Full-Scale Demonstration of In Situ Bioremediation of Chlorinated-Solvents at SRS

by
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Dr. Hazen received his B.S. and M.S. degrees in Interdepartmental Biology from Michigan State University. His Ph.D. is from Wake Forest University in Microbial Ecology. He was Professor, Chairman of Biology and Director of Graduate Studies at the University of Puerto Rico for 8 years. In 1987 he took his present position of Principal Scientist at the Savannah River Site, is a fellow of the American Academy of Microbiology, and has authored more than 100 scientific publications, not including more than 250 abstracts. His area of specialty is environmental microbiology, especially as it relates to bioremediation. He currently is principal investigator on four major bioremediation efforts at SRS.

Summary

The U.S. Department of Energy's Office of Technology Development has been sponsoring an integrated demonstration for the clean-up of chlorinated solvents in groundwater and soils at the Savannah River Site (SRS) near Aiken, South Carolina. For the past four years the scientists at the Savannah River Technology Center have been coordinating and implementing innovative tests of remediation, characterization, monitoring, analysis, and modeling technologies for the clean-up of chlorinated solvents. These technologies are better, faster, safer, and less expensive than conventional clean-up methods. All of the tests were conducted at a test bed in the site's M-Area, thereby utilizing the extensive characterization and monitoring already complete and allowing the technologies to cross fertilize each other. By testing all of these technologies at the same site, DOE has realized tremendous savings in characterization and monitoring costs. It has also resulted in valuable simultaneous cross comparisons of conventional and innovative technologies; more than 100 technologies have been demonstrated in past three years. The latest full-scale demonstration to be completed was *in situ* bioremediation using methane and gaseous nutrient injections via horizontal wells.

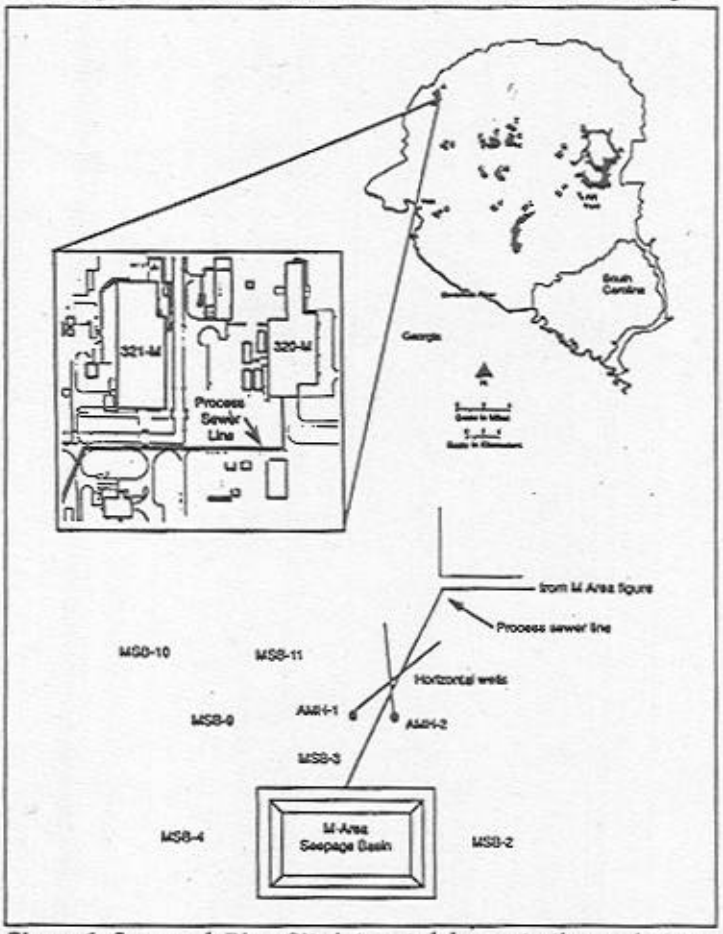

Figure 1. Savannah River Site integrated demonstration project area location map.

Introduction/Background

All of the tests completed at the Savannah River Integrated Demonstration Site (SRIDS) were permitted by the South Carolina Department of Health and Environmental Control. The *in situ* bioremediation demonstration was preceded by the *in situ* air stripping test (December 1990), the first test completed at the IDS. The results from this first test provided a basis (i.e., precharacterization and control data) for the *in situ* bioremediation demonstration.

The *in situ* bioremediation demonstration stimulated naturally occurring soil bacteria that were capable of degrading chlorinated solvents. The primary stimulant for the demonstration was methane or natural gas. This process has the following advantages:

- stimulates only those bacteria that are capable of degrading the contaminant
- involves a gas that can be directly injected, thereby facilitating mass transfer
- uses a naturally occurring compound (methane, i.e. environmentally safe compound)
- stimulates bacteria that degrade the contaminants to carbon dioxide and chloride without the production of toxic intermediates
- does not alter the physical environment in ways that may have adverse environmental effects (i.e., it does not cause the environment to become

anaerobic, thereby altering physical chemical equilibrium in the subsurface)

Materials and Methods

The test was conducted at the test bed located along the abandoned process sewer line for the M-Area Seepage Basin (Figure 1). Over a 30+year period, hot caustic and degreasing solvents [trichloroethylene (TCE), tetrachloroethylene (PCE), and 1, 1, 1, trichloroethane] were disposed of in this basin (estimates suggest as much as 3,000,000 lb). In 1986, the basin was closed and the process sewer line removed. An air stripper with 11 recovery wells was established in 1984 to contain the contaminant plume. A clay-cap Resource Conservation and Recovery Act closure was completed on the basin in 1991. The containment of the one-square-mile contaminant plume has allowed the testing of innovative treatment technologies within the contained area.

The *in situ* bioremediation test consisted of injection of methane and air using a horizontal well. The injection well was installed at a depth of 150-175 ft below the surface for a distance of 300 ft with a diameter of 3 in. (Note: The water table is at 120 ft.) A parallel horizontal well was installed at a depth of 75-95 ft deep for a distance of 175 ft. This upper well served as an extraction well to encourage gas movement through the vadose zone and inhibit plume spreading. Air and methane were injected at 200 standard cubic feet per minute (scfm) during the 14-month test. The air extracted from the upper well (240 scfm) was treated with a thermal catalytic oxidation system (Cat Ox). The Cat Ox heated the extracted air to 800°F before exposing it to a catalytic block of Halo-hydrocarbon Destruction Catalyst (Allied Signal). The Cat Ox was greater than 95% efficient at TCE/PCE destruction since 99% of the time the stack emissions were below detectable limits (<5 ppm vol/vol). The extraction system removed and destroyed 12,000 lb of TCE/PCE (Figure 2).

The test consisted of several injection strategies that a panel of bioremediation experts from all over the country determined would be best for demonstrating the technology. On February 26, 1992, the extraction system began operation without air or methane for the first six weeks, followed by six more weeks of air-alone injection. Methane was then injected at 1% of air for three months, followed by 4% methane for three months, 4% methane pulses (air constant) for three months, and finally, 4% methane pulses combined with gaseous injection of nitrous oxide (0.07%) and triethyl phosphate (0.007%). Gas Research Institute supplied all of the compressed natural gas used for the test. The natural gas was compressed from a domestic gas line of South Carolina Electric and Gas Company.

Results

Sediment samples were taken at 1-ft intervals at the beginning and end of the study and every three months during the test. Soil gas was collected weekly from five vadose zone parameters at different depths. Groundwater has been collected every two weeks from 13 wells at the test bed for three years. More than 100 different physical, chemical, and biological parameters were measured. The results and analyses completed to date are extremely encouraging. The methane injection caused the density of contaminant-degrading bacteria (methanotrophs) to increase as much as 7 orders of magnitude (i.e., from less than 10 to more than 10,000,000 cells/ml groundwater). The stimulation was immediate with injection of 1% methane. The 4% methane injection showed some decrease in stimulation. Pulsed methane further enhanced the stimulation, as did the addition of nitrogen and phosphorus. Water concentration of TCE/PCE decreased by as much as 99% in some of the wells, reaching below detectable limits (<2ppb). This level of clean-up was never observed for the in situ air stripping process alone, suggesting that the *in situ* bioremediation process can achieve a much cleaner endpoint. Sediment analyses and soil gas analyses indicated that after only three months of 1% methane injection, most sample locations were below detectable limits. The area of reduced contamination was about the size of a football field. Other notable results are:

- Microbial biomass never increased sufficiently to cause biofouling.
- No anaerobic breakdown intermediaries were ever detected (e.g., vinyl chloride).
- The groundwater remained well oxygenated.
- Destruction *in situ* was complete since chloride concentration in the groundwater increased proportionally with decreasing TCE/PCE concentrations.

Conclusions

This *in situ* bioremediation demonstration has shown that low concentrations of methane in air can significantly stimulate contaminant-degrading bacteria in the subsurface. This process has the promise of being cost effective and environmentally sound, allowing complete destruction onsite, and being easily applied to a wide variety of waste sites. Several companies have already applied for licenses for the technology and several either have started remediation projects or have them planned.

The information contained in this document

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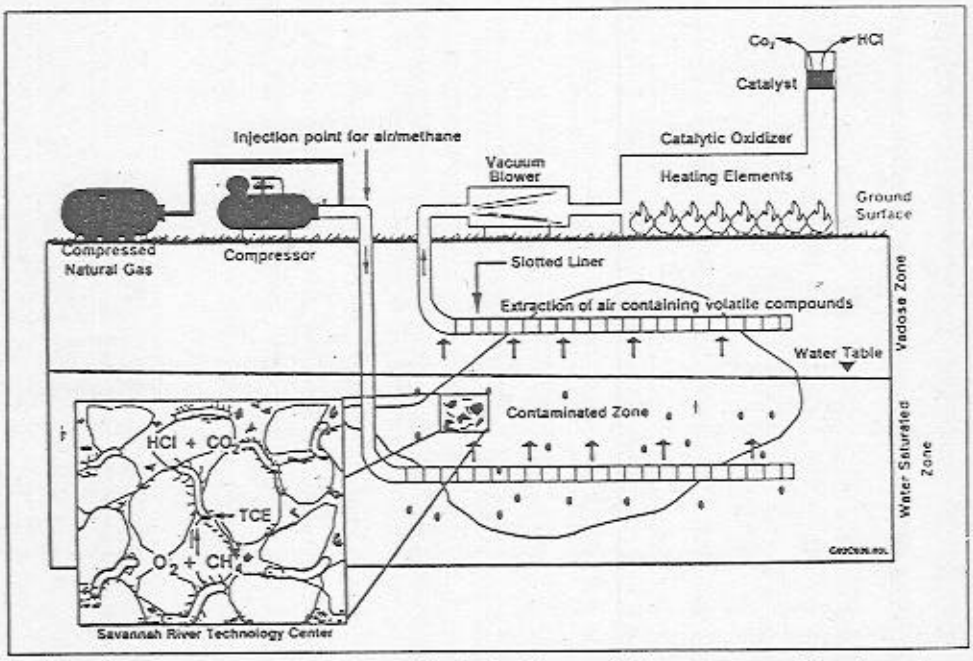

Figure 2. Schematic Diagram of the* in situ *bioremediation process and equipment.

Electroplating Wastewaters

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the toxicity of the discharge to the mixed stream.

Consequence of Restrictions

An environmental reason that almost all electroplaters seem to have chosen to discharge to city sewers can be deduced fairly easily from the Table of Limits below. Allowable concentrations in receiving streams are drastically lower than limits required by pretreatment, in many cases. Although Federal minimum-treatment guidelines for discharge to streams are the same as Federal minimum-treatment guidelines for pretreatment and discharge to city sewer, the dilution flow in a city sewer is often much greater than occurs during the design period in a receiving stream accessible to a particular manufacturing site. Therefore, protection of streams (that is, meeting the permit conditions necessary to do so) is often easier for an electroplater by discharging to a city sewer than directly to a stream. However, no Department policy dictates this, and an NPDES permit was issued in 1991 for a rather large, 100,000± gallons per day (gpd), discharger, Oak-Mitsui. Fortunately, this company discharges to a large stream, the Wateree River, and no water quality restrictions applied.

Wastewater Recirculation

While it is our policy to require a permit for most electroplating wastewater treatment systems which are used for recycling, we have few such permits. A major reason for permitting is that many recycling projects only achieve partial recycle and end up with a discharge, though typically somewhat reduced. Because of this the inspection of operations resulting from permitting may lead to correcting many environmental problems.

Recently Permitted Treatment Systems

Below are listed some examples of the general treatment units included in some recently permitted treatment systems. All the manufacturing facilities are pretreaters.

1. Equalization, cyanide destruction, neutralization, precipitation, flocculation, sand filter, deionization.
2. pH adjustment, chemical feed, precipitation (single-tank, batch treatment).
3. Metals equalization, chrome reduction, metals precipitation, inclined-plate settler, fluoride equalization, fluoride precipitation, fluoride settler, sludge belt-filter press.
4. Neutralization, clarifier, nickel evaporator, sludge press.

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In Situ Bioremediation

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was developed during the course of work under Contract No. DE-AC09-89SR18035 with the U. S. Department of Energy.

Further information about *in situ* bioremediation for chlorinated contaminants can be obtained by writing to Dr. Terry C. Hazen, Savannah River Technology Center, Bldg 773-48A, Westinghouse Savannah River Company, Aiken, SC 29808.

Improved Pumping System Patented

Patent No. 5,135,361 was issued to Thomas R. Dion, Department of Civil Engineering, The Citadel.

This invention relates to a pumping station adapted for use in water flow systems to effectively discharge widely fluctuationg inflows of water. Waste water pumping stations are normally configured to operate using centrifugal pumps in either parallel or series modes to accomodate the head loss requirements of the system. Provisions have not been made in the past to allow an interchange of pumping modes in a station; however, parallel-series systems allow both modes. As a result, smaller pump sizes often can be used or more pumping capacity usually can be attained. This patent describes several variations of parallel-series pumping systems.

Supplemental reading: Land Development for Civil Engineers, Thomas R. Dion, pp.421-427, 1993, John Wiley & Sons, Inc., NY,NY.

Successful 1993 Meeting

More than 50 members and guests of the Society paricipated in the technical and business meetings, the ladies program and social activities during July 23-25, 1993. The Camden program planning committee is to be complimented.

Two excellent presentations were given on Saturday morning, one covered the construction and mangement of a tailings impoundment for a modern gold mine and the second described the evolution of bridge designs from the 19th century to the modern structures. Many took the tour of Dupont's May Plant to see the processes for producing the nylon fibers that are used for several products.

Summer '94 in Beaufort

On July 29-31, 1994, the South Carolina Society of Engineers will meet at the Holiday Inn, Beaufort, S.C. The Summer Meeting Planning Committee chairman, Bill Schneider reports that arrangements all well along. Mark your calender. More information will be sent next spring.

News of Members

New members:

Cliflon Z. Davis, Assoc, member
Lugoff, SC
Employer: CompuSystems, Inc.