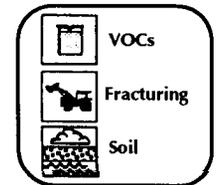




TECH TRENDS

The Applied Technologies Journal for Superfund Removals and Remedial Actions and RCRA Corrective Actions



Pneumatic Fracturing Increases VOC Extraction Rate

by Uwe Frank, Risk Reduction Engineering Laboratory

The Pneumatic Fracturing Extraction (PFE) process: (1) increases the rate at which vapor extraction removes volatile organics (VOCs), and (2) broadens the range of vadose zones where soil vapor extraction (SVE) can be used. The low permeability of silts, clays, shales, etc., would otherwise make such formations

unsuitable for cost-effective SVE and would require more costly approaches. Pneumatic fracturing provides an innovative means of increasing the permeability of a formation, thus extending the radius of influence that can be reached to effectively extract contaminants that otherwise might not be reached by conventional SVE. The PFE was developed jointly by Accutech Remedial Systems, Inc. and the Hazardous Substance Management Research Center, located at the New Jersey Institute of Technology. The PFE was evaluated under the SITE (Superfund Innovative Technology Evaluation) Program at an industrial site in central New Jersey; and, it demonstrated the removal of chlorinated VOCs, specifically trichloroethene (TCE). The PFE should be equally suitable for other volatile contaminants, including hydrocarbons such

as benzene, toluene, ethyl benzene and xylenes.

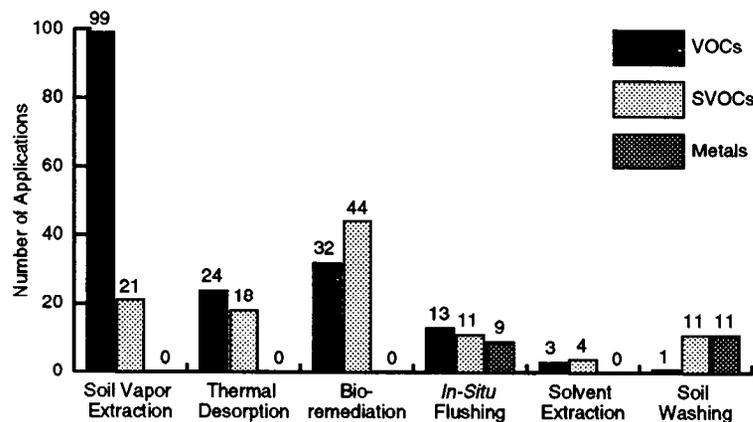
In the PFE process, fracture wells are drilled in the contaminated vadose zone and left open (uncased) for most of their depth. A packer system is used to isolate small (2 feet) intervals so that short bursts (~20 sec) of compressed air (less than 500 pounds per square inch) can be injected into the interval to fracture the formation. The process is repeated for each interval. The fracturing extends and enlarges existing fissures and introduces new fractures, primarily in the horizontal direction. When fracturing has been completed, the formation is then subjected to vapor extraction, either by applying a vacuum to all wells or by extracting from selected wells, while others are capped or used for passive air inlet or forced air injection.

Based on the results from the SITE demonstration, PFE is both technologically feasible and cost effective. The PFE process increased the extracted air flow rate by >600% relative to that achieved in the site formation prior to fracturing. While TCE concentration in the extracted air remained approximately constant (~50 parts per million), the increased air flow rate resulted in TCE mass removal rates after fracturing that were an average of 675% higher over the 4-hour test periods. Significantly increased extracted air flow rates (700% to 1,400%) were observed in wells 10 ft. from the fracturing well. Even in wells 20 ft. away, increases in air flow rates of 200% to 1,100% were observed. From well pressure and tiltmeter (surface heave) data, results suggest an effective extraction radius of at least 20 ft.

Soil Bioremediation Publications

Don't miss "New for the Bookshelf" in this issue of *TECH TRENDS* (p. 3) for information on issues and research related to bioremediation of soils and details about a guide to bioremediation resources.

Superfund Remedial Actions Application of Innovative Treatment Technologies



Note: Data are from EPA's *Innovative Technologies: Annual Status Report* (Fifth Edition)

(see *PFE*, page 2)



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Soil Washing Technology Removes Organics from Fine and Coarse Grained Soil

by Annette Gatchett, Risk Reduction Engineering Laboratory



The BioGenesisSM soil washing technology was developed to remove organic compounds from both fine- and coarse-grained soil. The technology, demonstrated under EPA's SITE (Superfund Innovative Technology Evaluation) Program, uses a proprietary solution called BioGenesisSM cleaner to transfer organic compounds from the soil matrix to a liquid phase. The process involves high-energy mixing of excavated contaminated soils in a mobile washing unit. The cleaner, a complex alkaline blend of surfactants, is rapidly degraded by soil microbes. Residual BioGenesisSM solution remaining on soil particles stimulates the biodegradation of soil contaminants not removed by the washing process. The process does not require the screening out of particles larger than 4 to 6 inches in diameter. In this SITE demonstration, BioGenesisSM was used as a stand-alone technology.

EPA's SITE demonstration occurred at a refinery contaminated with crude oil. Analytical results from a sample collected from the untreated soil prior to the demonstration revealed total recoverable petroleum hydrocarbon (TRPH) concentrations as high as 11,000 parts per million. After the initial soil washing, TRPH decreased by 65 to 73%. The biodegradation process continued in the treated soil; samples revealed that TRPH had decreased by 85 to 88% after 120 days. BioGenesisSM expects that TRPH levels in treated soil from this site will eventually be reduced to levels that meet regulatory requirements for use as fill material. TRPH concentrations in wastewater ranged from 76 to 1,500 milligrams/Liter (mg/L). Approximately 3,500 gallons of wastewater were generated during each run because the wastewater was not recycled; rather, it was treated at the refinery treatment facility.

The treatment cost calculated for SITE demo ranged from \$74 to \$160 per cubic yard of soil. This cost can be expected to vary depending on contamination type, level and volume of soil treated. Treatability studies are highly recommended before large-scale

applications of the technology are considered. Because results may vary with different waste characteristics, the BioGenesisSM treatment system's performance is best predicted with preliminary bench-scale testing. Additionally, treatment residuals may require off-site treatment.

The BioGenesisSM soil washing system consists of several major components: the wash unit, the volatile organic compounds (VOC) emissions hood, holding tanks, oil skimmers, strainers, transfer pumps, the American Petroleum Institute oil/water separator, oil coalescer, a bioreactor (not used at this SITE refinery demonstration) and a flat-bed trailer for ancillary equipment. Once onsite, the treatment system can be operational within one day if all necessary facilities, equipment, utilities and supplies are available. After the treatment is completed, the treatment system can be demobilized and moved offsite within one day. Approximately 30,000 sq. ft. are needed to accommodate the unit and support equipment, etc.

BioGenesisSM claims that the process is capable of extracting volatile and non-volatile hydrocarbons, including petroleum hydrocarbons, pesticides, PCBs and polycyclic aromatic hydrocarbons (PAH) from most soils. Soil containing large amounts of silt, clay and humic substances are not as effectively treated by soil washing technologies as are soils containing sand and other coarse materials. However, BioGenesisSM claims that its technology may be effective for soils containing high percentages of silt and clay. The BioGenesisSM technology's silt and clay cleaning capability is being tested in Environment Canada's Contaminated Sediment Treatment Technology Program. The technology was used in June 1993 to treat sediments contaminated by wood treating activities at Thunder Bay Harbour, Ontario, Canada. Primary contaminants on site included PAHs containing two to five aromatic rings. Particle size distribution analysis showed that 80% of the sediment consisted of silt and clay sized particles.

BioGenesisSM used a field prototype wash unit capable of treating two cubic yards of sediment per hour. Results of PAH analyses showed that removal efficiencies from washing alone ranged from 83.3 to 94.8% for the individual PAHs. Average PAH removal from soil washing was reported at 89.5%. BioGenesisSM is currently modifying its wash unit and is manufacturing a unit capable of treating up to 40 cubic yards of soil per batch.

For more information, call Annette Gatchett at EPA's Risk Reduction Laboratory at 513-569-7697. A SITE Technology Capsule (Document No. 540/SR-93/510) and its companion *Innovative Technology Evaluation Report* (Document No. EPA/540/R-93/510) can be ordered from EPA's Center for Environmental Research Information at 513-569-7697.

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Even higher increases in air flow rates and TCE mass removal were observed when one or more of the monitoring wells was opened to allow passive air inlet. Under these conditions, air flow rates increased an average of 19,000% and TCE mass removal rates increased 2,300%.

The developer also has proposed that catalytic oxidation (not demonstrated during this SITE evaluation) can be cost-effectively used for above ground treatment of the extracted VOCs, particularly when contaminant concentrations are above ~50 to 100 parts per million. Catalysts suitable for oxidation of chlorocarbons such as TCE now are commercially available. In addition, Accutech has suggested injecting the waste heat from catalytic oxidation either directly or indirectly (using a heat exchanger) into the formation to further enhance volatilization and removal of VOCs.

For more information, call Uwe Frank at EPA's Risk Reduction Engineering Laboratory at 908-321-6626.



There are three recent EPA publications addressing soil remediation. Two of these address issues and research related to bioremediation. The third is a bioremediation resource guide. These publications are briefly described below.

***In-situ* Bioremediation**

Although *in-situ* bioremediation has been used for a number of years in the restoration of ground water contaminated by petroleum hydrocarbons, it has only recently been directed toward contaminants in unsaturated subsurface

soils. EPA's Robert S. Kerr Environmental Research Laboratory, in conjunction with Utah State University, has prepared a document which provides an overview of the factors involved in *in-situ* bioremediation, outlines the types of information required in the application of such systems and points out the advantages and limitations of this technology. The document focuses on processes which are currently being utilized or are in development to treat contaminated unsaturated subsurface soils in place. It is based on findings from the research community in concert with

experience gained at sites undergoing remediation.

Specific environmental processes, factors and data requirements for characterizing and evaluating the application of subsurface *in-situ* bioremediation are addressed as are selected field-scale applications of recovery and delivery systems that enhance *in-situ* subsurface soil bioremediation. Discussed are: *in-situ* subsurface microbial processes and controlling environmental factors; enhancement of *in-situ* subsurface bioremediation; making the saturated zone

(see *Bookshelf*, page 4)

Electra-Osmosis Holds Promise for *In-Situ* Extraction

By Randy Parker, Risk Reduction Engineering Laboratory

Electrokinetics, Inc. has developed an electro-osmosis (EO) process that promises to be an effective *in-situ* separation technology for extracting heavy metals, radionuclides and other inorganic contaminants, as well as some volatile organic compounds, from both saturated and unsaturated zones in soils. The technology has already been evaluated for lead recovery in a pilot-scale field study under EPA's Emerging Technologies SITE Program (Superfund Innovative Technology Evaluation Program) at a lead contaminated site in Baton Rouge, Louisiana. The Electrokinetics process was developed in conjunction with Louisiana State University's Louisiana Business and Technology Center. A full-scale SITE demonstration will occur in early 1994.

EO uses electricity to affect chemical concentrations and ground water flow. The Electrokinetics process employs direct currents across electrodes; conditioning pore fluids move with the current across the electrodes and circulate at the electrodes where the contaminants are removed. The type of pore fluids are based on remediation goals and specific contaminants. The fluid

moves between the soil particles because a constant, low direct current is applied through the electrodes inserted into a soil mass.

Studies indicate that an acid front is generated at the anode. This acid front eventually migrates from the anode to the cathode. Movement of the acid front by ionic migration and advection results in desorption of contaminants. The concurrent mobility of the ions and pore fluid under the electrical gradients decontaminates the soil mass. The contaminants are either deposited at the electrode or removed from the fluid by a purification process. These phenomena provide an added advantage over conventional pumping techniques for *in-situ* treatment of contaminated fine-grained soils.

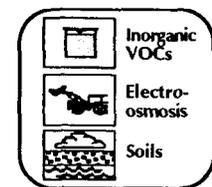
The process leads to temporary acidification of the treated soil. However, equilibrium conditions are rapidly reestablished by diffusion when the electrical potential is removed. If the electrodes are made of carbon or graphite, no residue will be introduced into the treated soil mass.

The efficiency of electro-osmotic water transport under EO varies with the

type of soil. EO can be an efficient process for removing contaminants from fine-grained, low permeability soils.

In addition to lead, bench-scale laboratory data demonstrate the feasibility of removing arsenic, benzene, cadmium, chromium, copper, ethylbenzene, lead, nickel, phenol, trichloroethylene, toluene, xylene and zinc. Bench-scale tests have also demonstrated the feasibility of removing uranium and thorium from kaolinite. Limited field tests showed zinc and arsenic removal from both clays and saturated and unsaturated sandy clay deposits. Lead and copper were removed from dredged sediments. Treatment efficiency depended on the specific chemicals, their concentrations and the buffering capacity of the soil. The technique proved 85 to 95% efficient when removing phenol at concentrations of 500 parts per million. The removal efficiency for lead, chromium, cadmium and uranium, at levels up to 2,000 micrograms per gram, ranged between 75 and 95%.

For more information, call Randy Parker at EPA's Risk Reduction and Engineering Laboratory at 513-569-7271.



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unsaturated; recovery technologies such as soil vacuum extraction and soil flushing; and delivery techniques such as currently used gravity/forced hydraulic delivery and bioventing. Research on hydraulic fracturing and radial drilling are also discussed. Additionally, the document covers waste, soil and site information requirements for evaluation and management of *in-situ* bioremediation and a mass balance approach to *in-situ* subsurface bioremediation.

A copy of *Engineering Issue: In-situ Bioremediation of Contaminated Unsaturated Subsurface Soils* can be ordered from EPA's Center for Environmental Research Information (CERI) at 513-569-7562. When ordering, please refer to the Document Number: EPA/540/S-93/501.

Bioremediation Using Land Treatment Concepts

Bioremediation processes using the land treatment concept, whereby contaminated soil is treated in place or

excavated and treated in prepared-bed treatment units, are common soil remediation technologies proposed for hazardous waste sites. However, RSKERL and other research and demonstration studies have identified complex biological, chemical and physical interactions within contaminated subsurface media which may impose limitations on the overall effectiveness of bioremediation processes utilizing the land treatment concept. RSKERL has prepared a report to summarize and discuss basic considerations necessary to implement and manage these types of bioremediation systems to improve their efficiency and effectiveness in reclaiming contaminated soils.

The report suggests design and operation criteria in areas ranging from pH control to tilling practices and moisture and nutrient requirements. Contaminants commonly related to the wood preserving and petroleum industries are addressed with respect to their applicability to land treatment in terms of treatability, loading rates and cleanup levels. A bibliography containing

references for further information is provided along with appendices covering soil properties important in land treatment and a discussion of monitoring procedures.

A copy of the report, *Bioremediation Using the Land Treatment Concept*, can be ordered from EPA's CERI at 513-569-7562. When ordering please refer to the Document Number: EPA/600/R-93/164.

Bioremediation Resource Guide

The *Bioremediation Resource Guide* is intended to support decision-making by those involved in evaluating cleanup alternatives. The *Guide* directs readers to bioremediation resource documents, databases, hotlines and dockets and identifies regulatory mechanisms that have the potential to ease the implementation of bioremediation at hazardous waste sites.

A copy of the guide, *Bioremediation Resource Guide*, can be ordered from EPA's CERI at 513-569-7562. When ordering please refer to the Document Number: EPA/542-B-93/004.

To order additional copies of this or previous issues of *Tech Trends*, or to be included on the permanent mailing list, send a fax request to the National Center for Environmental Publications and Information (NCEPI) at 513-891-6685, or send a mail request to NCEPI, 11029 Kenwood Road, Building 5, Cincinnati, OH 45242-0419. Please refer to the document number on the cover of the issue if available.

Tech Trends welcomes readers' comments and contributions. Address correspondence to: Managing Editor, *Tech Trends* (5102W), U.S. Environmental Protection Agency, 401 M Street, S.W., Washington, DC 20460.

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