TECH TRENDS

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TECH TRENDS IS CHANGING!

March issue of *Tech Trends* is our last. This July, the Technology Innovation Office will publish a new newsletter that combines *Tech Trends'* updates on innovative soil cleanup technologies with *Ground Water Currents'* updates on innovative ground-water technologies. The new bimonthly newsletter will be mailed out to all of our current subscribers to *Tech Trends* and *Ground Water Currents*.

Passive Bioventing Demonstration Conducted by DOD

by Sherrie Larson and Ron Hoeppel, Naval Facilities Engineering Service Center

Through a series of field pilot tests and a recent demonstration at Castle Airport (formerly Castle Air Force Base) near Merced, CA, the U.S. Department of Defense (DOD) is evaluating the use of natural passive bioventing to remediate unsaturated soils contaminated with petroleum hydrocarbons. Passive bioventing frequently has been demonstrated as cost-effective at sites lacking the electricity needed to run electric blowers for conventional bioventing. Most of these demonstrations, however, were conducted in arid regions with deep unsaturated zones (greater than 100 feet), high permeability, and low moisture content. The Castle Airport field demonstration, which was sponsored by DOD's Environmental Security Technology Certification Program, indicated the technology can be used successfully in a setting with higher soil moisture and a shallower unsaturated zone.

Passive bioventing utilizes the difference between gas pressure in unsaturated soil and in the atmosphere to move air into or out of vent wells. This technology can promote the extraction of any volatile contaminant from unsaturated soil by using the natural movement of soil gas out of vent wells. It is used most often to enhance soil aeration and resultant aerobic biodegradation of organic contaminants in unsaturated soil.

Once air moves into a soil profile, flow is delayed and dampened by a natural resistance of the soil to airflow. Research has shown that higher rates of airflow into passive bioventing wells occur in deep soil profiles with high air permeability, such as a thick sand zone above the water table. The presence of low permeability layers above a zone with high air permeability is expected to provide comparable airflow into shallower unsaturated sandy soils. Such low permeability layers could be silt and clay strata or manufactured surface layers such as asphalt. Tests also have shown that increased soil moisture will decrease the air permeability of the soil.

The Castle Airport demonstration took place between April and October 1998 in an area comprising three moderate- to high-permeability zones of fine- to medium-grain sand with minor silt and gravel deposits. Seasonal precipitation and irrigation pumping in this area routinely vary ground-water depth, which ranges from 10 to more than 70 feet below ground surface (bgs). At the time of the demonstration, a ground-water depth of 60 feet and soil moisture content of 5.8 percent (by weight) were measured. Analysis of soil and soil vapor samples indicated petroleum contaminant concentrations as high as 28,000 mg/kg in the gasoline range and 4,400 mg/kg in the JP-4 jet fuel range. Soil gas contaminant concentrations

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reached 54,000 parts per million by volume, with a virtual absence of oxygen gas due to natural fuel biodegradation.

The demonstration used one 4-inch diameter vent well with three 10 foot-long screened and bentonite-plugged intervals covering a depth range of 25-65 feet bgs. The vent well was equipped with a one-way, passive valve to increase the potential radius of influence (Figure 1). Eight vapor-monitoring points (VMPs) with multi-depth sensors were installed in two transects extending outward from the vent well at radial distances of 4, 8, 12, and 16 feet. Additional VMPs were installed at greater distances from the vent well in order to delineate larger radii of influence or to serve as background stations in uncontaminated areas.

At ten-minute intervals, a continuous data logger at each VMP recorded the ambient temperature, ground-water elevation, barometric pressure, and rates of total and screened-interval gas flow into the vent well. In addition, subsurface differential pressures and oxygen concentrations were recorded in the same frequency at each screened interval of the VMPs.

Demonstration tests indicated that the average daily volume of air entering the bioventing well was 3,400 cubic feet, with peak flow rates ranging from 5 to 15 cubic feet per minute. These rates are comparable to or greater than those encountered in passive bioventing applications at arid sites with unsaturated zones over 100 feet deep. Tests indicated that the one-way valve increased the vent well's radius of influence significantly by preventing the backward flow of oxygenated air from the well during daily periods of low atmospheric pressure.

Results also showed that the radius of influence expanded during longer operation periods. For example, a 5-percent oxygen concentration in the soil gas (the level commonly required to sustain aerobic microbial metabolism) was detected at a distance of 16 feet after 16 days of testing and as far as 42 feet after 52 days. Researchers found that the low-permeability silt and clay layers above and below each vented zone, and a ground cover consisting primarily of asphalt, aided in driving the air pressure gradient through the vent well system. Significant airflow rates were encountered even in the shallowest (25-35 feet) screened interval of the well.

The performance of this technology was compared to that of conventional bioventing with electric blowers, which had been selected for soil remediation and previously tested at this site under the same geological and hydrological conditions. Airflow rates of the passive system generally were 80-90 percent lower than those obtained through the conventional system. Operation of the passive system over an extended time period is expected to compensate for this rate difference. In addition, twice the number of vent wells were installed in the passive system to address the lower radius of influence commonly associated with shallow wells.

The costs for passive bioventing were very competitive with those of the conventional system. Higher costs for the installation of additional vent wells in passive bioventing were balanced by the system's low operation and maintenance costs. A total project cost of $300,000 was estimated for each technology, with a unit cost ranging from $1.90 to $2.10 per cubic yard of contaminated soil. At a site lacking access to electricity, however, DOD estimates that passive bioventing could save approximately $100,000, which otherwise would be spent on the installation of additional power lines or generators.

These studies show that passive bioventing is cost-effective for promoting biodegradation of petroleum-

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Figure 1: One-Way Passive Valve System

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contaminated sandy soils at depths of less than 50 feet when covered by low-permeability layers. DOD anticipates additional demonstrations and field tests during 2002 in eastern regions of the U.S. with higher levels of soil moisture. For additional information, contact Sherrie Larson (Naval Facilities Engineering Service Center) at 805-982-4826 or larsonsl@nfesc.navy.mil.

New EPA Resources Available

- To improve the current "state of the art and science" of soil venting applications, the Office of Research and Development's National Risk Management Research Laboratory recently released the report, *Development of Recommendations and Methods to Support Assessment of Soil Venting Performance and Closure* (EPA/600/R-01/070). The report provides a regulatory approach for assessing soil venting closure, reviews relevant literature on gas flow and vapor transport, and summarizes research on methods for improving venting applications. The complete report can be downloaded at www.epa.gov/ada/pubs/reports.html.

- The Technology Innovation Office now offers a *Field-Based Geophysical Technologies Online Seminar* to assist in site characterization and remediation. The two-hour seminar addresses factors to be considered in scoping, executing, and reviewing projects that involve geophysical instruments and techniques, and walks viewers through the use of technologies such as resistivity profiling and ground-penetrating radar. Throughout the seminar, instructors describe how to apply systematic planning, dynamic work plans, and field technologies to site cleanups guided by geophysical tools. To view the most recent seminar or to find out when future online sessions will be offered, visit www.clu-in.org/conf/tio/geophysical.

Phosphate-Induced Metal Stabilization Used for Lead-Contaminated Soil

by Judith Wright, Ph.D., PIMS NW, Inc., Andrea Leeson, Ph.D., and Brian Murphy, U.S. Department of Defense

Under the Environmental Security Technology Certification Program, the U.S. Department of Defense (DOD) is holding its first field-scale demonstration of phosphate-induced metal stabilization (PIMS) in soil. The demonstration is evaluating the use of PIMS with Apatite II™ for remediation of lead-contaminated soil at the Camp Stanley Storage Activity (CSSA) subinstallation of the Red River Army Depot in Boerne, TX. In addition to validating the technology's effectiveness, the demonstration will determine its field costs, assess its regulatory acceptance, and provide an acceptable alternative to offsite disposal. Preliminary results show lead stabilization of all 3,000 cubic yards of soil treated.

Through simple soil mixing, PIMS stabilizes metals using a natural and benign phosphate additive (apatite) that chemically binds soluble metals into stable, insoluble minerals. Apatite II holds up to 20 percent of its weight in lead, uranium, and other metals. Once the metals are removed by precipitation from the soil solution and sequestered in the new apatite phase (within minutes), the metals are considered stable, i.e., with significantly reduced mobility and bioavailability for geologically long time periods.

DOD selected onsite stabilization at the CSSA due to the large volume of contaminated soil involved, insufficient space for contaminated soil disposal, the technology's ability to return the soil to viable future use, and implementation costs that were lower than other technologies considered. Evaluation of PIMS indicated that it would produce a stable end-product mineral for the metal (pyromorphite [$K_{sp} \sim 10^{-80}$]) and could be implemented through existing technology. It also was determined that PIMS would have little impact on soil properties and would not affect nearby wetlands bioremediation activities.

The primary mission of CSSA is the receipt, storage, issue, and maintenance of ordnance. Until 1986, an open burn/open detonation area operated at a location now known as solid waste

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management unit B-20 (SWMU B-20). Site investigations at SWMU B-20 indicated that particulate lead occurred in localized soil zones at concentrations ranging from 200 to 40,000 parts per million (ppm) and averaging 3,100 ppm. SWMU B-20 occupies approximately 35 acres. It is underlain by three soil types with an average density of 104 pounds per cubic foot and an average permeability of 3.3×10^{-4} inches per second. The area receives approximately 28 inches of precipitation annually.

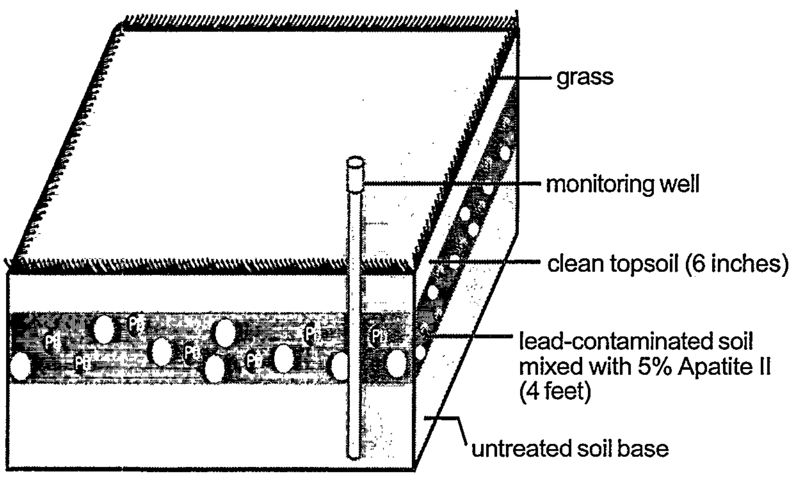
To measure leachate and comply with regulatory requirements, CSSA conducted a trial application of the technology at SWMU B-20 prior to full-scale operation. The treatment area was underlain by a landfill-type leachate collection system with a 2-inch layer of Apatite II to control the lower boundary condition. Using a standard backhoe, approximately 35 tons of Apatite II was mixed into 500 cubic yards of lead-contaminated soil to achieve a 5-percent (by weight) mixture of Apatite II. (Feasibility study results had indicated that larger amounts of Apatite II would not increase performance but would increase costs significantly, while lower amounts were difficult to mix evenly into the soil.) The trial mixture then was covered with coarse gravel to encourage infiltration and recharge, to provide a walking surface for workers performing periodic maintenance of the system, and to prevent vegetation growth. Over the following month, the treatment area was irrigated heavily at a rate equivalent to its annual precipitation. Analysis of the system leachate indicated dissolved lead concentrations below detection limits (3 parts per billion).

Based on the trial results, similar methods were employed to remediate the remaining 2,500 cubic yards of lead-contaminated soil at SWMU B-20. Contaminated, upper layers of soil were collected from the entire unit and placed in onsite piles that were mixed with Apatite II (Figure 2). The mixtures were spread into a single 4-foot layer across approximately one acre, and covered with 6 inches of clean topsoil that was vegetated through grass seeding. Due to the continuous nature of the PIMS process, the site will be monitored over the next two years to assess lead mobility, bioavailability, and leaching behavior. As a result of this treatment, the State of Texas Natural Resources Conservation Commission now classifies the remediated soil at SWMU B-20 as a class II non-hazardous material. CSSA estimates a total cost of $38 per treated ton of soil to employ PIMS at this site, while offsite disposal would have cost approximately $105 per ton.

This technology was deployed in 2001 at other federal and commercial sites to remove metals in both soils and ground water. Examples include the Los Alamos National Laboratory, NM, for remediation of depleted uranium-contaminated soil, and the Success Mine, ID, for removal of zinc, lead, and cadmium from tailings-contaminated ground water.

For more information, contact Dr. Judith Wright (PIMS NW, Inc.) at 505-670-5809 or judith@pimsnw.com, or Dr. Andrea Leeson (DOD) at 703-696-2118 or andrea.leeson@osd.mil. Contact Ken Rice (Parsons) at 512-719-6050 or Ken.R.Rice@parsons.com for detailed information on the Camp Stanley demonstration. Details on other PIMS applications and technology comparisons are available from Dr. James Conca (Los Alamos National Laboratory) at 505-699-0468 or jconca@lanl.gov.

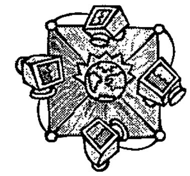
Figure 2: Soil Mixing for Lead Stabilization



What's New from the Technology Innovation Office

SPECIAL INSERT TO TECH TRENDS

The Technology Innovation Office (TIO), a component of EPA's Office of Solid Waste and Emergency Reponse, was created in 1990 to act as an advocate for new technologies. TIO's mission is to increase the application of innovative technologies for the characterization and treatment of contaminated waste sites, soils, and groundwater. TIO's newest products and services and those of partner organizations are listed below. All documents can be viewed or downloaded at **http://clu-in.org/techpubs.htm.** For hard copies, contact 800-490-9198 or 513-489-8190 or fax to 513-489-8695.



Web Resources

Live Internet Seminars

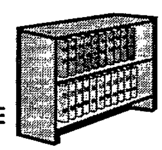
TIO and our partners continue to host free two-hour Internet Seminars on technical topics related to waste site remediation. In previous seminars, we have had participants from around the world. Never before has it been this easy to stay abreast of emerging technical clean-up issues without leaving your desk. Three to four seminars occur every month, and are announced on the CLU-IN Studio site at **http://clu-in.org/studio.**

FRTR Perchlorate Page

The Federal Remediation Technologies Roundtable (FRTR) recently posted a website devoted to Federal activities related to perchlorate in the environment. Major subheadings on the site include: Interagency Committees and Workgroups; Treatment Technology; Environmental Measurements; Toxicology; Conferences, Workshops, and Presentations on Perchlorate; Ecosystems; and State Agency Information. For more information, see **http://www.frtr.gov/perchlorate.**

In Situ Thermal Treatment Site Profile Database (Beta Version)

Recent developments in the area of *in situ* thermal treatment methods offer the potential for a significantly increased ability to address subsurface contamination. Approaches to *in situ* thermal treatment include steam, hot air, or hot water injection, conductive heating, electrical resistive heating, and radio-frequency heating. These methods are in various stages of development and deployment, largely as a function of the cleanup problem (size and type of site, location and nature of contamination) under consideration. The *In Situ* Thermal Treatment Site Profile Database is an initial attempt to capture information on sites deploying or planning to deploy these methods. **See http://clu-in.org/products/thermal**



New Publications

⇨⇨⇨ Check boxes and fax to 513-489-8695 to order document ⇦⇦⇦

☐ **Groundwater Pump and Treat Systems: Summary of Selected Cost and Performance Information at Superfund-financed Sites (EPA 542-R-01-021a)**
This report summarizes Phase 1 (the data collection phase) of the Nationwide Fund-lead Pump and Treat Optimization Project. Each EPA Region was contacted to identify their Fund-lead pump-and-treat (P&T) systems. Twenty Fund-lead systems were selected to undergo Remedial System Evaluations (RSEs). This report identifies the 88 Fund-lead P&T systems, summarizes the information submitted by the EPA Regions, and presents the screening and selection of those systems to receive RSEs (December 2001, 76 pages).

☐ **Remediation Technology Cost Compendium - Year 2000 (EPA 542-R-01-009)**
This report provides a summary and analysis of historical cost information for six commonly-applied remediation technologies: bioremediation, thermal desorption, soil vapor extraction, on-site incineration, groundwater pump-and-treat systems, and permeable reactive barriers. Cost data were obtained from federal agency sources with data extracted from approximately 150 projects. (September 2001, 77 pages)

☐ **A Citizen's Guide to *In Situ* Thermal Treatment Methods (EPA 542-F-01-012)**
The Citizen's Guide Series are 2-page fact sheets that provide a general description on approaches to clean up contaminated waste sites, soil, and groundwater. Each fact sheet answers the questions: What is it? How does it work? Is it safe? How long will it take? Why use it? This latest guide describes how *in situ* thermal treatment removes harmful chemicals from soil by using heat.

- **Improving Sampling, Analysis, and Data Management for Site Investigation and Cleanup (EPA 540-F-01-030a)** and **Resources for Strategic Site Investigation and Monitoring (EPA 542-F-01-030b)**
  These two fact sheets describe EPA's support (A) and resources available (B) for the streamlined approaches to sampling, analysis, and data management activities conducted during site assessment, characterization, and cleanup. This position reflects the growing trend towards using smarter, faster, and better technologies and work strategies. (April 2001, 4 pages/September 2001, 4 pages).

- **Using the Triad Approach to Improve the Cost-effectiveness of Hazardous Waste Site Cleanups (EPA 542-R-01-016).**
  This paper discusses the Triad approach to site decision making, i.e., use of systematic planning, dynamic work plans, and real-time analysis as the foundation upon which cost-effective, defensible site decisions and actions are built. A central theme of the triad approach is a clear focus on overall decision quality as the overarching goal of project quality assurance, requiring careful identification and management of potential causes for errors in decision-making (October 2001, 8 pages).

- **Abstracts of Remediation Case Studies, Volume 5 (EPA 542-R-01-008)**
  This report is a collection of abstracts summarizing 56 case studies of site remediation applications prepared primarily by federal agencies. Abstracts, Volume 5, covers a wide variety of technologies, including full-scale remediation projects and large-scale field demonstrations of soil and groundwater treatment technologies (May 2001, 168 pages)

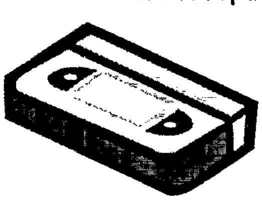
- **The State-of-the-Practice of Characterization and Remediation of Contaminated Ground Water at Fractured Rock Sites (EPA 542-R-01-010)**
  This report was published in TIO in cooperation with the Ontario Ministry of the Environment and the U.S. Department of Energy. The report summarizes two conferences held in 2000 on Fractured Rock Sites. The report suggests high priority characterization and remediation needs to research and development laboratories. It also documents the current state of the practice.

- **Innovations in Site Characterization - Technology Evaluation: Real-Time VOC Analysis using a Field Portable GC/MS (EPA 542-R-01-011)**
  This report describes the use of a field GC/MS to measure trichloroethylene on a real-time basis. The results were effective for making real-time decisions that guided characterization of the plume and optimal placement of the monitoring wells (July 2001, 32 pages).

Brownfields Publications and Resources - TIO's publications and resources to support Brownfields redevelopment can be found at: **http://brownfieldstsc.org.**

- **Road Map to Understanding Innovative Technology Options for Brownfields Investigation and Clean, Third Edition (EPA 542-B-01-001)**
  The third edition of the Road Map has been expanded significantly to include new and updated resources. The Road Map is not a guidance document. Rather, each section describes the steps involved in the characterization and cleanup of brownfields sites and connects those steps with available resources. (September 2001, 68 pages)

- **Brownfields Technology Primers.** The first two installments in a series focusing on technology issues and topics related to site redevelopment and reuse. "Selecting and Using Phytoremediation for Site Cleanup" (**542 R-01-006**) provides information on the use of this technology in a Brownfields setting in a manner understandable to nontechnical audiences. "Requesting and Evaluating Proposals that Encourage Innovative Technologies for Investigation and Cleanup" (**542 R-01-005**) provides information to help localities ensure that procurement efforts are receptive to innovative approaches.



Videos on the CLU-IN Studio - These videos were produced by the U.S. EPA Environmental Response Team and deal with selected environmental remediation topics. The videos range in length from 7-25 minutes. Videos, located at **http://clu-in.org/studio**, include:

Alabama Oil Burn	Clandestine Drug Labs	Revegetation with Native Plants
Divex	Manasota Plating	Green Pond Oil Spill
Navajo Vats	Summitville Mine	Environmental Dredging
Superfund Seniors	Wyoming Bioremediation	Clean Green - Phytoremediation

Thermal Desorption Removes Range of Organics

by Al Calise, U.S. Air Force Base Conversion Agency

As part of the National Environmental Technology Test Sites (NETTS) Program, the U.S. Air Force Base Conversion Agency (AFBCA) completed a pilot-scale demonstration of ex situ thermal desorption technology at the former McClellan Air Force Base (AFB) near Sacramento, CA. Soils from three sites at the base were treated to remove a wide range of nonvolatile and semivolatile organic compounds (SVOCs), including polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), dioxins/furans, and pesticides. The range of contaminants, together with low target cleanup goals, made this demonstration a more stringent test of the technology than prior applications. Based on the demonstration results, the AFBCA is considering full-scale implementation of thermal treatment as a remedial option for several hundred thousand tons of contaminated soil.

McClellan AFB was closed in 2001 after 65 years of operations involving the use, storage, and disposal of hazardous materials such as industrial solvents, caustic cleaners, electroplating chemicals, heavy metals, low-level radioactive wastes, fuels, and oils. Site investigations indicated contaminants in areas comprising landfills, waste disposal pits, and spill sites located across the base. For the contaminants of concern, concentrations encountered during the demonstration ranged from non-detect to a maximum of 5.5 mg/kg for SVOCs (pentachlorophenol), 0.35 mg/kg for PAHs (benzo(a)pyrene), 900 mg/kg for petroleum hydrocarbons (motor oil), 58 mg/kg for PCBs (Arochlor 1260), 40 pg/g for dioxins/furans (2,3,7,8-TCDD equivalents), and 0.09 mg/kg for pesticides (4,4'-DDD). Soils in this area are primarily unconsolidated sediments with moisture content of 10-14 percent.

Low-temperature (650°F-1,000°F) thermal desorption relies on heating of the contaminated soil to temperatures at which organic compounds will be liberated through volatilization, leaving behind the toxic inorganic compounds. Desorbed organic compounds are recovered from the carrier gas stream using scrubbers, condensers, and filters. Soils to be treated at the McClellan demonstration site were excavated, screened to remove oversized material, and stockpiled on a treatment pad. After processing through the thermal desorption unit, treated soils were returned to the sites of origin.

The demonstration equipment used at McClellan AFB included an indirectly heated rotary dryer inside a natural gas-fired furnace, a screw feed assembly, an indirect fuel firing system, and a gas handling unit to supply and capture nitrogen carrier gas and to condense the contaminants. Equipment was mounted on two portable trailers located on the base's existing soil treatment pad (Figure 3). Although rates varied during testing, the pilot operation unit was limited to a maximum soil feeding rate of 1,800 pounds per hour and a maximum treatment temperature of 1,000°F.

Contaminated soils from three different sites were treated during the demonstration. Five days of processing were performed for each site in two phases. In the first phase, soils were treated at 100-degree increments between 700°F and 1,000°F over two days to determine the minimum temperature required for effective treatment. In the second phase, soil was treated at a temperature of 1,000°F over three days to determine the maximum efficiency of the system. A total of 69

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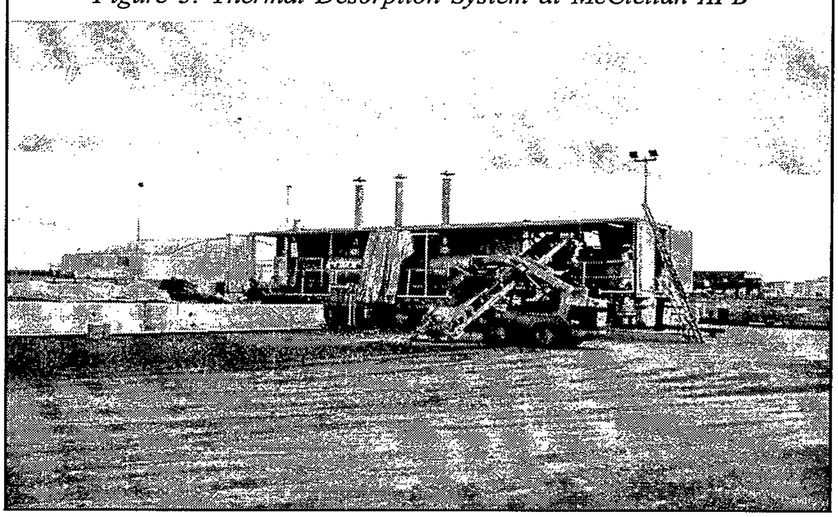
Figure 3: Thermal Desorption System at McClellan AFB



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tons of contaminated soil was processed during the 22-day demonstration.

Results indicated that, with the system operating at its maximum treatment temperature, concentrations of all organic contaminants of concern were reduced to nondetectable levels with the exception of dioxins/furans that were reduced to target cleanup goals. PAHs, SVOCs, and pesticides were removed at temperatures as low as 700°F, while nearly complete removal of petroleum hydrocarbons could be achieved at temperatures exceeding 800°F. Due to the difficulty in desorbing residual dioxins, treatment of soils containing PCBs and dioxins required temperatures of 1,000°F to achieve remediation goals.

The AFBCA estimates a cost of $59-$83 per ton of soil (exclusive of excavation and backfill costs) for full-scale thermal treatment using commercially available systems. System throughputs are projected to range from 26-46 tons of soil per hour. Other factors found to impact thermal treatment include the need for an appropriate 5-acre treatment pad for process operation and soil staging, and for adequate water, gas, and electric utility connections. Demonstration results also indicate that treatment of soils with a moisture content greater than 20 percent would involve much higher fuel requirements and lower throughputs.

To accommodate soil with a higher moisture content more consistently, full-scale implementation of this technology at McClellan AFB would include a thermal unit with a maximum furnace temperature of 1,400°F. In addition, the system would employ a larger, 2-inch conveyor screen mesh to ensure more consistent feeding rates, and would incorporate a treatment system for the scrubber blowdown to minimize residual contaminant.

Also under the NETTS Program, McClellan AFB researchers will conclude a field-scale soil washing demonstration early this spring, and have begun planning additional demonstrations on soil vapor extraction optimization and remedial process optimization. For more information, contact Al Calise (AFBCA) at 916-643-0830 x. 221, or e-mail acalise@afbda1.hq.af.mil.

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