COST AND PERFORMANCE REPORT

Methane Enhanced Bioremediation Using Horizontal Wells
at Savannah River Site,
Aiken, South Carolina

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

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Summary Information [1,4]

Site Name, Location	Savannah River Site, Aiken, SC
EPA ID Number	SC1890008989
Mechanism(s)	Aerobic Oxidation (Cometabolic and Direct)
Technology	Nutrient Addition Electron Acceptor Addition (Oxygen) Electron Donor Addition (Methane)
Configuration	Direct Injection
Technology Scale	Field demonstration
Media Treated	Sediment and Groundwater
Contaminants Targeted	TCE, PCE
Period of Operation	February 26, 1992 to April 30, 1993

Site History/Source of Contamination [1,4,5]

The U.S. Department of Energy (DOE), Savannah River Site (SRS) is a 300 square mile facility located in Aiken, South Carolina that has been used for a wide range of operations associated with the research and production of nuclear materials. Area M at the facility was used for aluminum forming and metal finishing operations. From the 1950's to the 1980's, wastewaters from Area M operations were discharged to an unlined settling basin and a nearby stream, resulting in soil and groundwater in the area becoming contaminated with high levels of chlorinated solvents, primarily trichloroethlyene (TCE) and tetrachloroethene (PCE). Dense nonaqueous phase liquids (DNAPLs) have also been observed. In September 1985, a full-scale pump and treat system began operating at the site. This site is was added to the National Priorities List on November 21, 1989. A Record of Decision (ROD) had not been signed for this facility at the time of this report.

DOE, as part of the volatile organic compound (VOCs) in Non-Arid Soils Integrated Demonstration program, tested several innovative technologies to augment the pump and treat system in Area M. This report focuses on the field demonstration of methane enhanced bioremediation using horizontal wells. The demonstration site was located within the VOC groundwater plume, estimated to cover about 1200 acres and to be about 150-ft thick. Prior to the demonstration, concentrations of TCE and PCE in groundwater ranged from 10 to 1,031 ug/L and 3 to 124 ug/l, respectively. Sediment TCE and PCE concentrations ranged from 0.67 to 6.29 mg/kg and 0.44 to 1.05 mg/kg, respectively.

Geology/Hydrogeology/Contaminant Characterization [1,5]

The demonstration area was underlain by relatively permeable sands with thin lenses of clayey sediments. The clay layers generally were relatively thin and discontinuous, with thicker clay layers

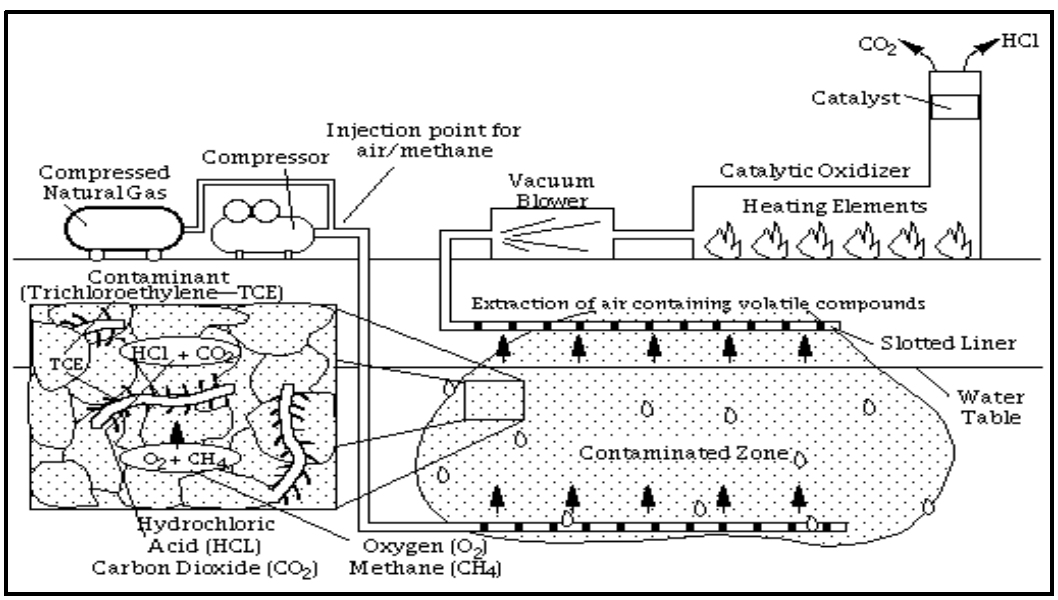
found at depths of 90 and 160 feet below ground surface (bgs). The water table occurred at depths ranging from 120 and 135 feet bgs. The groundwater flow was radial, extending outward from a groundwater plateau under the demonstration area. In addition, there was a moderate downward gradient beneath the site, with vertical flow rate estimated to be 2 to 8 feet/year.

Matrix Characteristic	Value
Soil Type	sand, clay, and gravel
Depth to Groundwater	ranges from 120 to 135 feet bgs
Thickness of Aquifer(s)	150 feet
Groundwater Velocity	15 to 100 feet/year (horizontal)

Technology Description [1,2,3]

Figure 1 presents a process schematic of the methane enhanced bioremediation (MEBR) system used for the demonstration at the M area. The system included two horizontal wells. The "lower" horizontal well was placed below the water table (saturated zone) at a depth of 175 feet bgs , with a screen length of 310 feet. The "upper" horizontal well was placed in the vadose zone at a depth of 80 feet bgs, with a screen length of 205 feet. Air and gas were injected into the saturated zone through the lower horizontal well at a rate of 200 scfm. Air and contaminants were then extracted from the vadose zone through the upper horizontal well at a rate of 240 scfm. A thermal catalytic oxidizer, operated at 825° C, was used to treat the extracted vapors, prior to discharge to the atmosphere.

Figure 1: Methane Enhanced Bioremediation (MEBR) [1]



The demonstration was performed in six different operational modes, as described in Table 1. These included baseline tests of the vapor extraction and injection systems, a series of nutrient additions, a tracer test, and an assessment of microbiological assays for monitoring performance.

Table 1. Modes for the Demonstration [1,3]

Operational Mode	Description of system operation
Baseline Test	Initial vacuum extraction of vadose zone gases at a rate of 240 scfm
Baseline Test	Addition of air sparging - simultaneous injection of air into the saturated zone coupled with vacuum extraction of the vadose zone at a rate of 202 scfm (84% of the first baseline test)
Nutrient Addition -1	Addition of 1% methane
Nutrient Addition - 2	Addition of 4% methane
Nutrient Addition - 3	Pulsed 4% methane addition at a rate of 8 hr every two days
Nutrient Addition - 4	Continuous addition of a combination of nitrous oxide at 0.007% and triethyl phosphate at 0.07% in air in combination with pulses of 4% methane
Tracer tests	Helium tracer tests to measure the amount of injected methane consumed by the indigenous microbes
Microbiological Assays	Comparison of microbial assays for monitoring and control of in situ bioremediation

Technology Performance [1,2,3]

After 384 days of operation, concentrations of PCE and TCE in sediments were reduced to below detectable limits, and concentrations of PCE and TCE in groundwater were reduced to below 5 ppb each for PCE and TCE. In addition, soil gas concentrations decreased by more than 99%. The system removed about 17,000 lbs of VOCs through a combination of vacuum extraction and biodegradation. The concentration of TCE and PCE in the sediments before and after the demonstration were used to calculate the mass of VOCs degraded. The vacuum component of the system removed 12,096 lbs of VOCs and the biological component degraded 4,838 lbs of VOCs.

The addition of methane stimulated the growth of methanotrophs. During the 1% methane addition phase, the population of methanotrophs increased by several orders of magnitude, to levels close to 100,000 MPN/ml. During the 4% methane addition phase, the population of methanotrophs increased initially, then decreased as a result of nutrient depletion. The addition of nitrogen and phosphorous nutrients with pulsed methane stimulated microbial activity, and was reported to have optimized bioremediation and mineralization of TCE and PCE in groundwater and sediments. The results of the helium tracer tests indicated that more than 50% of the injected methane was consumed by indigenous

microbes before it reached the extraction well. No results were provided from the microbiological assays.

The zone of influence of the extraction well in the vadose zone was reported to be greater than 200 feet based on pressure measurements. The sparge zone of influence in the saturated zone, measured using electrical resistance tomography, was reported to be a "complex three-dimensional network of channels" extending as far as 100 feet from the injection well. The system was operational 90% of the time and no problems were reported during the demonstration.

Technology Cost [1,5,6]

Table 2 presents the projected costs for full-scale application of MEBR. The projected capital costs were $452,407 (including equipment costs amortized over 10 years, and costs for well installation and mobilization), and the projected operation and maintenance (O&M) costs were $236,465 (including monitoring, consumables, and demobilization).

Table 2. Project Costs for Full-scale MEBR Application [1,5]

Element	Cost ($)
Capital	
Site cost	5,400
Equipment cost	9,200
Design and Engineering	10,000
Mobile equipment	18,000
Well Installation	183,000
Other fixed equipment	183,732
Mobilization	43,075
Total Capital Equipment and Mobilization Cost	**452,407**
O&M Costs	
Monitoring/maintenance	71,175
Consumables	122,215
Demobilization	43,075
Total O&M	**236,465**

Summary Observations and Lessons Learned [1,2]

The in situ bioremediation system demonstrated as SRS removed about 17,000 lbs of VOCs through vacuum extraction (about 12,000 lbs) and through biodegradation (about 5,000 lbs). According to DOE,

the addition of nitrogen and phosphate nutrients in conjunction with 4% pulsed methane provided the best results of the four nutrient addition campaigns tested.

No toxic intermediates were produced during the demonstration. However, the use of technical grade methane was found to be growth inhibiting because it contained small amounts of acetylene which is poisonous to the microbes.

Los Alamos National Laboratory completed a cost-benefit analysis that showed that in situ bioremediation could reduce costs by more than 30% compared to a baseline technology of SVE/pump and treat. According to DOE, in situ bioremediation could reduce the time required to remediate a site by 5 to 7 years compared to SVE/pump and treat.

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References:

1. U.S. Department of Energy, Office of Environmental Management, Office of Technology Development. In Situ Bioremediation of Using Horizontal Wells. Demonstrated at M Area, Savannah River Site, Aiken, SC. April 1996.

2. Methane Enhanced Bioremediation for the Destruction of Trichloroethylene Using Horizontal Wells. Westinghouse Savannah River Company. Technology Catalog Site Remediation Profiles. July 1998.

3. Methane Enhanced Bioremediation for the Destruction of Trichloroethylene Using Horizontal Wells. Technology and Systems Solutions. Em-50.em.doe.gov/BEST/techs/aa/tech0210.html. July 1998.

4. Superfund EPA. EPA National Priorities List. Savannah River Site (USDOE). July 1998.

5. Fax transmittal from Kurt Gerdes, U.S. DOE, to Richard Weisman, Tetra Tech EM Inc. 1999. Review Comments on Preliminary Draft. February 4.

6. U.S. DOE/EM/OTD. 1995. In Situ Bioremediation Using Horizontal Wells; Innovative Technology Summary Report. April.