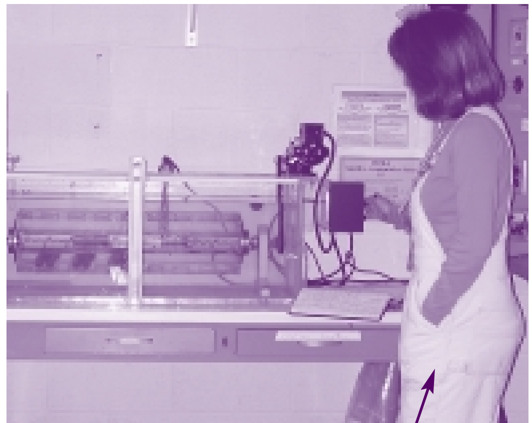
SERDP
Strategic Environmental Research and Development Program
DoD EPA DOE

SUCCESS STORY

NEW TOOLS ESTIMATE RISK FROM METAL-CONTAMINATED SOILS

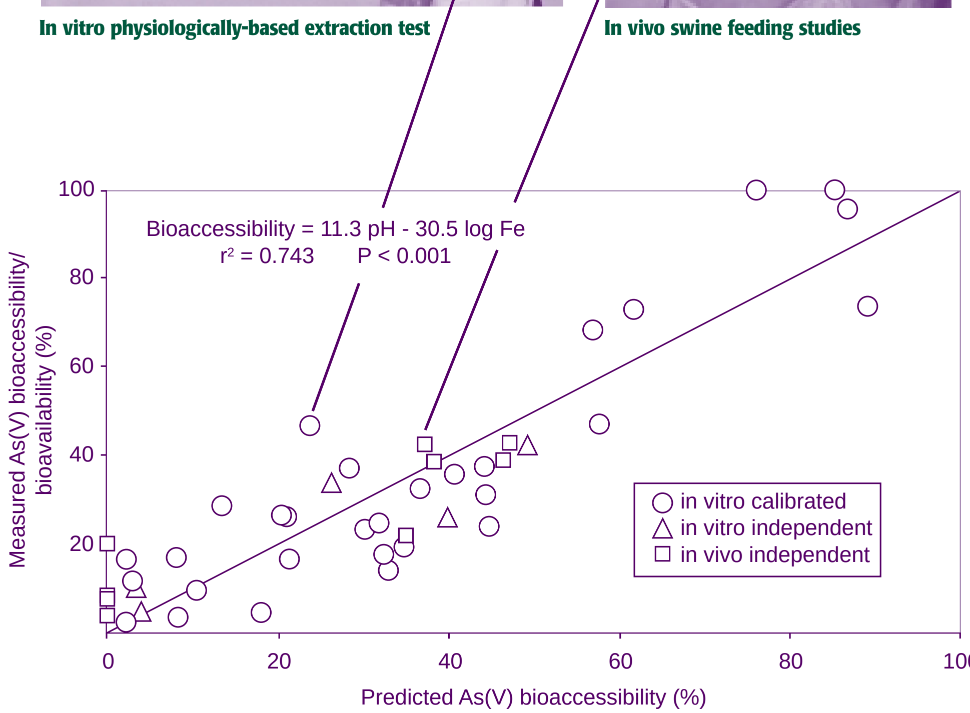
Thousands of sites at Department of Defense (DoD) installations contain metal-contaminated soils, including lead, arsenic, chromium, and cadmium. SERDP researchers are investigating methods to facilitate better cleanup decisions at these sites. When evaluating a contaminated site, risk assessors estimate the risk from a number of different potential exposure pathways. For future residential or recreational land use scenarios, the ingestion of soil by children is almost always the critical human health exposure pathway. When metal contaminated soil is ingested, the default risk assessment guidelines for most metals implicitly assume that the metal is completely absorbed by the body (i.e., 100 percent bioavailable). Soils, however, often tightly bind metals, potentially reducing their bioavailability. As a result, implicitly assuming metals in soil are 100 percent bioavailable may overstate the risk posed by the soils. The generally low bioavailability of lead and arsenic in soils in mining areas has been well documented, and the bioavailability of metals in soils at DoD sites also may be lower than traditionally assumed.

The SERDP project *Quantifying the Bioavailability of Toxic Metals in Soils (CU-1166)* led by Dr. Philip Jardine of Oak Ridge National Laboratory, Dr. Mark Barnett of Auburn University, and Dr. Scott Fendorf of Stanford University is investigating the factors that control the bioavailability of metals in soils at DoD sites around the country and developing methods to predict soil metal bioavailability based on major soil properties. Their results have indicated that soil-metal interactions significantly reduce the leachability



In vitro physiologically-based extraction test

In vivo swine feeding studies



Models are being developed to predict the bioavailability of metal contaminants based on major soil properties.

(bioaccessibility) of chromium and arsenic from soils. Naturally-occurring organic matter in soil, for example, can reduce chromium(VI) to chromium(III), thereby significantly reducing its bioaccessibility. To provide a better fundamental understanding of the relationship between bioaccessibility and speciation, macroscopic laboratory measurements also are being correlated with microscopic metal speciation measured with synchrotron-generated x-ray absorption spectroscopy. From this information, models are being developed that will allow risk assessors to estimate soil-metal bioavailability based on common soil properties. Recently, as illustrated above, a model developed through this research successfully predicted the bioavailability of arsenic in soils (as measured in swine feeding studies) to within an average of 10 percent based on the soil's pH and iron oxide content. Results for arsenic recently were

See BIOAVAILABILITY, page 4

TECH N•O•T•E•S

SERDP'S ECOSYSTEM MANAGEMENT PROJECT RECEIVES MODIS DESIGNATION

On September 10, 2002, the SERDP Long-term Ecosystem Management Project (SEMP), hosted by Ft. Benning, GA, was confirmed as a MODIS (Moderate Resolution Imaging Spectroradiometer) ASCII (American Standard Code for Information Interchange) site. MODIS is an instrument currently on two NASA satellites (Terra and Aqua) that generates a suite of products for land, atmosphere, and ocean science studies. The suite of MODIS Land Products most useful for the SEMP research sites include: fraction of Photosynthetically Active Radiation (fPAR), Net Primary Photosynthetic Production (NPP), Vegetation Indices (VI), Leaf Area Index (LAI), and Land Cover types. The data will begin to become available in an ASCII format in 2003. Eventually all data collected (beginning in 2000) for a select area on Ft. Benning will be included. For an overview of the MODIS ASCII sites, please refer to http://public.ornl.gov/fluxnet/modissubsetsites.cfm.

ELUCIDATION OF DNT DEGRADATION PATHWAYS AND THEIR EVOLUTION TO AID BIOREMEDIATION EFFORTS

Dinitrotoluenes (DNT) are major contaminants associated with explosives manufacturing and use. Bacteria can biodegrade DNT under appropriate circumstances, but little is known about the later stages of degradation or how the pathways evolved. The lack of understanding limits the practical application of bioremediation at sites contaminated with DNT.

Previous research defined the initial steps in 2,4-dinitrotoluene (2,4-DNT) metabolism. Under SERDP Project *Bacterial Degradation of DNT and TNT Mixtures* (CU-1212), recent work at the Air Force Research Laboratory (AFRL) by Drs. Glenn Johnson and Jim Spain in collaboration with Dr. Rebecca Parales at the University of Iowa has revealed the biochemical mechanisms of the subsequent steps in the pathway that allow the bacteria to convert the toxic compound into harmless minerals. Findings were described in a recent paper featured on the cover of the Journal of Bacteriology (*Johnson, G.R., R.K. Jain, and J.C. Spain. 2002. Origins of the 2,4-dinitrotoluene pathway.* J.Bact. 184:4219-4232).

The degradation of synthetic compounds requires bacteria to recruit and adapt enzymes from pathways for naturally occurring compounds. The work at AFRL has led to an understanding of the recruitment and assembly of the pathway that allows the bacteria to use 2,4-DNT as a source of carbon, nitrogen, and energy. The results have substantially advanced the understanding of how bacteria evolve to biodegrade synthetic chemicals that have only recently entered the environment. The project provides insight about bacterial evolution as well as a mechanistic understanding that will enable prediction and enhancement of DNT biodegradation in the field. *For additional information, contact Dr. Jim Spain, Air Force Research Laboratory, at (850) 283-6058 or via e-mail at Jim.Spain@tyndall.af.mil.* ◆

AIRBORNE MAGNETOMETRY, from page 2

Airborne magnetometry surveys represent state-of-the-art in detection and mapping for characterizing potential UXO contamination where low altitude flight is possible. For large areas, these surveys can be conducted at considerably lower cost than surveys using ground-based systems. On-going demonstrations of both the NRL and ORNL systems will continue to define the capabilities of the current airborne magnetic systems.

For further information about this technology, please contact Mr. Scott Millhouse, U.S. Army Corps of Engineers, Huntsville, Huntsville, AL, at (256) 895-1607 or via e-mail at scott.d.millhouse@hnd01.usace.army.mil or Dr. Herbert Nelson, the Naval Research Lab, Washington, D.C., at (202) 767-3686 or via e-mail at herb.nelson@nrl.navy.mil. ◆

BIOAVAILABILITY, from page 3

published in Environmental Science and Technology *(Yang, J.K., M.O. Barnett, P.M. Jardine, N.T. Basta and S.W. Casteel. 2002. Adsorption, sequestration, and bioaccessibility of As(V) in soils. Environmental Science and Technology 36 (21): 4562-4569).*

Improved fundamental understanding and predictive capabilities (via computer models) of the processes that control the long-term sequestration and bioaccessibility of metals in a wide array of DoD soils will allow site managers and risk assessors to make better initial estimates of site risk. Although site-specific data always will need to be considered in final cleanup decisions, results can be used to prioritize sites and to justify site-specific bioavailability studies, thereby avoiding the unnecessary diversion of DoD funds for unwarranted site cleanup. In future SERDP-funded research, the project team will expand on its finding that certain soil chemical and physical processes can sequester metals and limit bioavailability. The researchers will investigate the strategic use of non-toxic, low-cost, commercially available soil amendments to decrease the bioaccessibility of toxic metals at sites where the natural conditions do not promote sequestration.

For further information about this research, please contact Dr. Philip Jardine, Oak Ridge National Laboratory, Oak Ridge, TN, at (865) 574-8058 or via e-mail at jardinepm@ornl.gov or Dr. Mark Barnett, Auburn University, AL, at (334) 844-6291 or via e-mail at barnettm@eng.auburn.edu. ◆