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EMERGING SITE CHARACTERIZATION TECHNOLOGIES FOR VOLATILE ORGANIC COMPOUNDS

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ABSTRACT

A Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) expedited response action (ERA) has been initiated at Hanford Site's 200 West Area for the removal of carbon tetrachloride from the unsaturated soils. In coordination with the ERA, innovative technology demonstrations are being conducted as part of DOE's Volatile Organic Compounds - Arid Integrated Demonstration in an effort to improve upon baseline technologies. Improved methods for accessing, sampling, and analyzing soil and soil-vapor contaminants is a high priority. Sonic drilling is being evaluated as an alternative to cable-tool drilling, while still providing the advantages of reliability, containment, and waste minimization. Applied Research Associates, Inc. used their cone penetrometer in the 200 West Area to install a permanent soil-gas monitoring probe and to collect soil-gas profile data. However, successful application of this technology will require the development of an improved ability to penetrate coarse gravel units. A Science and Engineering Associates Membrane Instrumentation and Sampling Technique (SEAMIST) system designed for collecting in situ soil samples and air permeability data in between drilling runs at variable depths is being tested in 200 West Area boreholes. Analytical technologies scheduled for testing include supercritical fluid extraction and analysis for non- and semi-volatile organic co-contaminants and an unsaturated flow apparatus developed by Washington State University for the measurement of transport parameters.

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Background

Fig. 1: Radioactively contaminated acidic aqueous wastes and organic liquids containing carbon tetrachloride were discharged to the soil column at three adjacent disposal sites within the 200 West Area of the DOE Hanford Site, Washington. The 200 West Area is approximately 11 km east of the western boundary of the Hanford Site and approximately 8 km south of the Columbia River.

Fig. 2: The three disposal sites are located within a 120 x 520 m area in the 200 West Area. At Hanford, carbon tetrachloride was used primarily in plutonium recovery processes.

Fig. 3: It is estimated that between 363,000 to 580,000 L of carbon tetrachloride were discharged to the soil column at the carbon tetrachloride disposal sites between 1955 to 1973, along with 190 kg of plutonium and americium. The total amount of carbon tetrachloride disposed to the soils represents less than 1/10 of the total liquid (mostly aqueous) disposed to the sites. Other organic co-contaminants include tributyl phosphate, dibutyl butyl phosphonate, and lard oil; degradation products include chloroform, methylene chloride, dibutyl phosphate, monobutyl phosphate, and butyl alcohol.

Figure 4: The geology of the 200 West Area consists primarily of basalts overlain by fluvial and glaciofluvial sediments. The unsaturated zone beneath the carbon tetrachloride disposal sites is approximately 60 to 66 m thick and consists primarily of sands and gravels. A laterally continuous, relatively impermeable zone ("caliche layer") occurs at about 40 m depth.

Figure 5: By 1991, approximately 12.5 km^2 of the underlying unconfined aquifer is contaminated with carbon tetrachloride up to several orders of magnitude above the maximum contaminant level (MCL) accepted for a drinking water supply (5 ppb). It is thought that a substantial amount (98% of the estimated volume) of carbon tetrachloride remains in the unsaturated soils beneath these disposal sites and continues to contribute to the long-term contamination of the ground water.

To minimize further contamination of the ground water, an expedited response action (ERA) has been initiated to remove the contamination in the unsaturated soils using existing technologies. Site characterization is being conducted in a phased approach, designed to optimize the use of field screening level data and existing wells, and to minimize the generation of radioactive and hazardous wastes. The phased approach is being conducted to meet the accelerated ERA time schedule, constrain costs, and meet the safety requirements for working in a radiologically contaminated area.

In coordination with the ERA and in an effort to improve upon baseline technologies, innovative technology demonstrations are part of DOE's VOC - Arid ID. The VOC-Arid ID was initiated in 1991 by DOE's Office of Technology Development to develop, demonstrate, and transfer for deployment the suite of technologies necessary to characterize, remediate, and/or monitor arid or semiarid sites containing VOC (e.g., carbon tetrachloride) with or without associated metal and radionuclide contamination. Improved methods for accessing, sampling, and analyzing soil and soil-vapor contaminants is a high priority.

Current Site Characterization Technology Demonstrations

Figure 6: The primary methods for accessing subsurface soils for characterization is through vertical drilling. At the DOE Hanford Site, cable-tool drilling techniques have been used because of 1) better sample quality obtained during drilling through unconsolidated sands, gravels, and cobbles; 2) containment of potentially contaminated drill cuttings; and 3) minimal generation of secondary wastes from drilling fluids. Unfortunately, cable-tool techniques are generally slower than other well drilling techniques. Sonic drilling is being evaluated as an alternative to the cable-tool technique. It is faster and still provides the advantages of sample quality, containment, and waste minimization.

The sonic drilling method's primary component is the sonic drill head. Sonic frequencies range up to 150 Hz with a peak force of 21,800 kg. The hole is advanced through shearing or cutting of the formation. Drill cuttings are captured in a core tube and brought to the surface via a wireline winch retrieval system.

Figure 7: STATUS OF SONIC DRILLING DEMONSTRATION AT HANFORD

- operated by Harrison Western Drilling of Lakewood, Colorado
- conducted spring 1992
- advanced 10-inch diameter casing to 150 ft
- advanced 7-inch diameter casing to total depth of 226 ft
- used to complete vadose zone monitoring well (4-in stainless steel casing, two screened intervals)
- produced deepest sonic hole (10-in diameter or larger) ever recorded. Previous record was approximately 40 ft.

Figure 8: BENEFITS OF SONIC DRILLING

- faster drilling rate than cable-tool
- drilling fluids not required

- minimizes waste generation
- disturbs the subsurface hydrogeologic and microbial characteristics less than cable-tool

Figure 9: Another technology that could augment and, in some cases, replace standard drilling at Hanford is cone penetrometer testing (CPT). The cone penetrometer is an instrumented rod that is hydraulically inserted into the soil. The coarse-grained Hanford soils present a challenge for the successful use of the CPT at the DOE Hanford Site. In optimal soil conditions, the cone penetrometer can penetrate 60 m at speeds up to one meter per minute, a rate significantly greater than standard drilling methods. There is little waste generation, no drill cuttings and no drilling fluids. Several soil parameters can be measured in situ with various probe instrumentation. Samples of soil gases and ground water can also be extracted for analysis. The CPT can now grout the hole as the probe is withdrawn from the soils.

Figure 10: STATUS OF CONE PENETROMETER TESTING DEMONSTRATION AT HANFORD

- Operated by Applied Research Associates, South Royalton, Vermont
- Conducted first phase in September 1991
- Tested in coarse-grained sands and granule to boulder gravels
- Conducted 13 penetration tests at eight locations within a 20-km^2 area
- Achieved depths >3 m in six of the tests, each at a different location
- Reached a maximum depth of 20 m
- Used to install a permanent soil-gas monitoring probe at 20-m depth near one of the disposal sites
- Conducted soil-gas sampling using the cone penetrometer
- Tested grouting techniques
- Scheduled second phase for summer 1992

Figure 11: BENEFITS OF CONE PENETROMETER TESTING

- Brings no material to surface
- Uses no drilling fluid
- Minimizes contact of equipment and personnel with contaminants
- Promises to be faster and cheaper than conventional borehole drilling
- Measures continuous data with depth
- Performs in situ measurements
- Delineates very thin layers

Figure 12: Determining the identity and distribution of VOC in the subsurface is critical to the design and operation of the vapor extraction system (VES). Currently, there is no technology at Hanford for routinely collecting in situ soil-gas samples during borehole drilling. Instead, soil samples that are brought to the surface may be screened at the drill site with a photoionization device or transferred to containers for subsequent analysis. However, VOC may easily escape from the sample due to disturbances during drilling, sample retrieval, and/or sample handling.

The SEAMIST system is designed to collect in situ soil samples and air permeability data while drilling. This system consists of an impermeable membrane, deployed down a borehole. As the membrane is lowered into the borehole, it presses against the borehole wall with the effect of a continuous packer. A small sample line allows extraction of vapor to the surface for analysis. As the gas is withdrawn, the flow rate, the pressure at the flowmeter outlet, and the withdrawal zone pressure are measured. These data can be used to calculate air permeability. The alternative to the SEAMIST system would be a conventional packer assembly.

Figure 13: STATUS OF SEAMIST DEMONSTRATION AT HANFORD

- Designed and built by Science & Engineering Associates, Santa Fe, New Mexico
- Tested spring - summer 1992
- Designed for use in cased boreholes in between drilling runs
- Deployed in boreholes 6 to 12 inch diameter
- Deployed to depths up to approximately 200 ft
- Used to collect in situ soil gas samples
- Proposed disposable membrane will reduce decontamination requirements
- Will be used with other sensors

Figure 14: BENEFITS OF SEAMIST

- No drilling rig or hoist required
- Only 1-2 people needed to place and operate
- Minimizes exposure of users

Figure 15: Supercritical fluid extraction (SFE) technology is being tested for analysis of non- and semi-volatile organic co-contaminants disposed with carbon tetrachloride. Their presence in subsurface soils may alter the effectiveness of monitoring and remediation strategies; therefore, methods are needed for their detection in soil samples. Currently, analysis of these contaminants requires solvent extraction and liquid chromatography techniques. These methods generate secondary wastes, are time consuming, and are costly. SFE is an available technology that may provide a faster , low cost alternative for characterization when integrated with appropriate detection systems. These systems are undergoing evaluation for applicability to these organic co-contaminants. They will be integrated into a field transportable detection (FTD) system for rapid field analysis.

Figure 16: STATUS OF SUPERCRITICAL FLUID EXTRACTION/FIELD-TRANSPORTABLE DETECTION DEMONSTRATION AT HANFORD

- Initial studies have shown that TBP and DBBP can be extracted from a TBP- and DBBP-amended Hanford soil in 15 minutes using CO2 as the supercritical fluid
- Detection of 80 ppm TBP in a supercritical fluid extract from Hanford soil using IR spectroscopy.
- SFE and FTD evaluation will continue.
- Field demonstration scheduled for FY 1993

Figure 17: BENEFITS OF SUPERCRITICAL FLUID EXTRACTION/FIELD-TRANSPORTABLE DETECTION

- Minimize generation of secondary waste
- Relatively rapid
- Field screening method for non- and semi-volatile organic compounds

Figure 18: An unsaturated flow apparatus (UFA™) developed by Washington State University is being tested for the measurement of transport parameters. Transport properties of VOC and co-contaminants are necessary for defensible model predictions of the migration of VOC and water in the arid subsurface. This information is site specific and traditionally requires long (>3 months), costly, and difficult experiments. Application of UFA circumvents these problems by allowing rapid achievement of steady-state unsaturated flow conditions in soils/sediments through the use of centrifugal force and precision fluid flow. Acquisition of data requires hours to days rather than months to years.

Figure 19: STATUS OF UFA DEMONSTRATION AT HANFORD

- Obtain and prepare samples FY 1992
- Initial transport characterization of single phase/single component arid soils in FY 1992
- Characterization of soil chemical, physical, and mineralogical properties in FY 1992
- Initial transport characterization of multiphase/multicomponent arid soils in FY 1993

Figure 20: BENEFITS OF UFA

- Acquires data rapidly
- Measures undisturbed samples
- Tests remediation strategies in the laboratory under field conditions prior to field testing
- Determines the effects of multiphase/multicomponent systems on the migration of VOC's and water

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