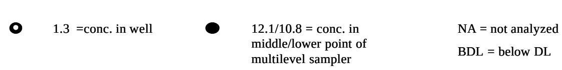


Figure 10. Analytical Results from Release Panel Tests – 12/29/99 [2, 3]





Emplaced MTBE Degraders

Starting in mid-August 1999, gas (oxygen/SF_6) was supplied to the pea gravel section of the trench. Microbes are scheduled to be placed in the pea gravel section after the conditions are identified as aerobic. No performance data were available at the time of this report.

Technology Cost [4]:

Efforts are underway to develop projected cost data for full-scale systems; however, no cost data were available at the time of this report.

Observations and Lessons Learned [6]:

The results of the pilot tests to date at Vandenberg Site 60 indicate that native MTBE-degrading microbes, when stimulated with sustained oxygen release to the subsurface, can reduce the concentrations of MTBE in the groundwater. According to the researchers, the field results are consistent with the results of laboratory tests performed on site sediments.

The pilot tests are continuing at Vandenberg Site 60, with the most recent work focusing on the emplaced MTBE degrader (trench) pilot test. Additional investigations are underway to identify the MTBE-degrading microbes and to better understand enhanced aerobic intrinsic bioremediation of MTBE.

References:

1. Douglas M. Mackay, University of Waterloo, et. al. 1999. "Field Studies of *In Situ* Remediation of an MTBE Plume at Site 60, Vandenberg Air Force Base, California". In Proceedings of the 2000 Petroleum Hydrocarbons and Organic Chemicals in Groundwater: Prevention, Detection, and Remediation; Conference and Exposition, Houston, TX. November 17-19.

2. Douglas M. Mackay, University of Waterloo, et. al. 2000. "Field Tests of Enhanced Intrinsic Remediation of an MTBE Plume". Preprint Extended Abstract for Proceedings of ACS National Meeting in San Francisco, CA. March 26-30.

3. Douglas M. Mackay, University of Waterloo, et. al. 2000. "In Situ Treatment of MTBE by Biostimulation of Native Aerobic Microorganisms". Presentation at EPA/API MTBE Biodegradation Workshop, Cincinnati, Ohio. February 1.

4. Douglas M. Mackay, University of Waterloo. E-mail to Linda Fiedler, EPA/TIO. Comments on Draft Case Study Report for Vandenberg MTBE Demo. April 3, 2000.

5. Douglas M. McKay, University of Waterloo, et. al. 2000. "In Situ Treatment of MTBE at Vandenberg Air Force Base, Update on Progress and Plans". March 31.

6. Bernadette Conant, University of Waterloo. Telephone Conversation with Richard Weisman, Tetra Tech EM Inc. Case Study Report for Vandenberg MTBE Demo. June 21, 2000.