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OVERVIEW OF DOE'S FIELD SCREENING TECHNOLOGY DEVELOPMENT ACTIVITIES

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ABSTRACT

The Department of Energy (DOE) has recently created the Office of Environmental Restoration and Waste Management, into which it consolidated those activities. Within this new organization, the Office of Technology Development (OTD) is responsible for research, development, demonstration, testing, and evaluation (RDDT&E) activities aimed at meeting DOE cleanup goals, while minimizing cost and risk. Site characterization using traditional drilling, sampling, and analytical methods comprises a significant part of the environmental restoration efforts in terms of both cost and time to accomplish. It can also be invasive and create additional pathways for spread of contaminants. Consequently, DOE is focusing on site characterization as one of the areas in which significant technological advances are possible which will decrease cost, reduce risk, and shorten schedules for achieving restoration goals. DOE is investing considerably in R&D and demonstration activities which will improve the abilities to screen chemical, radiological, and physical parameters in the field. This paper presents an overview of

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the program objectives and status and reviews some of the projects which are currently underway in the area.

INTRODUCTION

The Department of Energy (DOE) has recently consolidated its environmental restoration and waste management activities into the Office of Environmental Restoration and Waste Management, formed by Secretary James Watkins in early 1989. Within that new organization, the Office of Technology Development (OTD) oversees DOE's Technology Development Program, whose objective is to establish and maintain a national program for applied research, development, demonstration, testing, and ev. luation (RDDT&E). These activities will pursue technologies that will enable DOE to meet its 30-year compliance and cleanup goals safely, efficiently, and effectively.(1)

The first step in environmental restoration is site and contaminant characterization. Characterization of the current distribution of contaminants and the geohydrological factors that promote and control their spread will provide the starting point for determining what must be remediated and for selecting and designing remediation methods.

STATUS OF OTD ACTIVITIES

A cross section of the technology development activities which have been or are being conducted are described below. Space limitations preclude describing all activities in this area. Some of these activities will be described in more detail by the principal investigators at this conference.

DUVAS Fiberscope for in Situ Groundwater Monitoring. Because of its proven ability to detect compounds such as benzene and its derivatives, which are common solvents and components of fuels, derivative ultraviolet absorption spectrometry (DUVAS) is being developed as a rapid and reliable method for in situ detection of aromatic pollutants. To date, a prototype DUVAS fiberscope has been constructed and tested for measuring spatial and temporal distribution of organics in groundwater. An important component of the fiberscope is a rugged, down-well probe with a unique "detector-in-head" design that increases the maximum depth of subsurface detection. Results comparable to those obtained with a conventional laboratory spectrometer have been achieved with optical fiber lengths up to 50 meters. The portable DUVAS fiberscope will provide faster, more reliable, and less expensive measurement of subsurface groundwater contamination. For further information, contact the Principal Investigators, J.W. Haas III and R.B. Gammage, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831-6113. Phone: (615) 574-5042 (Haas), (615) 574-6256 (Gammage).

Advances in Surface-Enhanced Raman Spectroscopy for Applications in Real-Time Subsurface Monitoring. Because of its excellent selectivity, surface-enhanced Raman scattering (SERS) has attracted considerable attention as a potentially powerful analytical tool for detecting and screening trace-level contaminants in groundwater. The narrow Raman bands hold promise for simplifying the identification of individual components in complex mixtures. An inexpensive computer-controlled portable spectrometer system coupled to a fiber-optic probe is being developed for rapid on-site and in situ determination of organic groundwater contamination. Critical issues pertaining to durability, repeatability, sensitivity, selectivity, and universality are being examined, while means for improvement in these areas are being tested. The feasibility of utilizing SERS under harsh conditions has been demonstrated. Substrates have been tailored for maximum efficiency at particular excitation wavelengths as a means for increasing the sensitivity of the technique. Ongoing efforts have refined the state-of-the-art Raman optrode design and have shown the feasibility of producing a simple, inexpensive instrument for field applications. As the technique approaches maturity, SERS will provide powerful screening capabilities for numerous organic and inorganic materials. It promises rapid, reproducible, quantitative detection of trace-level contaminants in aqueous solutions. For further information, contact the Principal Investigator, Eric A. Wachter, Oak Ridge National Laboratory, Health and Safety Research Division, P.O. Box 2008, Oak Ridge, TN 37831. Phone: (615) 574-6248 (FTS 624-6248).

Fiber Optic Raman Spectrograph for in Situ Environmental Monitoring. A small (suitcase-sized) surface-enhanced Raman spectrometer (SERS) is being developed to use in field screening for a wide variety of organic and metallic pollutants in ground and surface waters. The focus of this contract is twofold: (1) to demonstrate a small spectrograph with high resolution (<1cm^{-1}) and wide spectral range (>3500 cm^{-1}) and (2) to demonstrate a micro-optical SERS probe head with substrates engineered to detect certain critical pollutants at ppm to ppb levels.

The spectrograph will have no moving parts and will employ fiber-optic sampling, an ultracompact solid-state diode laser for Raman excitation, a high-order diffraction grating, holographic optical filters, and a state-of-the-art charge-coupled device (CCD) detector. The probe head will be contained at the sampling end of a fiber-optic probe over 50 meters long inserted into a well less than 5 centimeters in diameter. The system will identify trace contaminants in groundwater in real time.

This technique will increase the efficiency of environmental characterization and mapping, reduce costs of field sampling and ex situ laboratory analysis, reduce personnel exposure, and provide site characterization information. For further information, contact the Principal Investigator, Michael Carraba, EIC Laboratories, Inc., 111 Downey St., Norwood, MA 02062, Phone: (617) 769-9540.

In Situ Detection of Organics. The long-term objective of this research is to develop a fiber-optic-based system for monitoring contaminant species in groundwater and to demonstrate it on contaminated groundwater at Lawrence Livermore National Laboratory (LLNL). These efforts require the development of optical indicator reagents that are compatible with fiber-optic chemical sensors (optrodes). Development of optrodes for ppb-level detection of trichlorethylene (TCE) and chloroform ($CHCl_3$) is complete and has moved into the demonstration phase. Carbon tetrachloride (CCl_4) and perchloroethylene (PCE) optrodes are currently being developed.

The fiber-optic approach has the potential of providing less expensive measurements of groundwater contaminants. Also, the reagent indicators and the chemistry developed in the process of developing the optrodes will "spin off" into other applications. For example, one chemistry that was developed serves as the basis for a proposed TCE remediation technique, the "TCE sponge". Finally, it should be pointed out that these simple indicators are new and could be used in other types of contaminant assays. For further information, contact the Principal Investigator, Mike Angel, Lawrence Livermore National Laboratory, Environmental Sciences Division, P.O. Box 808, L-524, Livermore, CA 94550. Phone: (415) 423-0375 (FTS 543-0375).

Optical Fiber Photothermal Spectroscopies for in Situ Monitoring and Characterization. Optical fiber sensors using thermal lens and photoacoustic spectroscopies for remote, on-site, real-time optical absorption measurements of chemical species in groundwater environments are being developed. Optical fiber sensors based on photothermal spectroscopies are ideal for ultrasensitive optical absorption measurements of actinides and other chemical species in aqueous environments. An optical absorption spectrum provides qualitative and quantitative analysis of the species present in the aqueous environment. The spectra can also provide complexation information for actinides, which is important for migration behavior. These photothermal sensors rely on tunable wavelength for selectivity and therefore do not require immobilized agents at the distal fiber end (in the sample area).

Research has demonstrated two optical fiber photothermal sensors with excellent sensitivity for rare earth and actinide ions in aqueous solutions. A remote photoacoustic sensor was demonstrated using a 100-meter fiber to deliver the tunable laser beam to a glove box located in a separate room from the laser. Acoustic signals were returned to the instrument lab via coaxial cables. An all-fiber thermal lens sensor was demonstrated using a fiber to deliver the laser light to a remote sample solution and a second fiber, with a photodiode attached to the distal end, to measure optical absorption; electrical cables were not required at the sample area. For further information, contact the Principal Investigators, Richard Russo, Lawrence Berkeley Laboratory, Applied Science Division, M.S.90-2024, Berkeley, CA 94720, Phone: (415) 486-4258 (FTS 452-4258); and Robert Silva, Lawrence Livermore National Laboratory, Nuclear Chemistry Division, L-396, Livermore, CA 94550. Phone: (415) 423-9798 (FTS 543-9798).

Field Measurement of Groundwater Contamination by Ion Trap Mass Spectrometry. A transportable ion trap mass spectrometer for the in situ characterization of soil, air, or water at chemical waste sites is being developed and demonstrated. The instrument will have a turnkey operating system for use by minimally trained personnel. The approach uses modular design to produce an instrument that can be readily modified and repaired in the field. Specifically, this project will develop a daughter microprocessor system to control ancillary hardware for sampling and separation and will develop new software, write macros, and modify existing software for semi-automated computer control of the instrument.

The instrument consists of specialized sampling modules for air, soil, or water samples; a separations module containing sorbent traps and a megabore capillary chromatography column; and a detection module, the Finnigan Ion Trap Detector. Soil or water samples are purged with helium and the evolved organics are collected on sorbent traps. A sampling pump is incorporated for air samples. The full analysis sequence required 10 minutes. The Finnigan software was modified through the addition of macros and Forth routines. The analytical procedure can be selected from a menu from the instrument's data system. Sampling, calibration, analysis, and data reduction proceed under computer control.

The detection limit for TCE in water is approximately 20 picograms. Mass spectral identification of 50 picograms of TCE is possible by library comparison of spectra. A linear calibration curve can be obtained from 10 ppt to 10 ppm organics in water.

Although transportable mass spectrometers are commercially available for environmental analyses in the field, the transportable ion trap technology described here provides several additional benefits, including low cost. The instrument can be assembled for a parts cost of about $75K. For further information, contact the Principal Investigator, Philip H. Hemberger, Los Alamos National Laboratory, Analytical Chemistry Group, Mail Stop G740, Los Alamos, NM 87545. Phone: (505) 667-7736 (FTS 843-7236).

Direct Sampling Mass Spectrometry. Rapid analytical technology based upon direct sampling mass spectrometry is being developed to determine trace organic pollutants in the environment. This project is jointly sponsored by DOE, the Department of the Army, and EPA. Closely related work is sponsored by the National Cancer Institute (NCI) for analyses of physiological fluids. Oak Ridge National Laboratory (ORNL) has developed sampling, sample interface, and ionization chemistry techniques that are first being combined with commercial mass spectrometers to provide rapid laboratory-based methods. Knowledge gained is used to develop instrumentation optimized for on-site analysis. Field-sampling and field-sample-processing methods are being developed to support the mass spectrometric technologies. The general approach involves a systematic comparison of the developed methods using accepted EPA methods to analyze organics in water, soil, air, and waste. Ion trap mass spectrometry (ITMS) and glow discharge ionization quadrupole mass spectrometry (GDMS) are being investigated. Both GDMS and ITMS are applicable to the quantitative determination of ppb concentrations of organics in water and in soil with analysis times of five minutes or less. This is achieved by purging the water or soil-water slurry with air or helium and routing the purge stream directly into the mass spectrometer. Less volatile organics may be similarly determined by collection on a suitable solid sorbent followed by thermal desorption. The method has thus far been demonstrated for the quantitative determination of benzene, trichloroethylene, and tetrachloroethylene. Applicability to semivolatiles has been demonstrated by the successful determination of nicotine and cotinine in urine for the NCI and for the determination of military chemical agents in air for the Army. A method is under development for the simultaneous collection of samples for subsequent confirmatory analysis in those cases where interferences cannot be distinguished by mass spectrometry or by mass spectrometry/mass spectrometry alone.

Successful development and validation can reduce costs and increase sample throughput by up to 90% as compared to current regulatory analytical methods. Field-versions of the technology will allow real-time monitoring of remedial action progress, monitoring of associated occupational exposure, and screening of samples prior to shipment to the laboratory for regulatory analyses. For further information, contact the Principal Investigators, M.B. Wise, M.R. Guerin, and M.V. Buchanan, Oak Ridge National Laboratory, P.O. Box 2008, Bldg. 4500-S, MS-6120, Oak Ridge, TN 37831-6120. Phone (615) 574-4862 (FTS 624-4862) (Mike Guerin).

Assessment of Subsurface Volatile Organic Compounds (VOCs) Using Chemical Microsensor Arrays. A new monitoring instrument that utilizes an array of coated surface-acoustic-wave (SAW) microsensors is being developed. Pattern recognition analysis of the multidimensional sensor output permits determination of the identity and quantity of target vapors from difference chemical classes typically found in contaminated soils and groundwater. The small size, low cost, low power requirements, high sensitivity, and large dynamic range of the instrument will facilitate its use in a variety of applications related to site assessment and process and control.

The project addresses some fundamental questions: (1) what is the performance of the SAW microsensor array instrument in applications relevant to site assessment and restoration, namely, monitoring volatile organic chemicals (VOCs) in high humidity environments, (2) how are the measurements provided by this instrument related to soil contaminant levels, and (3) how can they best be utilized in site assessment and restoration activities? A series of controlled laboratory experiments will be performed to address these questions.

The results of this research will demonstrate that microsensor array instruments can provide rapid and reliable compound-specific concentrations of volatile organics in soil vapor. The low projected cost of manufacture (less than $1000 in production quantities), the capabilities of continuous, unattended operation, and the ability to transmit data from remote locations make the SAW sensor-based monitors a cost-effective and desirable monitoring approach. For further information, contact the Principal Investigator, Stuart Batterman, University of Michigan, Department of Environment & Industrial Health, 2505 School of Public Health, Ann Arbor, MI 48109-2029. Phone: (313) 763-2417.

Thin-Layer Detectors: NO_2 Detection with Polystyrene Thin Layers. A solid-state sensor that can be used to detect NO_2 without interference by other species is being developed. The device incorporates an interdigitated electrode with a polystyrene thin layer and operates by simply monitoring the change in conductance of this thin film as a function of NO_2 exposure. Although the film is an insulator in the absence of NO_2 , showing conductance of less than 10^{-12} S, upon exposure to NO_2 gas, an increase in conductivity of this highly insulating material occurs over several orders of magnitude to 10^{-8}-10^{-9} S. No interference from ambient gases or water vapor has been observed, and the effect is very specific to NO_2. Upon elimination of the NO_2 gas, the device becomes completely insulating again, all effects occurring at ambient temperature and pressure.

The mechanism of the conduction within the film remains unclear, although the level of conductivity is related to the amount of residual benzene solvent within the film. Thus, as the benzene evaporates from the film, the change in conductivity of the film upon NO_2 exposure diminishes dramatically. This effect appears to be related to a stabilization of NO_2 dimer by benzene within the film. The increased conductivity of the film in the presence of benzene is attributed to the well-known self-ionization of N_2O_4 to $NO^+ + NO_3^-$. For further information contact the Principal Investigator Stephen F. Agnew, Los Alamos National Laboratory, Los Alamos, NM 87545. Phone: (505) 665-1764 (FTS 843-1764).

Antibody-Based Fiberoptics Sensors For in Situ Monitoring. Sensitive and selective chemical sensors for in situ monitoring of hazardous compounds in complex samples are being developed. Special focus is on a unique fluoroimmuno-sensor (FIS) which derives its analytical selectivity through the specificity of antibody-antigen reactions. Antibodies are immobilized at the terminus of a fiberoptic within the FIS for use in in situ fluorescence assays under field conditions. High sensitivity is provided by laser excitation and optical detection techniques. The technique can detect femtomoles (10^{-15}M) of the carcinogen benzo(a)pyrene and other chemicals of environmental interest. For further information, contact the Principal Investigators, T. Vo-

Dinh and G.D. Griffin, Oak Ridge National Laboratory, P.O. Box 1008, MS-6101, Oak Ridge, TN 37831-6101. Phone: (615) 574-6249 (Vo-Dinh) and (615) 576-2713 (Griffin).

Underground Imaging for Site Characterization and Clean Up Monitoring. State-of-the-art image reconstruction techniques (tomography) can be used to characterize the geology and hydrology of hazardous waste sites. These methods extend spatial information of geologic structure and hydrology between boreholes. Both two- and three-dimensional imaging can be done using these techniques. High-frequency electromagnetic (HFEM) tomography is a proven technology for imaging water content with high spatial resolution, (i.e., submeter scale for small geologic scale applications (ten meters). Electrical resistance tomography (ERT) is a newer technology which has been used in the field with moderate-scale resolution on larger scale images (meters on tens to hundreds of meters).

Characterization of the subsurface geology and hydrology is needed to select the most appropriate remediation alternative and to demonstrate regulatory compliance. Design of remedial actions must be based upon knowledge of the often anisotropic and heterogenous nature of the subsurface environment and the natural processes that act upon the waste, as well as upon protective barriers. Groundwater flow strongly influences contaminant mobilization and transport and geologic structure affects the flow of groundwater. Current subsurface characterization techniques for addressing these above problems depend heavily upon drilled boreholes. Drilling is expensive and time consuming and also creates conduits for contaminant spread. A special need exists for three-dimensional noninvasive subsurface characterization technologies. For more information, contact the Principal Investigator, William Daily, Lawrence Livermore National Laboratory, P.O. Box 808, L-156, Livermore, CA 94550. Phone: (415) 422-8623 (FTS 532-8623).

Development of the SEAMIST Concept for Site Characterization and Monitoring. This project is developing the Science and Engineering Associates' Membrane Instrumentation and Sampling Technique (SEAMIST). The technique permits rapid emplacement of instrumentation and sampling apparatus in a punched or drilled hole. The objective of the technique is to pneumatically emplace an impermeable membrane liner carrying many instruments into a hole to provide simultaneous access to the entire hole wall (e.g., many measurement horizons per hole), elimination of circulation of fluids within the hole, and isolation of instruments at discrete locations between the hole wall and the membrane. The membrane is emplaced by eversion--it is rolled inside out and then everted using air pressure. This causes minimal disturbance to the hole because the assembly does not slide down as with traditional rigid casings. Instruments such as fiber-optic sensors, thermocouple psychrometers, gas- and liquid-sampling systems, and other small instruments are easily attached to the membrane and carried into the hole with it.

Using this technique will save 50%-90% of the field costs, as compared to current monitoring well practices. In addition, the technique is applicable to both vertical and horizontal wells. For further information, contact the Principal Investigator, Carl Keller, Science and Engineering Associates, 612 Old Santa Fe Trail, Sante Fe, NM 87501. Phone: (505) 646-5188.

Site Characterization and Analysis Penetrometer System (SCAPS). DOE is working with the Department of Defense on the further development and demonstration of the SCAPS for use on DOE facilities. The SCAPS, as developed by the Army Corps of Engineers Waterways Experiment Station for the Army Toxic and Hazardous Materials Agency, includes surface geophysical equipment, survey and mapping equipment, sensors for contaminant detection, and soil sampling equipment. Computer systems have been integrated with the SCAPS in order to provide data acquisition, data processing, and 3-D visualization of site conditions. The system is mounted on a uniquely-engineered truck that provides protective work spaces to minimize worker exposure to toxic chemicals. The truck also provides equipment to seal each penetrometer hole with grout.

Real-time sensors that are currently available for characterization work include those which can determine the strength, electrical resistivity, and spectral properties of soils. Two sensors successfully demonstrated to detect contaminant plumes at DOD facilities are the soil resistivity unit and a fiber optic contaminant sensor. The primary advantage of the fiber-optic sensor over resistivity measurements is based on laser-induced fluorescence, which presents a problem for contaminants such as TCE that do not fluoresce; however, colorimetry and absorption techniques such as the sensors which are being developed by Lawrence Livermore National Laboratory and by Fiberchem are tentatively planned to be demonstrated in conjunction with the penetrometer at the Savannah River integrated demonstration in FY-91. Additionally, samplers such as the "Terra Trog" developed by the Army Corps of Engineers may be tested in FY-91 at the Savannah River Site. For further information, contact the Principal Investigator, Stafford Cooper, Waterways Experiment Station, P.O. Box 631, Vicksburg, MS 39181-0631. Phone: 601-634-2477.

Design, Manufacture, and Evaluation of a Hydraulically Installed, Multi-Sampling Lysimeter. A new lysimeter sampling device design, approximately 1 inch in diameter, having multiple sampling zones and capable of being hydraulically installed at a desired depth in the vadose zone without drilling will be developed. This lysimeter will be readily retrievable for reuse and will provide an inexpensive monitoring technique in comparison to installation of lysimeters into predrilled holes. In this project, the hydraulically inserted lysimeter will be designed and constructed. The effect of hydraulic insertion on the operation of the lysimeter will be investigated by comparing hydraulic insertion with standard boring procedures. The lysimeter should be commercialized within three years. This new design is less disruptive to the subsurface, both during installation and after removal, requiring only a 1-inch-diameter hole vs. the 4-inch holes commonly drilled for monitoring wells. Costs are estimated to be under 50% of that to drill monitoring wells. This project is a collaborative effort among Bladon International, Inc., Institute for Gas Technology, and Timco Manufacturing. For further information contact the Principal Investigator, Joe Scroppo, Bladon International, Inc., 880 Lee Street, Des Plaines, IL 60018. Phone: (505) 883-3636.

Minimally Invasive Three-Dimensional Site Characterization. Hardware and software are being developed to permit data acquisition from three minimally invasive measurement techniques--cone penetrometer, synergistic electromagnetic mapping technology and reflection seismology. The software will permit rapid feedback, comparison, co-calibration, and data analysis from the combined technology. Simultaneous application of these three technologies permits physical and electrical property measurements to be used to cross-calibrate each data set. The early acquisition of preliminary data allows field personnel quickly to adapt their field study strategy to changes in the perceived site conditions or contamination distribution.

Costs will be saved by rapid feedback of the data to field personnel, the improved informational quality, and the lower cost of an integrated system. The minimally invasive system reduces environmental impact and reduces risk to field personnel. For further information contact Principal Investigator, John Gibbons, Applied Research Associates, Inc., 4300 San Mateo Blvd., N.E., Suite A220, Alburquerque, NM 87110. Phone: (505) 883-3636.

High Resolution Shear Wave Seismic Reflection Surveying for Hydrogeological Investigation. This technology will enhance the ability to directly determine aquifers in the characterization and sensing of geologic and hydrogeologic features. The project will extend the state-of-the-art of shallow subsurface hydrogeological characterizations by means of high resolution shear (S) wave seismic reflection profiling. High resolution seismic reflection profiling using conventional compressional (P) wave technology has evolved over the past ten years to the point where this technique has become a major component of numerous environmental investigations. Extension of the existing technology to include S-wave reflections has the potential for greatly enhancing the data which can be extracted from the subsurface. Unlike a P-wave, an S-wave will not travel through a purely liquid medium, hence its advantage over current P-wave techniques.

Conventional high-resolution seismic reflection profiling has proven cost-effective for environmental assessment by reducing the number of holes and the cost of boring. S-wave reflection technology will enhance the information content of the seismic reflection technique and improve the cost-effectiveness of the technique. For further information contact the Principal Investigator, William Johnson, Paul C. Rizzo Associates, Inc., 300 Oxford Dr., Monroeville, PA 15146. Phone: (412) 856-9700.

Field Measurements for the Hydrology and Radionuclide Migration Program (HRMP) at the Nevada Test Site. The HRMP was begun in 1974 for the purpose of determining the potential for migration of radionuclides from underground test areas. HRMP is a multi-agency research project and is coordinated by the Nevada Operations Office of DOE. The participants are Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Desert Research Institute, and the U.S. Geological Survey. The present goals of the program are to learn more about the groundwater rates and directions of flow on the Nevada test site (NTS), which is located approximately 80 miles northwest of Las Vegas, in regional and local systems, to develop mathematical models of the flow systems, to determine the effects of nuclear tests on the systems, and to measure the migration rates of selected radionuclides under various conditions.

Transport mechanisms for radionuclides from underground nuclear detonations are studied by sampling both the contaminated cavity water and groundwater pumped from the surrounding formation. Radioactivity in water greater than 9-cavity-radii distance from the detonation point has been measured without stressing or pumping the aquifer. A plume of radioactivity which is being rapidly transported by the local groundwater has been intercepted. Micro- and ultrafiltration studies on this groundwater have shown that radionuclides can be present and mobile in groundwater systems in colloidal form. Water pumped from a tritium contaminated satellite well over a 20-year period drains into a mile-long ditch and has created a secondary site emphasizing the unsaturated zone. Current studies along the discharge ditch are investigating the moisture and tritium front through shallow alluvium. This project is developing systems which can measure contaminants such as organics, tritium, and long-lived radionuclides in wells in depths from 1400 to 3300 feet. For further information, contact the Principal Investigator, Jo Ann Rego at Nuclear Chemistry Division, Lawrence Livermore National Laboratory, P.O. Box 808, L-234, Livermore, CA 94551. Phone: (415) 422-5516 (FTS 532-5516).

Depth Profiling in the Water Table Region of a Sandy Aquifer. The feasibility of using a new multilayered sampler to investigate organic contaminants in groundwater is being explored. The device passively collects simultaneous groundwater samples from multiple levels in the subsurface. In addition, the project will develop a new device based on experience with existing sampler.

The sampler, developed at the Weizmann Institute of Sciences, Rehovot, Israel, was used to detect the presence of several inorganic and organic species at a contaminated Brookhaven site. The presence of microscale heterogeneities in concentration gradients over a vertical interval of 200 cm was observed for eight solutes, including metals, organics, and anions. A planned remediation was modified based on results of this short sampling event. It is believed that the new plan will be more cost effective than the original because the contamination was better defined in the vertical plane and because an oxygen-depleted zone was found where it was previously thought to be fully saturated. For further information, contact the Principal Investigator, Edward Kaplan, Brookhaven National Laboratory, Radiological Sciences Division, Building 703M, Upton, NY 11973-5000. Phone: (516) 282-2007 (FTS 666-2007).

Kr^{81} Counting for Nuclear Waste Sites. A new technology to date groundwater is being developed. By combining resonance ionization spectroscopy and mass spectroscopy, ultralow levels of Kr^{81} in groundwater can be detected. From the quantity of Kr^{81}, the age of the groundwater can be determined. This information helps find suitable locations to store nuclear wastes or highly toxic chemical wastes in groundwater. Several samples from Europe have been tested and the results are adequate to search for new waste sites. It is beneficial to the Department of Energy waste program to find a geologically safe place to store nuclear wastes and highly toxic chemical wastes. For further information, contact the Principal Investigators, C.H. Chen and M.G. Payne, Oak Ridge National Laboratory, Photophysics Group, Building 5500, MS-6378, P.O. Box 2008, Oak Ridge, TN 37831-6378. Phone: (615) 574-5895 (FTS 574-5895).

FUTURE TECHNOLOGY DEVELOPMENT NEEDS

The OTD activities described here address some, but by no means all, of the key needs which DOE foresees in the area of in situ monitoring.

Present site characterization methods are imprecise, costly, time-consuming, and overly invasive. Improved site characterization methods will require better technologies for accurately describing the subsurface geohydrologic features of a site. For example, more efficient nonintrusive sampling strategies and practical models are necessary for understanding and predicting subsurface transport. Also needed are more reliable procedures for interpreting characterization data, such as how clean is "clean".

Traditional hydrologic characterization of the subsurface environment is highly dependent on data from groundwater monitoring wells. A thorough understanding of the subsurface environment requires a series of hydraulic wells. Interpretation depends greatly on proficiency of the scientific staff, making subsurface characterization highly subjective and at times uncertain. Research is needed to make hydrologic characterization more precise and more cost effective.

Currently accepted analytical procedures such as those in the Environmental Protection Agency's (EPA's) SW-846 do not cover all materials that need to be measured at DOE sites. DOE is working with the EPA and others to alleviate such problems with sampling and analyses. Close coordination with EPA and other regulatory agencies is needed not only to identify, develop, and validate appropriate methods, but also to ensure the acceptance of data generated using these methods.

Intrusive exercises, such as sampling and excavation during remediation of a site, often involve immediate hazards to workers in the form of exposure to radioactive and/or toxic materials. Remote real-time analyses of ambient levels of potential hazards in the air, water, and soil during characterization, as well as in the remedial action phase, would help ensure worker safety and allow continuous operation. Instrumentation capable of detecting broad classes of hazardous materials and specific compounds is needed to indicate cleanup status. Better characterization methods based on real-time analyses are especially important to confirm the most effective use of certain in situ remediation technologies. In the absence of real-time monitoring, excessive volumes of soil and water must be treated to guarantee compliance; otherwise, pockets of contamination may be missed.

Special characterization technologies are necessary for inactive facilities, underground storage tanks, and wastewater lagoons. These facilities often contain significant quantities of radioactive wastes, in certain cases mixed with heavy metals and/or hazardous organic compounds that make personnel entry unacceptable. Thus, the development of advanced robotic samplers, smart probes, mobile and in situ fiber-optic devices, and nonintrusive characterization instrumentation (based on electromagnetic, thermographic, and acoustic principles) is needed for sampling and chemically characterizing these sites. The development of such techniques will significantly reduce radiological exposure to workers and provide more assurance that the correct remedial technology has been selected.

Clearly, there are more technology development needs and more good ideas than there are resources to devote to these investigations. Priorities must be set to support those activities deemed most urgent.

OPPORTUNITIES FOR PARTICIPATION

OTD is interested in eliciting broad participation from qualified organizations who can contribute to its RDDT&E activities. We are becoming increasingly aware of the wealth of technological talent and good ideas in all sectors. OTD has initiated steps during the past year to increase participation of the private sector (academia and industry) through competitive solicitations and through funding of unsolicited proposals. We have also worked to increase participation by academia through interagency agreements for cooperative funding of research and through establishment of DOE educational consortia. Several significant technology development activities are being conducted at DOE sites such as national laboratories. DOE is funding technology development activities beyond the United States through direct contracts, international agreements, and other mechanisms.

DOE plans to continue this type of support for technology development in the coming years. Organizations interested in responding to solicitations should contact Dr. Erickson (for applied R&D) or Mr. Snipes (for DT&E) at the above addresses to be placed on distribution lists. Organizations wishing to submit unsolicited proposals should contact Larry Harmon, Director, Division of Program Support (EM-53), Department of Energy, 12800 Middlebrook Road, Trevion II Building, Germantown, MD 20874, for information on submission format and procedures prior to preparation of a proposal.

REFERENCES

1. United States Department of Energy Environmental Restoration and Waste Management, Five-Year Plan, Fiscal Years 1992-1996, June 1990, DOE/S-0078P.