The Challenge of Moving Science into Practice: Lessons Learned and New Approaches – 16443

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ABSTRACT

Remediation of residual subsurface soil and groundwater contamination remains a significant problem facing the U.S. Department of Energy Office of Environmental Management (EM). EM has completed cleanup activities at many of their sites, however, many of the remaining sites are technically complex, either due to the nature of the contaminants or to the nature of the subsurface environment. Often these complex sites require supporting scientific studies to resolve key technical uncertainties.

A key challenge is the difficulty in efficiently moving advancements from basic and applied science research studies to field applications to address key technical needs. The successful transfer of technologies from the laboratory to the field generally benefits from an overt structure that combines the results of scientific studies with professional judgement to translate them into actionable practice. The process requires a 'connecting of the dots', e.g., bringing the best science and technical judgement to real and measureable improvements to baseline remedial activities.

INTRODUCTION

The mission of the U.S. Department of Energy, Office of Environmental Management (DOE-EM) is to complete the safe cleanup of the environmental contamination legacy brought about from five decades of nuclear weapons development and government-sponsored nuclear energy research. The EM program has made significant remediation progress and has embraced a mission completion philosophy based on reducing risk and environmental liability. As an established, operating cleanup, completion and risk reduction program, EM is demonstrating the importance of remaining steadfast to operating principles while staying focused on the mission. Current programmatic goals include:

- EM is constructing and operating facilities to treat radioactive liquid tank waste into a safe, stable form to enable ultimate disposition.
- EM is securing and storing nuclear material in a stable, safe configuration in secure locations to protect national security.
- EM is transporting and disposing of transuranic and low-level wastes in a safe and cost effective manner to reduce risk.
- EM is decontaminating and decommissioning facilities that provide no further value to reduce long-term liabilities and maximize resources for cleanup.
- EM is remediating soil and groundwater contaminated with the radioactive and hazardous constituents.
- EM is fulfilling its commitments to reduce risk and complete cleanup across all sites for the generations to come.

- EM is planning for a DOE long-term management and storage facility for U.S. elemental mercury.

A challenge to successful resolution of these complex technical issues will be effective and efficient transition of basic and applied science research breakthroughs to the field to address site needs. DOE-EM recognizes that innovative technologies offer the potential to improve operational performance, accelerate schedule, and reduce costs for remaining environmental cleanup. A concern that often limits the acceptance of new technologies is the lack of information about their performance in real-world conditions, especially in the harsh radiological and chemical environments that exist at many DOE-EM sites.

Documented successes from the last three decades of EM technical innovation suggest that specific strategies can be used to translate scientific advances that address key technical uncertainties into actionable practice in the field. In this context, the successful transfer of technologies benefits from the application of an overt structure that combines the results of science studies with experienced professional judgement throughout the technology development process to transfer them into real and measureable improvements to baseline remedial activities.

METHODS

DOE-EM has identified key issues/challenges that site operations currently face and is focusing technology development efforts on addressing these issues – specifically, issues associated with the remediation of facilities, and soils and groundwater contaminated with Technetium (Tc-99), Mercury (Hg), Cesium (Cs-137), Strontium (Sr-90). Additionally, DOE-EM has identified that advanced robotic and remote sensing techniques offer the potential for increasing operational efficiency, reducing personnel exposures and enhancing safety. Operational drivers and detailed technical issues are being summarized in a series of technical roadmaps [1,2].

A key resource that is needed to manage efficient technology development is a process that provides access to well characterized, representative test beds where innovative technologies can be field tested under real-world conditions since most of these problem cannot be duplicated in the laboratory. Test beds can be viewed as field-scale, meso-scale, or lab-scale facilities or assets for the replicable testing of technologies and tools, with special emphasis on “real world” physical and chemical conditions.

Figure 1 shows a test bed strategy that we believe will facilitate rapid incorporation of solutions to the documented needs. This process begins with a careful identification of high priority needs, e.g., Technetium (Tc-99), Mercury (Hg), Cesium (Cs-137), Strontium (Sr-90). A series of workshops was held in late 2015 that brought together resources from a variety of DOE-EM and non-DOE sources to develop a specific strategy to address key contaminants. For example, management of technetium (Tc) is a high-priority activity, especially in the areas of waste management and remediation with problems that are unique to DOE-EM. A technetium management plan was developed that lays out the technology development activities as well as future technology needs that have to be developed [1]. This Plan addresses technetium issues across DOE-EM sites and across programmatic areas of tank waste, groundwater and soils, and facility decommissioning and deactivation in order to be comprehensive and to allow integration of similar activities. The Plan was developed in close coordination with site representatives and program offices. In the Plan, specific development of priority activities, based on specific goals and success criteria that will require the testing and evaluation of new technological approaches, are presented. This approach allows for strategic selection of technologies to meet high priority needs.

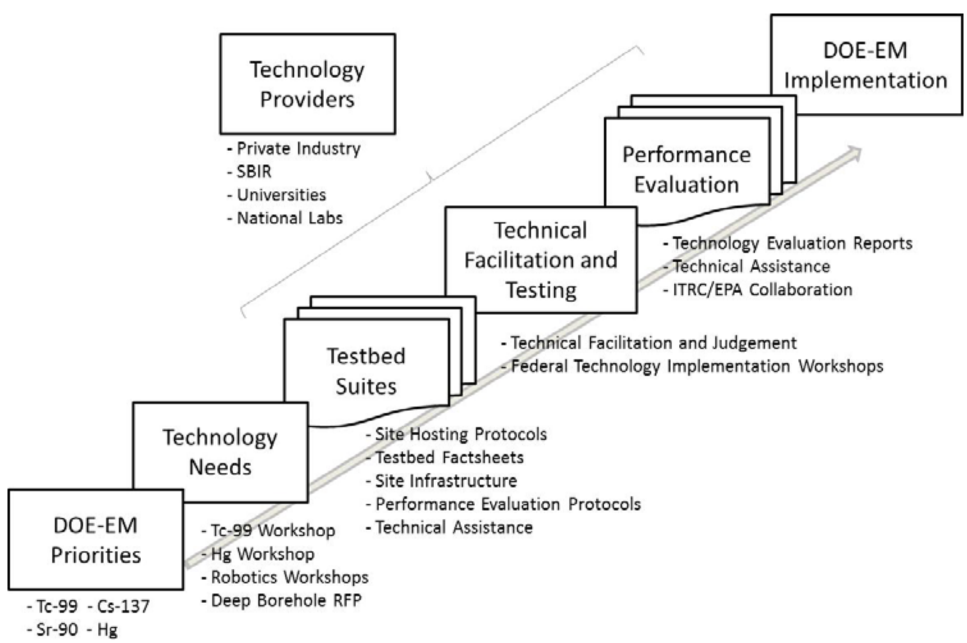


Figure 1. Schematic Showing Proposed Technology Implementation Process

A key process to streamline technology development is access to well characterized and representative test beds throughout the development process. The testing of technical strategies in consultation with site resources using realistic test beds at different scales, i.e. lab and field, in well characterized test beds that represent the complexity found in real applications is critical. We propose the use of a number of test beds at a variety of scales, laboratory to field-scale that will allow for realistic testing and evaluation throughout the technology development process. These test beds will be supported by documentation and infrastructure including DOE-EM site hosting protocols, access and operating procedures, and test bed descriptions/fact sheets that can be made available to describe site attributes and supporting infrastructure such that potential innovative technologies can be aligned with applicable test beds.

Documentation and preservation of testing data and knowledge is also important. As DOE-EM solves problems, it is important to preserve the record of technology development for future generations. For example, in the 1990's, DOE-EM funded a variety of technology development programs. These technologies were tested and implemented at a number of test beds through the DOE complex. At that time, DOE-EM developed the Innovative Technology Summary Report (ITSR) as the standard format for reporting technology evaluations from field demonstration. The purpose of these Innovative Technology Summary Reports was to document information that users would need to consider a technology for a particular environmental management application. These reports identified the range of problems that might applicable for a given technology, system or process and potential advantages to the DOE-EM in terms of system performance, cost, and/or cleanup effectiveness. Also considered was comparison to baseline technologies as well as other competing technologies. It is important to maintain a similar strategy for documenting evaluation results as well as to provide a mechanism to promulgate these results to other federal agencies and preserve them as a resource for the future. Consideration of web publishing of the new evaluations is encouraged as well as a federal interagency team to evaluate and publish previously developed ITSR's thus preserving a record of past activities for the federal complex.

Another key component of successful technology implementation is the knowledge transfer of technology successes to other entities. An overt structure needs to specified and funded that allows dynamic and efficient national technical assistance program to recommend strategies to address challenging environmental problems. Historically, DOE-EM, via the Savannah River National Laboratory (SRNL) and the DOE National Laboratory family, has provided teams of nationally recognized experts to support rapid and effective transfer of the state of the art to specific high priority problems. Since 2006, 25 DOE-EM sponsored teams have visited 11 DOE sites and made recommendations that yielded an estimated cost savings of $100M.

Discussion

Use of Test Beds at the SRS F-area

The F-Area Hazardous Waste Management Facility at SRS consisted of three unlined, earthen surface impoundments referred to as seepage basins. From 1955 through 1988, the F-Area seepage basins (FASB) received approximately 1.8 billion gallons (7.1 billion liters) of low-level waste solutions (Figure 2). The effluents were acidic and low activity waste solutions containing a wide variety of radionuclides and dissolved metals. Currently, the main risk drivers for the groundwater are Sr-90, uranium isotopes, I-129, tritium, and nitrate. An innovative treatment that uses a passive funnel-and-gate with *in situ* treatment zones has been successful for treatment of uranium and metals but anionic contaminants such as I are not impacted by this remedial strategy.

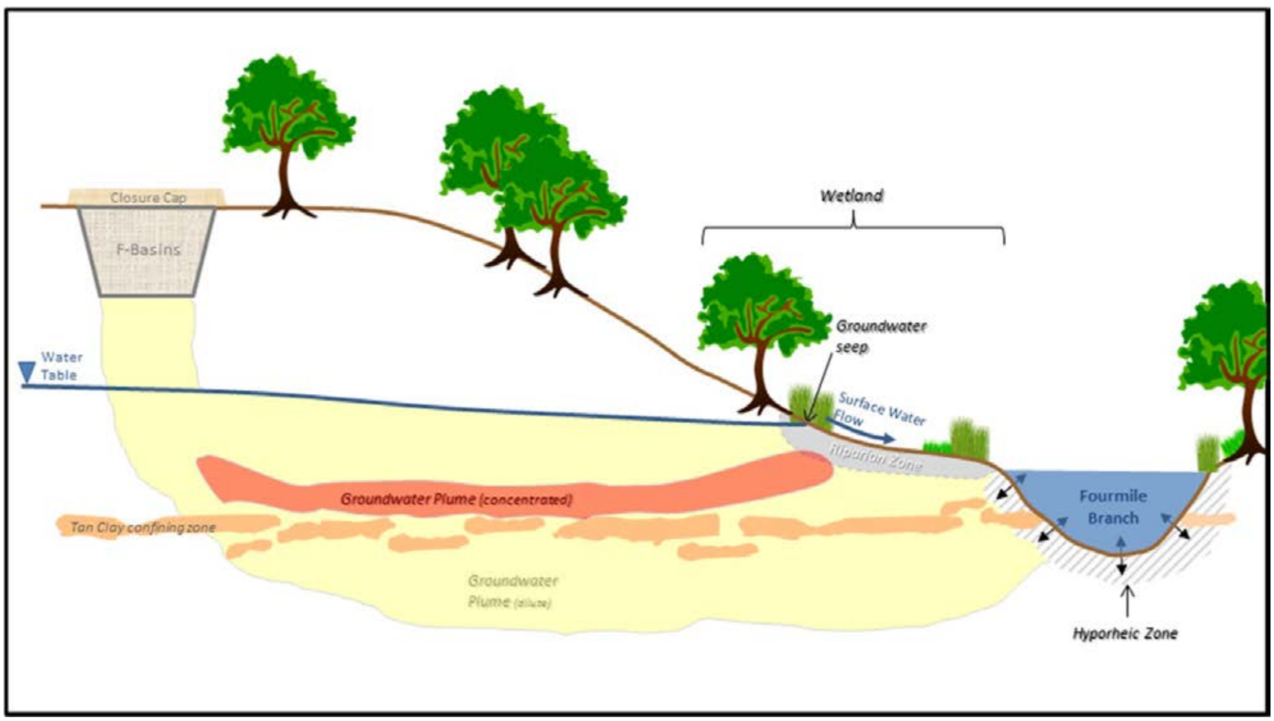
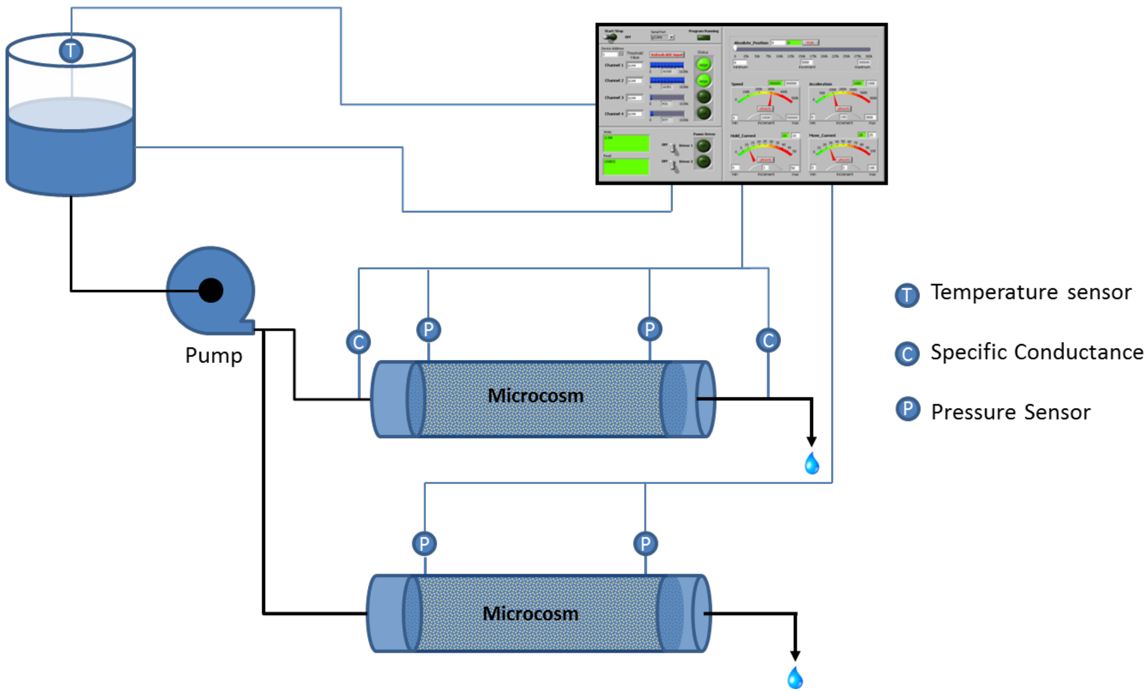


Figure 2. Cross Sectional Conceptual Model showing contaminant flow at the F-area test bed

Scientists at the SRNL developed a strategy to address treatment for ^{129}I contamination in groundwater. The successful approach used a phased strategy that combines laboratory analysis with the use of the F-area test bed. The initial laboratory studies performed by SRNL suggested that injection of silver chloride (AgCl) particles into the aquifer may provide an effective solution to retard or stabilize the ^{129}I in place. The low solubility AgCl particles when injected into the treatment zone should slowly dissolve and react with natural iodine and ^{129}I causing them to precipitate as lower solubility silver iodide (AgI). A series of laboratory tests were performed to provide proof of concept followed by testing in the laboratory with sediments for the F-area site. The laboratory tests were followed by a small-scale field demonstration of AgCl particles injected into the subsurface through well screens. It was determined that the chemistry of the technology was effective, but injected particles did not travel more than a few meters into the formation. Following these experiments, the Environmental Compliance and Area Completion Projects (EC&ACP) did two field injections in F-Area with AgCl in 2011 and 2015 with a cone penetrometer (CPT) to maximize distribution of AgCl particles in the subsurface at a lower cost than injecting through permanent well screens. At a given location, the CPT tip was driven to a target depth, retracted 5 feet, and the diluted AgCl amendment was injected into the void space created by the retraction. The initial phase of field testing was successful but follow-up studies suggest that widespread distribution of AgCl particles is still an issue as the particles tend to settle out or be trapped near the injection point. Laboratory column experiments and batch dispersant tests are currently being conducted to investigate enhancements that would produce a better distribution of AgCl in the subsurface in an effort to immobilize more ^{129}I. One enhancement to this technology involves precipitation of AgCl particles *in situ* by injecting dissolved silver into the subsurface to react with chloride present in the groundwater. Preliminary batch experiments (with no solids present) have demonstrated the viability of this enhancement [3]. Results from these column and batch dispersant tests will aid in determining whether enhancements to the AgCl technology are viable and if they are viable, how to best design a treatment system.



Technical Assistance -- Mound Operable Unit 1

A key strategy for successful technology implementation is the knowledge transfer of technology successes to other entities. Over the last decade, researchers at the SRNL have been investigating various enhanced attenuation techniques that focus on sustainable enhancements to bridge between active remediation (e.g., pump and treat) to Monitored Natural Attenuation (MNA) for a variety of contaminants including volatile organic contaminants and metals and radionuclides.

At the SRS T-area, in 2008, an active pump and treat system was projected to take 30 years to remediate residual contamination at a cost of $1M/year. SRNL scientists proposed a research approach to transition the active SVE to passive SVE, and designed and implemented a successful innovative enhanced attenuation strategy using emulsified edible oil injected into the plume to form multiple treatment zones coupled with deployment of neat edible oil in vadose zone to form a “water table” barrier and limit impact of residual soil sources. This strategy was successfully deployed in 2008 with a supplemental injection of oil in 2010 at D-area resulting in a cost savings of $10-15M.

In 2013, the DOE Office of Legacy Management (DOE-LM) requested assistance from SRNL to provide technical support to transition the active pump and treat system at the Mound Site in Ohio. At the Mound site, a groundwater pump-and-treat (P&T) system was initiated in 1996 to interdict the plume and a soil vapor extraction system (SVE) was installed and operated from 1997 to 2003 to remove the VOC sources from the vadose zone. Physical removal of the landfill waste and contaminated soil was performed between 2006 and 2010. The groundwater P&T system operation continued throughout this period. During the remediation timeframe, monitoring of residual contamination included standard groundwater monitoring.

In 2013, DOE-LM wanted to investigate the possibility of transitioning to a more passive system. SRNL provided technical assistance to provide a technical justification and strategy to deploy a passive remedial strategy at the site. A number of innovative characterization campaigns designed to assess the contaminant and biogeochemical conditions in the subsurface at OU-1 [4}. For example, in 2013, an integral pumping test (IPT) was performed to characterize the amount (mass) of the low-level VOCs in groundwater. Soil and groundwater were also collected to obtain site-specific data to determine if the geochemical conditions supported natural attenuation processes. Contaminant and hydrogeologic data collected from this study, as well as historical data were evaluated to identify the distribution and potential sources of VOCs, refine the hydrogeologic description, update the conceptual model of VOC fate and transport, and determine if MNA was a viable option to address VOCs in groundwater.

Given the positive results of the characterization, DOE-LM and the regulator Core Team determined the MNA should be viable and proceeded with a treatability study. The combination of technologies deployed in late 2015 include: (1) neat (pure) vegetable oil deployment in the deep vadose zone in the former landfill area and (2) emulsified vegetable oil deployment within the footprint of the groundwater plume. When injected the neat oil spreads laterally and forms a thin layer on the water table beneath residual soil sources to intercept and reduce future cVOC loading and reduce oxygen inputs to the local groundwater. The emulsified oil forms active bioremediation treatment zones within the plume footprint to degrade existing groundwater contaminants (via reductive dechlorination and/or cometabolism) and stimulates long-term attenuation capacity in the downgradient plume (via cometabolism). These activities will accelerate the progress of the Mound OU-1 toward remedial goals and convert the current active P&T remedy into a passive attenuation-based remedy that represents a cost-effective finishing step in a phased remedial strategy.

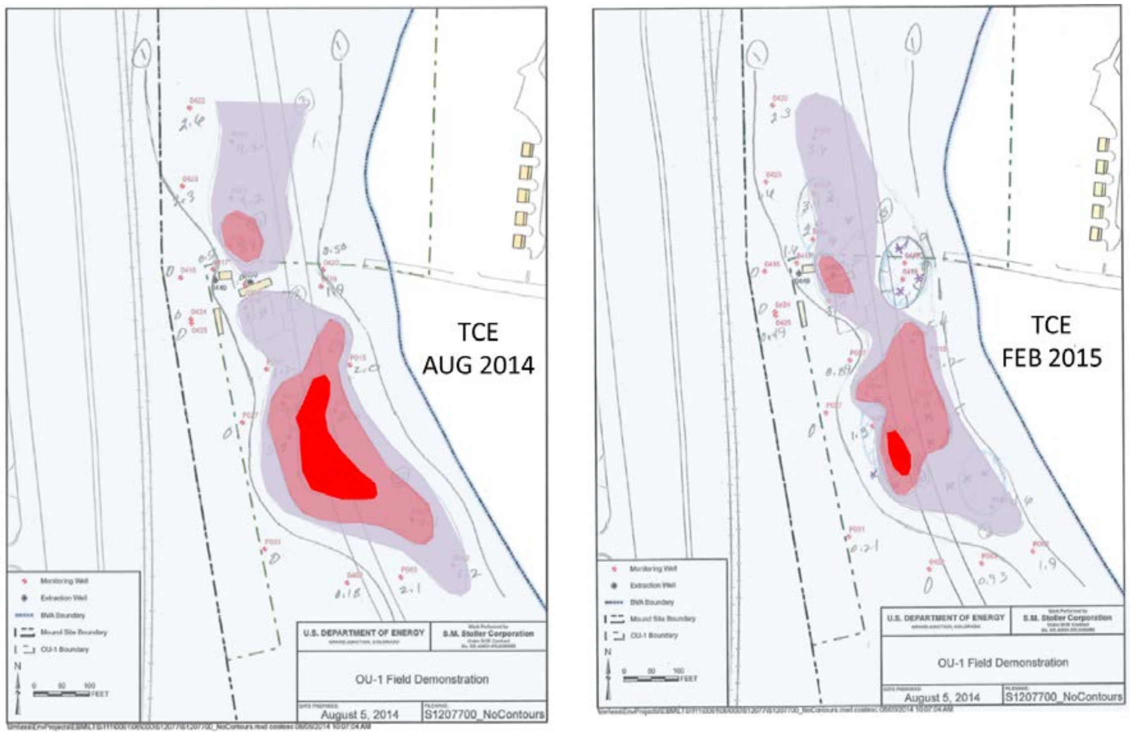


Figure 4. TCE distribution at the Mound sited before and after oil injection [5}

To date, the performance of this “phased-combined remedy” has resulted in significant reductions in the concentrations of VOCs in the groundwater. In 2013, for example, the TCE in all wells was less than 40 ug/L with a plurality of the wells near or below MCLs. The generally observed declining concentration trends and low 2013 concentrations represent the net impact of source removal actions, pump and treat operation and natural attenuation.

The technical support provided by SRNL allowed the DOE-LM to quickly and efficiently implement an innovative strategy within the existing regulatory structure. The participation of SRNL in the Core Team meetings provided an independent technical voice that allowed for preliminary testing and acceptance of an ‘out of the box’ strategy.

CONCLUSIONS

We believe that this tiered process can be used to strategically transfer applied science studies from the laboratory into actionable practice in the field. The process brings the best science and technical judgement to real and measureable improvements to baseline remedial activities. The utilization of selected technology test beds provide a needed mechanism for innovative technology providers to focus and prove their techniques and strategies under real world conditions thus improving their contribution to helping resolve key issues and challenges currently facing various DOE-EM site operators.

REFERENCES

1. *Technetium Management Program Plan,* Department of Energy, Office of Environmental Management, dated December 2015.
2. *Draft Integrated Research and Technology Development Plan to Address Mercury-Related Challenges in EM's Mission,* Department of Energy, Office of Environmental Management, dated December 2015.
3. *Results of Preliminary Experiments on In Situ Precipitation of Silver Chloride for Treatment of 129I Contamination in Groundwater. Denham, M.E, Shehadeh, A, and Millings, M.E., SRNL-STI-2015-00516, dated September 2015.*
4. *Field Demonstration Work Plan for Using Edible Oils to Achieve Enhanced Attenuation of cVOCs and a Groundwater Exit Strategy for the OU-1 Area*, dated July 2014