TECHNOLOGY DEVELOPMENT TO CLEAN UP CONTAMINATED SOIL AND GROUNDWATER

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ABSTRACT

Contamination of soils and groundwater is one of the most pervasive environmental restoration challenges in the Department of Energy (DOE). In the Eastern United States, where rainfall is more abundant, organic, radioactive, and heavy metal waste elements have been transported, causing contamination of the soil and groundwater usually found close to the land surface. In the more arid Western United States, lack of precipitation may reduce transport by the water mechanism; wind erosion and unsaturated vapor transport, however, pose equally challenging cleanup situations.

INTRODUCTION

This paper will describe DOE's general approach to demonstrating and developing technologies necessary to address the problems associated with the cleanup of organics, radionuclides, hazardous heavy metals, and mixed waste. To meet the 30-year time frame for cleanup of these contaminants at DOE facilities, several aggressive integrated demonstrations have been initiated. These demonstrations are primarily designed to stimulate the development and demonstration of faster, cheaper, better, and safer cleanup technologies to support the DOE environmental restoration efforts. Integrated demonstrations are cost-effective mechanisms that assemble groups of related and synergistic technologies to evaluate their performance individually, and most importantly, as part of complete systems for resolving specific environmental restoration and waste management problems existing in the DOE complex.

The group of integrated demonstrations organized in this category of environmental restoration is mobilized by needs to demonstrate cost-efficient, achievable means of cleaning up vast areas of contaminated soils and groundwater existing in the DOE weapons complex. The overall objective is to validate cleanup technologies for DOE implementation by demonstrating effectiveness, cost savings, risk-reduction potential, reduced waste generation, and enhanced ability to meet DOE's 30-year goal, consistent with regulatory requirements and public acceptance.

The four integrated demonstrations currently being implemented include (1) Cleanup of Volatile Organics in Non-arid Soils and Groundwater, (2) Cleanup of Volatile Organics in Arid Soils and Groundwater, (3) Cleanup of Plutonium-Contaminated Surface Soils (arid site), and (4) Cleanup of Uranium-Contaminated Soils (non-arid site). To date, the degree of progress differs for each of the demonstrations, depending on their stages of development. The planning and implementation stages of each of the integrated demonstrations are briefly described below in the individual project descriptions in this paper.

Cleanup of Volatile Organics in Non-Arid Soils and Groundwater

This Integrated Demonstration was DOE's first. Planning for the demonstration's activities is coordinated through the Savannah River Operations Office and began in October 1989. The initial objectives of this demonstration are to (1) develop, demonstrate, and compare technologies for remediation of volatile organics [e.g., trichloroethylene (TCE), tetrachloroethylene (PCE)] in soils and groundwater; (2) span the cradle-to-grave requirements from characterization and remediation to closure and monitoring; and (3) develop an integrated demonstration protocol as a basis for planning future integrated demonstrations. The approach involves the use of directional drilling techniques (horizontal wells) with physical, chemical, and biological remediation technologies. This integrated demonstration approach also provides for the evaluation of an array of newly developed characterization and monitoring methods from across the DOE complex and private industry.

The remediation of volatile organics is one of the top DOE environmental issues. Large cost reductions are anticipated through implementation of new technologies for remediation, characterization, and monitoring. Savings in development costs can also be attributed to the integrated demonstration approach. The in situ cleanup technologies being developed for the cleanup of the solvent contamination have applicability at other major DOE sites. Additionally, the characterization and monitoring technologies (e.g., fiber optic sensors and the cone penetrometer) are applicable at many sites and have the potential to significantly reduce costs for analytical sampling and monitoring well construction.

The demonstration's first phase involves evaluating an in situ air stripping process. Volatile contaminants (both TCE and PCE) were purged from the contaminated soil and groundwater by injecting air in a horizontal well installed below the contaminated aquifer and soil and extracted through a vacuum-extraction horizontal well installed in the vadose zone. The initial results show a consistent increase over comparable operations with vertical wells and maintenance of substantial removal through weeks of deployment. During this first field application, baseline characterization data on hydrogeology, geochemistry, and microbiology were accumulated, along with comparative data from coring techniques and monitoring well approaches (i.e., standard drilling and Hydropunch). In this integrated effort, standard monitoring techniques will be compared to new approaches in tomography and in situ groundwater flow measurements.

The next planned phase involves in situ bioremediation using stimulation of indigenous microorganisms to degrade TCE and employs directional drilling techniques as a delivery system for nutrients (principally methane) to the contaminated zone. Methane has been demonstrated to stimulate selected microbes (methanotrophs) that are capable of degrading TCE. Surface bioreactor treatment of the contaminated off-gas and water will be coupled to the in situ remediation. Again, an extensive monitoring system will be employed to evaluate the results of the biotreatment both in situ and aboveground. Monitoring will also include the development, demonstration, and evaluation of newly developed fiberoptic detectors and innovative sampling devices, regulatory requirements, and public acceptance.

Other plans for this integrated demonstration will include the demonstration of additional horizontal drilling techniques, innovative monitoring and characterization technologies, other in situ remediation techniques, and off-gas treatment systems.

Cleanup of Volatile Organics in Arid Soils and Groundwater

The objective of this integrated demonstration is to develop and compare technologies for removal/destruction of volatile organics (e.g., TCE and PCE) in arid sites. Additionally in keeping with the integrated demonstration philosophy, the experience and lessons learned from the Savannah River non-arid site demonstration will be used. The integrated demonstration is expected to encompass all phases of remedial action from site characterization and preliminary assessment through remediation, to evaluation of effectiveness and monitoring. Control and performance prediction methods must be applicable to arid zones or environments with large vadose zones. The integrated demonstration will survey and evaluate physical, chemical, thermal, biological, electrical, and/or mechanical technologies for characterization, remediation, and monitoring of contaminated soils and groundwater in arid environments. All regulatory and permitting requirements will also be addressed as a prime segment of the demonstration.

Characterization technologies will concentrate on reducing costs and schedules for sampling and analysis and reducing disturbance of the site. Remediation technologies will concentrate on degradation of organics to innocuous commodities, such as carbon dioxide and water; elimination or reduction to permissible limits of chemical toxicity; extraction of chemical constituents for treatment; and stabilization and segregation of the contaminants from the biosphere. Remediation techniques will focus on cost reduction without creating ancillary waste streams. The rationale for the demonstration is a function of the high level of concern for the environmental restoration of soils and groundwaters contaminated with organic solvents throughout the DOE system. Benefits arise from the applicability of these new technologies to priority cleanup needs at Richland, Idaho, Los Alamos, Pantex, Rocky Flats, Lawrence Livermore National Laboratory, Sandia National Laboratory, other DOE sites, and other Federal agencies (e.g., National Aeronautics and Space Administration, Department of Defense).

The integrated demonstration will be conducted through the Richland Operations Office (RL) at a Hanford carbon tetrachloride release site. The object of this integrated demonstration is the development and comparison of technologies for the characterization/removal/destruction of volatile organic constituents (e.g., CCL4, TCE, and PCE) at arid sites. Development and field validation of control and performance prediction methods applicable to arid climates or locales with large vadose zones are also vital considerations in the conduct of the integrated demonstration activities.

Cleanup of Plutonium-Contaminated Surface Soil

The integrated demonstration will initially concentrate on restoration of one of the safety shot sites within the Nevada Test Site (NTS). Safety shot sites are typically contaminated on the surface with plutonium and/or uranium; typically 90 to 95% of the activity resides in the top 5 cm. In the cleanup operation, selective removal of soil and vegetation will be made using techniques that reduce the volume of contaminated materials to be removed with possible replacement of the coarser uncontaminated particles on the original surface to serve as a protective cover to prevent future wind erosion of the newly exposed surface. Studies will be conducted on revegetating the site to rehabilitate the fragile ecology of desert ecosystems. A gravimetric separation process was developed and tested at Johnston Atoll which achieved a 95 to 98% volume reduction of plutonium contaminated coral; pilot equipment is now at NTS and is available for further evaluation and potential modification.

In addition, other techniques, such as wet screening, magnetic separation, centrifugation, or hydrocycloning, will be evaluated depending on the soil type and physical characteristics of the plutonium. Limited studies of nuclear shots in NTS have shown that plutonium contamination is present in certain size fractions, mainly as fine plutonium (Pu) oxide particles. At Rocky Flats investigations have shown that the plutonium, though occurring as fine particles in the waste, has chemically aggregated into granules of much larger sizes than the initial particle sizes. These existing situations support the concept of integrated demonstration, which would result in information useful for application at other NTS and DOE sites.

The contaminated soil particles removed from the surface must be disposed of so as not to create a new potentially hazardous site. In this regard, regulatory requirements would dictate the specific method to be used. While consideration is being given to traditional methods, including cementation and impermeable cover, advance techniques of in situ vitrification will also be explored.

Perhaps one of the more difficult challenges is to restore the cleaned site to its original ecosystem. Restoring the vegetation in the harsh environment, with limited water and without its original surface, requires careful management. Removal of the surface soil results in exposing the less productive subsoil; previous studies have shown that the subsoil remaining is less permeable to water than the original surface horizon, making the soil subject to erosion and compaction. In addition, young vegetation is attractive to wildlife, such as rabbits, and the plants are stripped of their tender leaves during the active growing season. Earlier studies that have provided valuable information on the requirements for revegetation, effective methods to improve water infiltration, such as returning the coarse noncontaminated particles to the surface, and surface soil treatment to improve plant growth potentials, are all being considered.

All cleanup efforts must be followed with a reliable monitoring system to establish successful remediation. The type of system to be employed will depend on the requirements for cleanup levels and the techniques used. Thus, the combined and coordinated efforts of characterization, cleanup with volume reduction, ultimate disposal of the contaminants, restoring the site to a sound ecologic system, and documenting the safe long-term cleanup of the contaminated site typify the integrated demonstration concept.

Cleanup of Uranium-Contaminated Surface Soil

The objective of this integrated demonstration program at Fernald is to develop and demonstrate remediation methods for soils contaminated with uranium. The integrated demonstration is being coordinated by the Oak Ridge Operations Office. Remediation techniques for the cleanup of large areas contaminated with uranium will be evaluated for removal efficiency, economic feasibility, risk reduction, and waste minimization. Traditional methods for remediation of radionuclide-contaminated soils, such as excavation, transportation, and permanent storage, are costly (i.e., estimates have been formulated of approximately \$700 or greater/yd^3 depending on site and conditions) due to the large volumes of soil to be removed. The demonstration will span the "cradle to grave" phases involved in an actual cleanup, addressing all regulatory and permitting requirements and expediting future selection and implementation of the most appropriate technologies to show immediate and long-term effectiveness for all DOE sites. The demonstration will complement the demonstration for Pu contamination being conducted by DOE-Nevada Operations at the Nevada Test Site.

The Feed Materials Production Center (FMPC), located in Fernald, Ohio, was chosen as the site for the integrated demonstration involving cleanup of uranium-contaminated soils due to off-site contamination and to address the concerns of the State of Ohio. Additionally, remediation technology information will be beneficial and may be transferred to the Oak Ridge, Portsmouth, Paducah, Idaho, Savannah River, and Richland sites for cleanup of radionuclide-contaminated soils. The primary problem that exists at the FMPC is widespread soil contamination with radioactivity, predominantly depleted uranium.

The prospective demonstration site at FMPC is an area of contaminated soils adjacent to the solid waste incinerator located at the northwest corner of the sewage treatment plant. This incinerator was operated from November 1954 through December 1979 and was used to burn contaminated and uncontaminated burnable trash. The importance of remediation for this site is that most of the contaminated soils are outside the fenced boundary of the sewage treatment plant and the site has been used primarily for grazing dairy cattle by a neighboring farmer through a lease agreement with DOE (i.e., DOE-owned land). Remedial Investigation (RI)/Feasibility Study (FS) soil and core sampling data were collected; results showed that the highest concentrations of uranium were exhibited in the immediate vicinity of the incinerator, and the apparent plume extended toward the northeast, which is the most probable wind direction. Additionally, limited data from core samples for this area, down to 7 ft, suggest that contaminant particle sizes are small enough (or soluble enough) to penetrate into the soil and may be adsorbed to the clay in the soils. The data also suggested that in some areas no remediation is necessary, while other samples showed that remediation may be necessary down to 1 ft, and in other areas down to 6 ft (probably due to fissure flow). In addition, physical cleanup techniques that may work in arid, sandy soils may not work well in the fine, clay soils that exist at the FMPC site due to the uranium's being chemically exchanged on the soil as opposed to discrete Pu particles in the Nevada Pu demonstration. Soil samples will be sent by FMPC to Nevada to determine the effectiveness of a gravimetric separation process (AWC process) for remediation of Fernald soils. Remediation techniques based on chemical removal (extraction) or desorbing radionuclides (uranium) from the soils may be required.

Additional characterization work is required for determining the actual chemical form of uranium and the binding mechanism by which uranium is adsorbed to clay containing soils. A planning group has been formed, and all DOE field offices have been invited to bring similar needs and potential team members to this project. A Technical Task Plan has been written, and samples will be taken at a later date for additional characterization purposes. The FY 1991 mission is to plan and implement the integrated demonstration. This project will grow aggressively in FY 1992.