

COST AND PERFORMANCE REPORT

Enhanced Bioremediation at the Texas Gulf Coast Site,
Houston, Texas

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U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

**Enhanced Bioremediation at the Texas Gulf Coast
Site, Houston, Texas**

Summary Information [1,2]

Site Name, Location	Texas Gulf Coast Site, Houston, Texas (actual site name confidential)
EPA ID Number	Not available
Mechanism(s)	Anaerobic Reductive Dechlorination (Cometabolic and Direct)
Technology	Nutrient Addition Electron Donor Addition (Methanol)
Configuration	Groundwater Recirculation
Technology Scale	Full scale
Media/Matrix Treated	Groundwater
Contaminants Targeted	TCE, cis-1,2-DCE, VC
Period of Operation	Ongoing (data available from June 1995 to December 1998)

Site History/Source of Contamination [1,2,3]

The Texas Gulf Coast site (actual site name confidential) is an abandoned industrial manufacturing facility located near Houston, Texas that operated between 1952 and 1985. Trichloroethene (TCE) was used in facility operations until about 1978. In 1986, elevated levels of TCE were found in groundwater at the site, and groundwater monitoring has been performed periodically since that time. Groundwater at the site is being remediated through the State of Texas Voluntary Cleanup Program, administered by the Texas Natural Resource Conservation Commission (TNRCC).

Monitoring data from 1986 to 1995 showed that TCE concentrations in the groundwater had decreased from approximately 50 to 22 mg/L, and that TCE degradation products such as DCE were present in the groundwater, indicating that natural attenuation was occurring at the site. In 1995, an enhanced bioremediation system was installed to actively remediate the contaminated groundwater at the site to a point where natural attenuation would prevent further migration of the plume. The TNRCC approved the work plan for the use of in situ bioremediation at the site and for reinjection of water under the Underground Injection Control (UIC) program.

Geology/Hydrogeology [1,3]

The area of groundwater contamination is approximately 600 ft by 700 ft, located in an unconsolidated aquifer which occurs at a depth of approximately 12 - 20 ft below ground surface (bgs). The upper aquifer is underlain by a 15-ft thick clay layer, below which is lies a deeper aquifer, which is not



contaminated. The natural flow direction for the upper aquifer is to the southeast. A flood control ditch is located on the eastern edge of the area, and intercepts the upper two feet of the aquifer.

Matrix Characteristic	Value
Soil Type	Silty sand
Depth to Groundwater	12 - 20 ft bgs
Thickness of Aquifer	Approximately 8 ft
Fraction of Organic Carbon	Not provided
DNAPL Presence	None identified
Hydraulic Conductivity	1×10^{-4} to 4×10^{-4} cm/sec
pH	Approximately 6.7 to 7.2
Nitrogen	<0.1 mg/L
Sulfur (as Sulfate)	Approximately 30 mg/L
Groundwater Velocity	4 - 18 ft/yr

Technology Description [1,3]

The in situ bioremediation treatment system being used at this site consists of an alternating series of four extraction (1,800 linear ft total) and four injection (1,100 linear ft total) trenches set at a spacing of approximately 100 ft, as shown in Figure 1. The furthest down-gradient trench is an extraction trench that runs along the portion of the down-gradient property line intersected by the plume.

The extraction trenches were completed to a depth of at least one foot into the bottom clay layer (20 - 22 ft bgs), and were sloped to a sump. A perforated pipe was installed along the bottom of each trench and the trenches were filled with gravel. The injection trenches were constructed in a manner similar to that used for the extraction trenches; however, the perforated pipes were installed at a depth of approximately 10 ft bgs. Extracted groundwater is pumped to a holding tank in the control building. Water drains from the holding tank to a wet well and then to the injection trenches. The above-ground equipment was designed to minimize the introduction of air into the equipment.

System operation began in August 1995 with a circulation rate of 12 gallons per minute (gpm). Addition of nitrogen and phosphorus nutrients began in September 1995. In June 1996, methanol was added, along with nitrogen and phosphorus, to serve as a primary substrate and to further reduce the dissolved oxygen and oxidation-reduction potential to levels that were thought to be more favorable to anaerobic degradation of TCE. Nutrient addition was discontinued in May of 1997 because it appeared to be preventing continued decrease in the redox potential within the treatment area; methanol addition continued. As of January 1999, the recirculation rate averages 6 to 8 gpm, and a total of 12 million gallons have been recirculated through the system (approximately 2.5 pore volumes). System operating parameters are summarized in Table 1.



Figure 1: System Layout, Extent of TCE Plume, and Groundwater Flow Directions for Texas Gulf Coast Site [1,3]

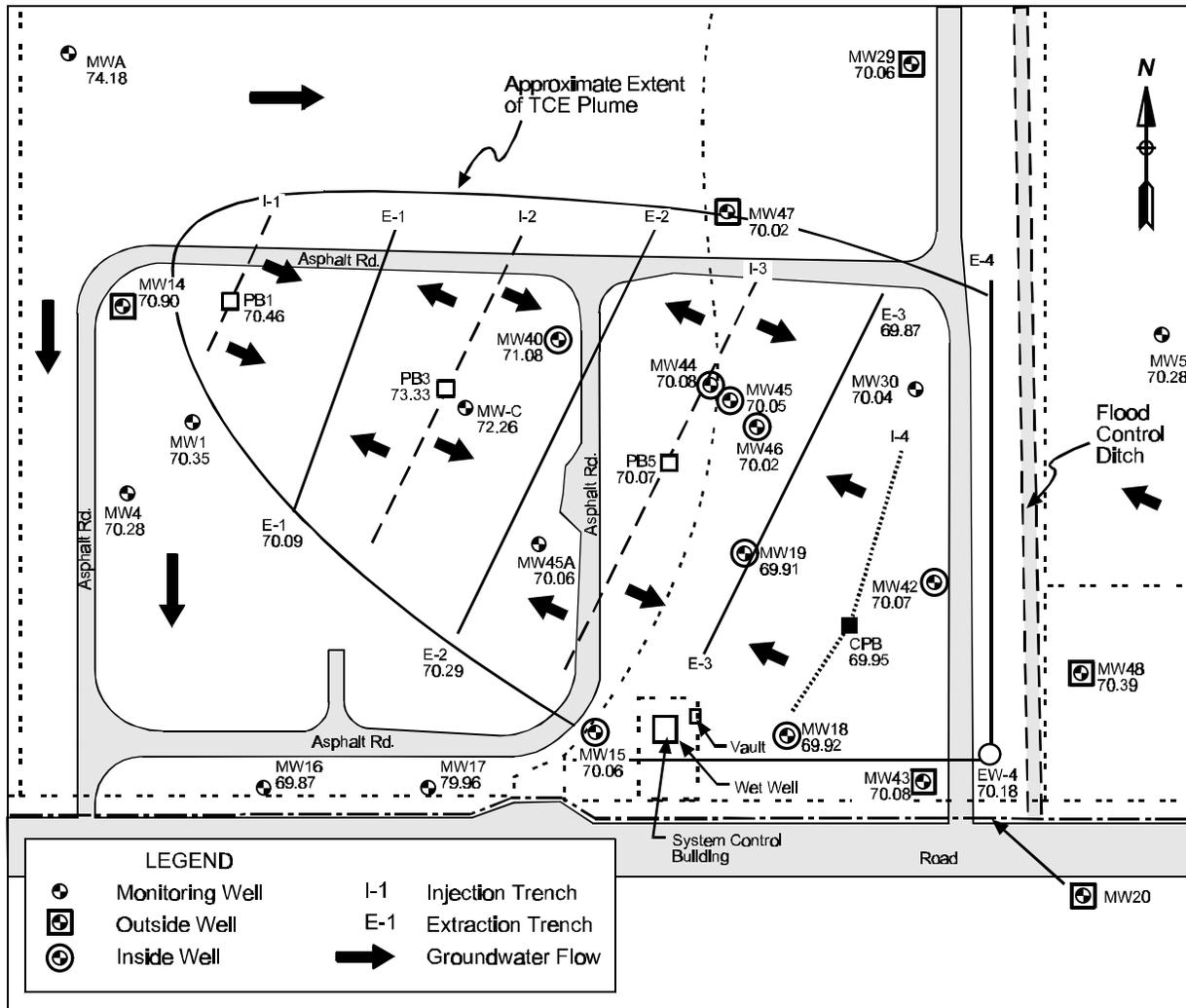


Table 1. Operating Parameters for the Enhanced Bioremediation System [1,3]

Parameter	Value
Circulation Rate	12 gpm (August 1995 - January 1999) 6 to 8 gpm (starting in January 1999)
Methanol Concentration	up to 500 mg/L (in January 1999)
Nitrate Concentration	initially 9 mg/L (as potassium nitrate) (discontinued in May of 1997)
Phosphate Concentration	initially 9 mg/L (as potassium tripolyphosphate) (discontinued in May of 1997)



Technology Performance [1,2,3]

The performance goals of this treatment system are to achieve stable or declining contaminant concentrations and to remediate the groundwater to a point where natural attenuation can be used to prevent future migration of the contaminant plume. Once these goals have been achieved, use of active bioremediation will be discontinued and groundwater at the site will be monitored for a period of 2 to 5 years to determine that the plume has not migrated. No specific cleanup goals have been identified for groundwater at this site.

Table 2 summarizes groundwater monitoring data from June 1995 (prior to system operation) to December 1998 for five sampling events, including data for TCE, DCE, and VC, as well as other parameters such as chloride, DO, and redox potential. The data presented are the average concentrations measured in six wells located outside of the treatment zone (“Outside Wells”) and in eight wells located within the treatment zone (“Inside Wells”), including one of the monitoring wells, well MW-40, that was located within the apparent “source” area. The average concentrations for the TCE, DCE, and VC in the “Inside Wells” were calculated two ways - one including the data from well MW-40, and one excluding the data from well MW-40.

For the results for the inside wells that include the source area well MW-40, average concentrations of TCE in the were reduced by about 88% (22.7 mg/L to 2.6 mg/L) and DCE by about 96% (1.91 mg/L to 0.682 mg/L). VC concentrations in the inside wells remained essentially unchanged (0.102 mg/L to 0.105 mg/L). If the results for well MW-40 are not included, average concentrations of TCE were reduced by about 99% (11.8 mg/L to 0.12 mg/L); DCE by about 87% (1.28 mg/L to 0.165 mg/L); and VC by about 30% (0.078 mg/L to 0.054 mg/L).

According to the site contractor, Well MW-40, located within the treatment area, has had consistently elevated concentrations of TCE. Recent excavation from within this area identified a potential source of continuing release to the groundwater that was preventing the rate of decrease observed in the remaining plume. Soil in the potential source area was excavated during October 1998 to allow volatilization of the chlorinated organic compounds. Debris (concrete, piping, and trash) was excavated in this area; however, no evidence of dense non-aqueous phase liquids (DNAPL) was identified. In addition, TCE concentrations in portions of the plume have now decreased to below the detection limit (0.005 mg/L).

The concentration of chloride was used to evaluate the potential impact of dilution on groundwater quality. As shown on Table 2, there is a difference between the chloride concentrations in the inside wells and those in the outside wells. According to the site contractor, assuming the chloride is due exclusively to dechlorination of TCE (and its degradation products), the average TCE concentration at project outset was estimated to be as high as 100 mg/L to 125 mg/L. During the active treatment period, chloride in the outside wells has decreased from approximately 35 mg/L to 14 mg/L. The site contractor applied the same assumptions about dilution to the treatment area and estimated that the December 1998 chloride concentration for the inside wells was approximately 65 mg/L. The differences between this and the measured concentration (120 mg/L) was assumed by the site contractor to be due to additional contributions from dechlorination of TCE (and the degradation products). Accounting for dilution, the site contractor reported that TCE concentrations were reduced by approximately 2% per month during the period of nutrient-only addition, and approximately 10% per month during the period of nutrient and methanol (substrate) addition. Also, the ratio of cis-1,2-DCE to TCE increased from approximately 0.06:1 to 0.30:1 after addition of methanol, suggesting more active dechlorination associated with higher concentrations of substrate.



Table 2. Summary of Technology Performance Data; Average Concentrations (mg/L) [3]

Parameter	Analytical Methods*	Jun-95		May-96		Jun-97		Mar-98		Dec-98	
		Inside Wells	Outside Wells								
Average including potential source well MW-40											
TCE	EPA 8260	22.7	0.070	16.7	0.07	4.02	0.748	2.80	0.046	2.60	0.065
cis-1,2-DCE	EPA 8260	1.91	< 0.005	1.0	< 0.005	1.31	0.049	2.90	0.006	0.682	0.009
Vinyl Chloride	EPA 8260	0.102	< 0.005	< 0.005	< 0.005	0.084	< 0.002	0.222	< 0.002	0.105	< 0.002
Average excluding potential source well MW											
TCE	EPA 8260	11.8	-	9.68	-	3.24	-	2.42	-	0.119	-
cis 1,2-DCE	EPA 8260	1.28	-	0.733	-	1.38	-	2.52	-	0.165	-
Vinyl Chloride	EPA 8260	0.078	-	0.016	-	0.095	-	0.181	-	0.054	-
Chloride	EPA 325.3	162	35	147	29	132	20	136	23	120	14
NO3-NO2	EPA 353.2	< 1.0	< 1.0	11	0.90	0.20	0.13	< 0.10	< 0.10	< 0.10	< 0.10
O-PO4	EPA 365.2	0.24	0.09	2.1	0.40	1.9	0.52	0.56	0.12	0.65	0.10
TKN	EPA 351.2	< 1.0	< 1.0	3.6	1.6	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ferrous Iron	EPA 6010	-	-	-	-	0.23	< 0.05	0.27	< 0.02	2.1	< 0.02
Total Iron	EPA 6010	-	-	-	-	-	-	3.4	0.25	4.4	0.07
Sulfate	EPA 375.4	-	-	-	-	170	28	146	24	42	38
Sulfide	EPA 376.1	-	-	-	-	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Methane	EPA 3810	-	-	-	-	0.69	0.007	2.8	0.009	3.6	0.85
Ethene	EPA 3810	-	-	-	-	-	-	-	-	0.09	0.02
DO		1.7	3.4	1.1	2.4	0.45	1.6	0.65	1.6	1.1	2.3
Redox (mV)		+292	+319	+111	+126	+85	+178	-61	+332	-116	+245
pH (SU)		6.56	6.75	6.69	6.84	6.46	6.83	6.38	6.74	6.85	7.23

Notes: (-) Not Analyzed.

(*) Latest sampling event only.



According to the site contractor, current plans are to shut down the active bioremediation system by the middle of 1999. Should this occur, this site will meet its design goal of completing the active remediation period within 3-5 years (actual period of operation would be 4 years). It is anticipated that the approval for system shutdown will be based on the following:

- The impacted aquifer has been designated as “low-yield” and, therefore, has less stringent groundwater remediation standards.
- The concentration and size of the plume will have been reduced to a point that growth or migration of the remaining plume will be controlled by natural attenuation.

Information is not provided about the analytical methods used in this application, however no exceptions to established quality assurance/quality control (QA/QC) protocols were noted.

Technology Cost [3]

Capital costs for construction of the extraction/injection trenches and control building were approximately \$600,000. Annual costs for operation, maintenance and monitoring are approximately \$100,000.

Summary Observations and Lessons Learned [1,3]

Methanol addition was found to increase the rate of biodegradation of TCE at this site, based on the reduction of TCE concentration and increase in the ratio of cis-1,2-DCE to TCE. This site is planning to stop using active bioremediation after four years of system operation (three years of methanol addition) to allow use of natural attenuation. According to the site contractor, natural attenuation will be used to prevent future migration of the plume, and to achieve stable or declining contaminant concentrations.

Excessive biomass formation, leading to a reduced flow rate, was found to be a concern for addition of methanol. Excess biomass was not noted during the period when nutrients alone were added; however, a significant increase in biomass formation was noted after addition of methanol. To remedy this, the site contractor modified their methanol addition to a batch system.

The site contractor found that it was difficult to balance the system hydraulics between the extraction and infiltration trenches, and that it required approximately one year of operating time to achieve a balance. In addition, they found it difficult to interpret the treatment performance data because of the non-homogeneous nature of the initial groundwater quality, and dilution due to recharge of rainwater and clean water from beyond the planned treatment area.

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2. Record of Telephone Conversation between David W. Anderson, P.E., P.G., Roy F. Weston, Inc., and Richard J. Weisman, Tetra Tech EM Inc. 1998. Bioremediation at Texas Gulf Coast Property. December 21.
3. Fax transmittal from Susan Litherland, Roy F. Weston, Inc., to Dawn Carroll, U.S. EPA. 1999. Draft Case Study - Revisions. January 28.

