HISTORICAL PERSPECTIVE ON SUBSURFACE CONTAMINANTS FOCUS AREA (SCFA) SUCCESS: COUNTING THINGS THAT REALLY COUNT

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ABSTRACT

The Subsurface Contaminants Focus Area, (SCFA) is committed to, and has been accountable for, identifying and providing solutions for the most pressing subsurface contamination problems in the DOE Complex. The SCFA program is a DOE end user focused and problem driven organization that provides the best technical solutions for the highest priority problems.

This paper will discuss in some detail specific examples of the most successful, innovative technical solutions and the DOE sites where they were deployed or demonstrated. These solutions exhibited outstanding performance in FY 2000/2001 and appear poised to achieve significant success in saving end users money and time. They also provide a reduction in risk to the environment, workers, and the public while expediting environmental clean up of the sites.

Examples of the technical solutions include Dynamic Underground Stripping with Hydrous Pyrolysis Oxidation, In Situ Redox Manipulation, Lasagna, Passive Reactive Barriers, Enhanced In Situ Bioremediation, and Phytoremediation. The implementation of these technologies in the DOE Site cleanup effort has advanced the baselines for subsurface remediation at many sites and will result in major cost savings, while continuing to lower the risks and expedite the cleanup of problems for DOE, other agencies, and the private sector.

INTRODUCTION

Each year, SCFA and the other DOE-Office of Science and Technology Focus Areas, report their performance in terms of “metrics” established by Headquarters in response to questions from Congress and others responsible forassessing the health and progress of the organization. Thus, SCFA annually counts successes in three required categories: the number of technologies deployed, the number demonstrated, and the number newly determined to be “ready for implementation” by virtue of the publication of an Innovative Technology Summary Report, or ITSR.

Although each of these successes clearly counts for *something*, it is difficult or impossible to judge whether 25 deployments in a given year are as good as, better than, or worse than 5 deployments in another year. It could be that a single deployment last year, or this year, is more important than all deployments, demonstrations, and ITSRs from the last two years, or five years, combined. The aims of replacing old, or no, technologies with new, or breakthrough solutions are to save money, save time, do a better job, and lower risks to workers, the public, and the biosphere. But these benefits are hard to compare across sites and years. There is just no good way to discern relative importance.

But there are some ways to mark absolute importance. One is the creation of a new, or a first, site technology baseline; for sites on the EPA's National Priorities List (Superfund), the inclusion of a technology in a Record of Decision (ROD), either original or amended; and for RCRA sites, the inclusion of a technology in a Part B Corrective Action Permit. The OST program began in 1989 because then-Secretary of Energy Admiral James D. Watkins (Ret.) recognized the need to change the foundation of the business of environmental management. He looked at pump-and-treat, as "muck, suck, and truck," and said, "There must be a better way." OST's predecessor, the Office of Technology Development, came into being to make that hope a reality.

And after a decade or so, which some, impatient for instant results, have thought a slow start—though normally it takes twice as long for new technology to develop and take hold, enough absolute successes have occurred to show that Watkins' hope was well founded. The following discussions highlight SCFA sponsored technologies that have become first or new site baselines for innovative technologies, or that have been approved in regulatory agreements. Note that these two categories may or may not overlap. Note, also, that there are likely more examples to be found in both categories, but that the finding is difficult because sites or RODs or permits may refer to technologies using words that do not necessarily tie to the names used for official tracking of results. Note, finally, that to say that an innovative technology has become "baseline" at a site does not mean that the former baseline technology for a given project or Project Baseline Summary (PBS)—the old "tried and true" or at least fallback solution—has been completely relinquished and put aside. It means that the new technology is a viable *candidate* for such replacement, a candidate that will have to stand the test of time.

A final point. The following vignettes note the official insertion of new technologies at one or a small number of sites. As time makes clear that these and other new ways of doing things really work, and work better, faster, safer, and cheaper than the old ways, they will catch on at other sites. Technical Assistance may well be required to help tailor systems for application where the geology and contaminant matrix is similar, but not identical, to those highlighted here.

In short, what we have here is the clear start of something big.

SCFA ABSOLUTE SUCCESSES: INCORPORATED IN REGULATORY DOCUMENTS AND/OR CANDIDATES FOR REPLACING BASELINE TECHNOLOGIES

Dynamic Underground Stripping (DUS) injects steam into the subsurface to volatilize organic contaminants, especially chlorinated solvents, into the vapor phase. Combining steam injection with vapor extraction allows removal of contaminant vapors. The technology, developed by Lawrence Livermore National Laboratory, is commercially available from Steam Tech Environmental Services, Inc., Integrated Water Resources, and Southern California Edison. DUS offers significantly faster and more complete remediation of chlorinated solvents at substantial cost savings. At the Portsmouth Gaseous Diffusion Plant, DUS became the new baseline after it removed approximately 80% of the estimated TCE mass from the treatment area in six months. In the same year, 1999, the Paducah Groundwater Operable Unit baseline was modified to address source removal using DUS.

DUS is likely to become the baseline at Savannah River also, given its performance at the 321-M Solvent Storage Area, where it has accomplished in one year what it would have taken 60 years to accomplish with pump-and-treat. DUS was incorporated and conditionally approved in the RCRA permit as part of the overall corrective action for the Savannah River M Area Hazardous Waste Management Facility with a one-year operational limit that ended in September 2001. There are future plans to redeploy DUS at the M Area Settling Basin to facilitate removal of DNAPL from the vadose zone. As with the corrective action performed at the 321-M site, modifications to the permit application will be made for inclusion of DUS into the overall Corrective Action Plan.

Passive Reactive Barriers are engineered structures placed in the subsurface to capture an advancing groundwater contaminant plume. Inside the barrier, reactive media, normally zero-valent iron, treat mixtures of metals, radionuclides, and organics. At Rocky Flats, the technology replaced pump-and-treat in 1999 as the baseline approach to remediate the Mound, East Trench, and Nitrate Plumes. Monitoring data indicated that contaminant levels were reduced to non-detectable levels within 1-2 years. Estimated cost savings from the three deployments were about $34 million. The technology was developed by the University of Waterloo, Canada, and can be purchased from EnviroMetal Technologies, Inc.

Deep Soil Mixing uses an auger to break up clay-rich soil and to deliver air, microorganisms, or chemicals for the in situ treatment of organics. The system can be enhanced by adding reactive components, such as air or heat, which increase the effectiveness of the technology. At ANL-E, the addition of iron particles to destroy chlorinated VOCs worked so well that a request was made to modify the RCRA cleanup project at the 317 Area from a removal approach, which risks exposing workers and the general public to chemical hazards, to an in situ treatment approach. The petition was approved by the regulator in 1998, and deep soil mixing was implemented as a replacement for the baseline technology of excavation and disposal. Deep soil mixing was developed by and is available from Geo-Con, Inc., and was demonstrated at DOE sites with SCFA support.

The Heavy Weight Cone Penetrometer is a truck-mounted device that rapidly penetrates the ground to evaluate groundwater and soil contamination. With a conical tip of up to 1.75 inches in diameter that pushes hydraulically into the ground with pressures up to 70,000 pounds, it can advance through fine-grained soil at 40 to 50 feet an hour and has been adapted for use in the gravel/cobble subsurface common to arid sites. At Hanford, the technology reduced cost and worker exposure to radiological and chemical hazards. The technology has the advantage of not generating secondary wastes while drilling and deploying many different state-of-the-art line sampling and instrument devices. The technology was developed by Argonne National Laboratory, Pacific Northwest National Laboratory, and Westinghouse Hanford Company through support from a contract with Applied Research Associates, Inc. and support from SCFA.

Iron Treatment Walls use zero-valent iron (iron filings) to dechlorinate organics in groundwater, in particular TCE, DCE, and vinyl chloride. As distinct from the engineered structure of the Passive Reactive Barrier, in this barrier the filings are placed in a treatment trench where groundwater will flow through them and react with the contaminants. The technology was developed by, and can be purchased from, EnviroMetal Technologies, Inc. It is applicable at any site with dissolved chlorinated organics in an aquifer of suitable depth, aereal extent, and hydraulic conductivity. The Iron Treatment Wall requires no external energy source, no daily operation and maintenance, produces no secondary waste stream, and reduces the long-term mortgage.

The Iron Treatment Wall was installed to replace the baseline technology of pump-and-treat at the Kansas City Plant. The pump-and-treat system had been operating for 10 years and became expensive to maintain and operate. The life cycle cost savings over pump-and-treat are estimated at about $30 million and regulatory closure in about 10 years.

Phytoremediation is a set of technologies for using plants and trees to remove metals or radionuclides from soils, sediments, and water. Among the phytoremediation mechanisms that can be incorporated into a cleanup scheme are evapotranspiration, phytoextraction, phytostabilization, phytostimulation, phytotransformation, or rhizofiltration. Phytoremediation is well suited for removing low to moderate levels of contaminants from large areas of surface soil. It’s an aesthetically pleasing, passive, solar energy–driven cleanup technique that is cost-effective and appeals to the general public.

At Argonne National Laboratory–East near Chicago, willows are used at the 317 French Drain Area to address problems with chlorinated solvent residues and replace the baseline technology of excavation and disposal. At the 319 Area landfill, poplar trees are used for hydraulic control of contaminated groundwater plumes. Basically, the trees are expected to reduce the flow of tritium-contaminated groundwater offsite. In doing so, phytoremediation is used as a hydraulic containment technology, not a treatment technology. The primary significance of phytoremediation at the 317 French Drain and 319 Landfill areas is the cost savings realized during the construction phase.

At four release sites within Waste Area Group 9 at Argonne National Laboratory–West, *Kochia scoparia*, a common weed, and hybrid willows were planted to extract and accumulate cesium-137 and metals from soils in the plant tissues and leaves. The ROD for OU 9-04, signed in September 1998, specified phytoextraction as the preferred remedy due to cost savings stemming from reduced waste volumes. Harvesting of the plants will contribute only 50 tons of waste for landfilling as opposed to excavating and disposing of several thousand tons of excavated soil. After two growing seasons, phytoextraction has shown that it's working faster than the 10-year time limit spelled out in the ROD to demonstrate cost effectiveness. Site personnel expect that remediation goals will be met in two more growing seasons. Although phytoremediation has been used previously to remediate organics from groundwater, ANL-W is the first site where it has been used on soil contaminated with cesium, silver, and chromium.

The Savannah River Site expects the South Carolina Department of Health and Environmental Control to respond affirmatively to its request to add phytoremediation to its strategy for removing tritium from F- and H-Area groundwater.

Enhanced In Situ Bioremediation (EISB) is the process of destroying subsurface contaminants through the use of microorganisms and the manipulation of natural processes, including the injection of air or nutrients or the provision of substrates to stimulate microbial growth and activity. Over the last few years, the technology has been endorsed as a remedial technology for recalcitrant contaminants, such as nonaqueous phase liquids. At the Idaho National Engineering and Environmental Laboratory, a ROD was written and approved by EPA in 2000 for injecting sodium lactate into the aquifer to stimulate bacteria to metabolize the TCE plume at the Test Area North. Scientists expect this application of EISB, which during testing reduced TCE concentrations from 3800 mcg/l to less than 10 mcg/l, to remediate the aquifer within 15 years—a feat up to twice as fast and nearly $23 million less than the originally selected technology of pump-and-treat.

Lasagna™ is a contaminant-source-removal technology that combines soil heating with the movement of water. This combination makes Lasagna the most thorough treatment system available for low-permeability soils, in particular those contaminated with dense nonaqueous phase liquids, such as trichloroethene. Lasagna, which received an R&D 100 Award for being one of the most technologically significant products in 1999, was developed by a private research consortium consisting of Monsanto, DuPont, and General Electric, with support from the Office of Science and Technology (SCFA). It is commercially available from three licensed companies—Geokinetics International, Weiss Associates, and CDM-Federal.

Lasagna is attractive to regulators and stakeholders because it requires less disturbance of the substrate, thereby reducing the risk of cross-contamination at a site. It was selected over the baseline technologies of soil vapor extraction and pump-and-treat as the preferred remedy for the cleanup of Operable Unit (OU) 15—the Cylinder Drop Test Area solid waste management unit at the Paducah Gaseous Diffusion Plant. The basis for naming Lasagna in a ROD, which was completed in August 1998, was the technology's overall effectiveness: more than 98% of TCE could be removed from soil after just three pore volumes of water had been moved between adjacent treatment zones. The remedial action started in 1999 and will run through FY02 before cleanup goals will be reached. In using Lasagna at OU 15, DOE is expected to save more than a million dollars compared to conventional technology.

In-Well Vapor Stripping employs a combination of air-lift pumping and aeration within the borehole of a well to strip volatile organic compounds from groundwater. The water inside the wellbore is aerated by injecting air at the base of the wellbore, creating a turbulent frothing action. The rising air bubbles strip contaminants from the water and carry them in a vapor stream to the surface where they can be treated. Regulators and stakeholders like in-well vapor stripping because treatment can be conducted with only a single well if desired and the technology requires no aboveground handling of contaminated water. Pacific Northwest National Laboratory developed the technology in collaboration with NOVOCs, Inc. It's commercially available through MacTech, Inc.

In-well vapor stripping was detailed in an amendment to the ROD for the Mound Plant in Ohio. EPA signed off on the amendment to incorporate the technology into the high vacuum vapor extraction at OU 1. The technology was also detailed in the request for modification to the 1992 Savannah River Site RCRA Part B Permit Renewal Application, which proposed adding in-well vapor stripping for the Phase I groundwater corrective action at the M-Area Hazardous Waste Management Facility. The South Carolina Department of Health and Environmental Control approved the revision March 2001. Finally, the technology was selected in the ROD for OU 3 at Brookhaven National Laboratory and also in the ROD for the Miscellaneous Chemicals Basin / Metals Burning Pit OU at the Savannah River Site as the preferred treatment over pump-and-treat. In-well vapor stripping is estimated to reduce pump-and-treat costs by 50%.

In Situ Redox Manipulation, a 1998 R&D 100 Award winner, creates a treatment zone within an aquifer for the destruction or immobilization of contaminants. The treatment zone is created by injecting reagents and/or microbial nutrients in the subsurface through groundwater wells to reduce iron molecules present in ferric clays. As the groundwater flows through the treated zone, the reduced iron molecules become sites for the reduction of redox-sensitive metals, radionuclides, and organics. Because the technology is easy to install, inexpensive to operate, and greatly diminishes the risk of human exposure to potentially hazardous materials, in situ redox manipulation is well accepted by stakeholders and regulators. Pacific Northwest National Laboratory developed the technology with SCFA support.

At Hanford, in situ redox manipulation is being used to treat chromium VI in groundwater at the 100-D Area. An interim ROD signed in September 1996, designated pump-and-treat and ion exchange for the 100-HR-03 OU. While the remedy was moderately successful, it did not lessen the risk of the plume migrating off site. A successful demonstration of in situ redox manipulation led to the proposal of using this technology as a remedial option for the full chromium plume. The proposal was accepted, and the technology was deployed in FY 2000 as the preferred remedial technology for 100-HR-03 OU The technology has proven successful and has prevented offsite plume migration. In situ redox manipulation is also estimated to generate cost savings over a 10-year period of $11.5 million over pump-and-treat.

ResonantSonic® Drilling employs a vibratory head with counter-rotating weights to expand and contract a hollow string as it is pushed through the subsurface. The expansion and contraction results in a cutting motion at rates up to 260 feet per day, depending upon the media penetrated. The technology is used to access the subsurface for installing monitoring or remediation wells and collecting characterization samples. The technology is of particular interest to regulators and stakeholders because it provides excellent quality, relatively undisturbed, continuous core samples for characterizing sites and designing subsurface structures. It uses no drilling fluids, so the generation of secondary waste is minimal. ResonantSonic® Drilling was selected as the preferred drilling technology in support of the remedial action for OU 7-10 at INEEL. The technology was developed by private industry with support from SCFA. It is available commercially from ResonantSonic, Inc.

A Permeable Reactive Treatment Wall (PeRT) is a zone of reactive material emplaced in the subsurface to treat and remediate metal- and radionuclide-contaminated groundwater that passes horizontally through it. The technology typically is deployed using a set of impermeable walls to funnel the groundwater into the permeable zone containing the reactive material. The reactive material can be zero-valent iron, amorphous ferric oxy-hydroxide, or some other material known to absorb metals and radionuclides. PeRT is applicable at any DOE site with dissolved redox-sensitive metal, or radionuclide contaminants in an aquifer of sufficient depth, areal extent, and hydraulic conductivity. Sandia National Laboratories developed PeRT, which is commercially available through MacTech, Inc.

PeRT was selected via an interim ROD for OU 3 at the Monticello Mill Tailings Site in Utah to address groundwater and surface water remediation. The ROD was signed in September 1998. PeRT proved promising during treatability studies and was selected over the baseline technology of long-term monitoring because of health and safety concerns associated with the radionuclides and heavy metals found in the water. Performance of the PeRT wall is monitored, and results from monthly and quarterly sampling show that concentrations of arsenic, selenium, uranium, and vanadium have been reduced to near nondetectable levels within the wall. In addition, concentrations of molybdenum and nitrate have also been reduced to near nondetectable levels. At Monticello, PeRT is estimated to avoid costs associated with pump-and-treat of about $ 38,000,000.

Purge Water Management System (PWMS) is an innovative technology for eliminating or significantly reducing purged groundwater generated during routine groundwater sampling events. The technology consists of a butyl bladder contained within a steel tank, a supply system, and a return system connected to the discharge pipe. A submersible pump located within the monitoring well pumps groundwater through the supply system into the bladder. After a sufficient quantity of groundwater has been purged from the well, a protocol groundwater sample is obtained, and the purge water is returned to the monitoring well. The technology was developed at the Savannah River Site, licensed by DOE, and is available commercially through American Waterworks, Inc.

The Savannah River Site detailed PWMS in the request for modification to its 1992 RCRC Part B Permit Renewal Application. The permit modification, which the South Carolina Department of Health and Environmental Control approved in March 2001, was for incorporating PWMSs at hazardous waste management facilities in the M-Area, F-Area, and H-Area. PWMS is of great interest to stakeholders because the technology eliminates the need to containerize and transport purge water to treatment/disposal facilities, thereby minimizing waste, eliminating unnecessary handling of purge water by site workers, and reducing costs. At SRS, cost savings associated with the installation of purge water management systems are estimated to be about $1,000 per well per year.

In Situ Air Sparging and Passive Soil Vapor Extraction is a combination of two technologies that utilizes horizontal wells to deliver air to the contaminants of concern. The system is well suited for remediating groundwater contaminated with volatile organic compounds by effectively simulating an air stripping system in the saturated zone. Recently, it has gained popularity with regulators, stakeholders, and cleanup contractors because its utilization of horizontal wells to deliver air to groundwater creates an infrastructure that can also be used for other remedial strategies, such as thermal treatment techniques. This dovetailing of multiple uses increases remedial technology efficiency and reduces cleanup costs. The in situ air sparging and passive soil vapor extraction technology was developed by the Savannah River Site Technology Center, through which the technology can also be licensed.

In situ air sparging and soil vapor extraction was the selected groundwater remedy identified in the ROD for the C-Area Burning Rubble Pit at the Savannah River Site. The ROD for OU 15 was signed in December 1998. The system was selected over the conventional technology of pump-and-treat because of its increased efficiency and reduced costs. Only about $1 million is needed to install the system, and annual operation and maintenance costs are estimated to be about $250,000. An added value is that injected air not only volatilizes and removes VOCs from groundwater and soil, but also stimulates microbial growth, thereby facilitating aerobic degradation of the organic compounds and significantly increasing the effectiveness of in situ air sparging and soil vapor extraction. This system has also been selected in the interim ROD, signed in April 2000, for the A Area Burning Rubble Pit, where it is now installed and operating.

CONCLUSION

These successes, and others in other focus areas, will assist the Department of Energy in meeting the goal of closing numerous small sites—and some not so small, like Rocky Flats—by the end of FY 2006. Because the Congress and many individual citizens and stakeholder groups have been (understandably) impatient for DOE to get about the business of cleaning up the hazardous and radioactive legacy of the nuclear weapons program, the time between the inception of OST and now seems long. But when we consider that the normal time between the successful demonstration of a new way of doing things and its penetration of the market is about 20 years, we have to say that this part of government has incontrovertibly been doing something right. And this is just the beginning. The conquest of the deep subsurface, in terms both of access and delivery of remediation systems and media, is the big tough nut. We will crack it.