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TECH TRENDS

CONTENTS

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ABOUT THIS ISSUE

This issue highlights various physical and chemical techniques for remediating and stabilizing large volumes of soils contaminated with organics compounds and metals.

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 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 was conducted to evaluate the technology in a setting with higher soil moisture and a shallower unsaturated zone. Results indicate that passive bioventing can be implemented at a broader range of contaminated sites, including those with more shallow unsaturated sandy soils that lie beneath low permeability silt/clay layers. Passive bioventing utilizes the difference between gas pressures in unsaturated soils and those in the atmosphere to move air into or out of vent wells. This technology can promote the extraction of any volatile contaminant from unsaturated soils by utilizing 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 soils.

Once air moves into a soil profile, it is delayed and dampened by a natural resistance of the soil to gas flow. 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. Accordingly, the presence of low permeability layers above a zone with high air permeability is expected to provide comparable airflow into more shallow unsaturated sandy soils. Such low permeability layers could be silt and clay strata or maufactured surface layers such as asphalt. Tests also have shown that increased soil moisture will increase the resistance of soils to airflow, thus decreasing their air permeability.

The Castle Airport demonstration took place between April and October 1998 in an area comprised of three moderate- to high-permeability zones comprising 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

[continued on page 2]

[continued from page 1]

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

The demonstration utilized 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. The low permeability silt and clay layers above and below each vented zone, and a ground cover consisting primarily of asphalt, were found to aid 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 and cost of this technology were compared to those 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. Although airflow rates of the passive system generally were found to be 80-90 percent lower than the rates obtained through the conventional system, operation of the passive system over an extended time period is expected to significantly reduce this rate difference. The costs for passive bioventing were very competitive with those of the conventional system, despite the use of twice the number of vent wells in the passive system. 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.

[continued on page 3]

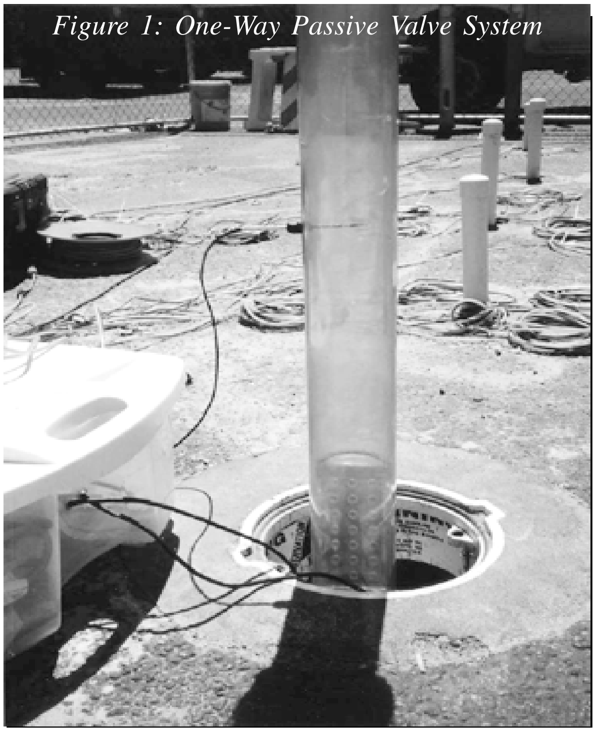

Figure 1: One-Way Passive Valve System

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

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 the 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.

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 entitled *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.

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 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 x 10^{-4} inches per second. The area receives approximately 28 inches of precipitation annually.

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), they are stable under environmental conditions for geologically long time periods.

DOD selected onsite stabilization at the CSSA due to the large volume of contaminated soil involved, insufficient

[continued on page 4]

[continued from page 3]

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 metal (pyromorphite $[K_{sp} \sim 10^{-80}]$) and could be emplaced by existing technology. It also was determined that PIMS would have little impact on soil properties and would not affect nearby wetlands bioremediation activities.

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 were 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 allow space 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 cost of $38 per treated ton of soil for employment of PIMS at this site, while offsite disposal would have run approximately $105 per ton.

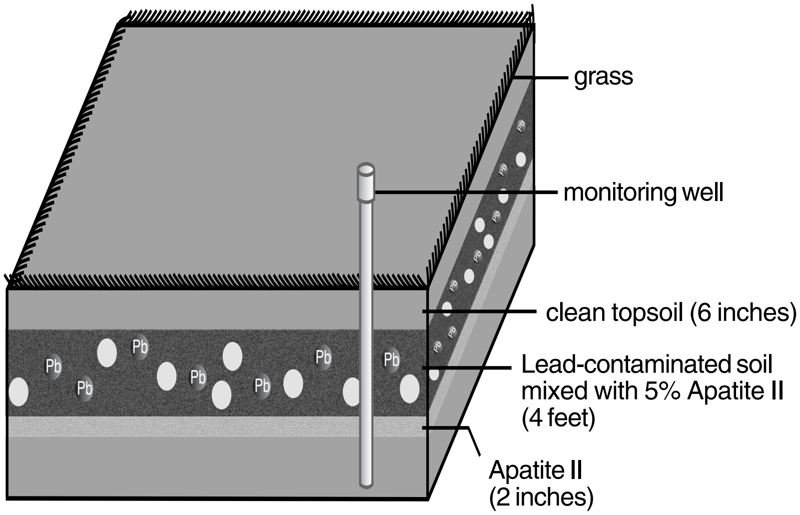
Figure 2: Soil Mixing for Lead Stabilization

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 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 James Conca (Los Alamos National Laboratory) at 505-699-0468 or jconca@lanl.gov.

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 polynuclear aromatic hydrocarbons (PAHs), petroleum hydrocarbons, polychlorinated biphenyls (PCBs), dioxins/furans, and pesticides. Based on the gathered information regarding implementation and life-cycle costs, technology performance, and achievement of cleanup goals, the AFBCA is considering use of thermal treatment at an additional site during 2004.

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 contaminant types 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), 900.0 mg/kg for petroleum hydrocarbons (motor oil), 58.0 mg/kg for PCBs (Arochlor 1260), 40.0 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 comprise primarily unconsolidated sediments with a moisture content of 10-14 percent.

Low-temperature thermal desorption relies on heating of the contaminated soil to temperatures at which organic compounds will be liberated through volatilization, leaving behind 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 1,000 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

[continued on page 6]

Figure 3: Thermal Desorption System at McClellan AFB

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[continued from page 5]

efficiency of the system. A total of 69 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 for implementation of thermal desorption technology using commercially available equipment. Other factors found to impact its application include the need for a treatment pad of a minimum 5-acre size and for adequate water, gas, and electric utility connections. Demonstration results also indicate that treatment of soils with moisture content greater than 20 percent would involve much higher fuel requirements and lower throughputs. To accommodate soils with 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.

Under the NETTS Program, McClellan AFB researchers also 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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