FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
Arlington, Virginia
May 13, 2010

FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
Arlington, Virginia
May 13, 2010

ACTION ITEMS

- ► Comments on the draft 2010 FRTR fact sheet should be sent to John Kingscott or Marti Otto by July 4.
- ► Bill Hagle will contact Paul Edmiston with information about opportunities for third-party data collection and analysis within the Environmental Technology Verification Program.
- ► The U.S. Geological Survey will take the lead in coordinating the Fall 2010 Roundtable meeting agenda with John Kingscott and Marti Otto.

WELCOME/INTRODUCTION

John Kingscott, Chief of the Technology Assessment Branch, Technology Innovation and Field Services Division (TIFSD) in the U.S. Environmental Protection Agency's (EPA) Office of Superfund Remediation and Technology Innovation (OSRTI), welcomed the attendees to the 40th meeting of the Federal Remediation Technologies Roundtable (FRTR). He pointed out that the roundtable has met twice each year since being established in May 1990, and the spring 2010 meeting marks 20 years of cooperation among the FRTR member agencies.

Attendees introduced themselves. Kingscott then provided a brief overview of the agenda and noted that people unable to attend the meeting would be able to monitor the presentations via the Internet.

FRTR ANNOUNCEMENTS AND MEETING OBJECTIVES

Agency Announcements (Projects/Initiatives)

Kingscott drew attention to the draft of the annual fact sheet, which highlights new resources and recent roundtable activities and accomplishments. Comments on the draft 2010 FRTR fact sheet should be sent to John Kingscott or Marti Otto (EPA/TIFSD) by July 4. The following new resources have been posted to the FRTR Web site:

- 10 remediation cost and performance case studies,
- 4 technology assessment reports,
- 7 site characterization and monitoring case studies, and
- 5 long-term monitoring and optimization case studies.

Carlos Pachon (EPA/TIFSD) announced the 2010 meeting on Green Remediation: Environment, Energy, Economics (www.umass.edu/tei/conferences/GreenRemediation/), June 15-17 at the University of Massachusetts at Amherst. Additionally, the Superfund Annual Status Report, which tracks the types of cleanup technologies used at Superfund sites, has been renamed the Superfund Remedies Report, and the 13th edition will be issued shortly.

Mark Schoppet, NASA Remediation Program Manager, said that development of a green remediation team within NASA has just begun. He is looking to the FRTR member agencies for benchmarks and experiences that will help NASA develop guidance for incorporating and implementing green remediation activities.

Erica Becvar, U.S. Air Force Center for Engineering and the Environment (AFCEE), reported that AFCEE held its 2010 Air Force Restoration Technology Transfer Workshop in April. The green and sustainable remediation (GSR), optimization, innovative technologies, and site characterization sessions were among the most heavily attended. The materials from the workshop should be posted on the AFCEE Web site in June. Planning is under way for the 2011 meeting, which will focus primarily on short courses and Air Force policy and guidance. AFCEE will soon post new fact sheets on its Emerging Contaminants page (www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/contaminants/index.asp). The Sustainable Remediation Forum (SuRF) put together six different technical sessions on GSR topics for the Battelle conference (Monterey, May 24-27) on GSR. AFCEE will present two short courses on sustainability tools.

Carol Dona, U.S. Army Corps of Engineers (USACE), said that USACE finalized its interim guidance, *Decision Framework for Incorporation of Green and Sustainable Practices into Environmental Remediation Projects*, in March 2010 and has posted the document on line (www.environmental.usace.army.mil/interim_guidance.htm). The Environmental and Munitions Center of Expertise recently has undertaken the following studies for the U.S. Army:

- Pilot studies on up to 12 different Army sites to follow the process of identifying, considering, and implementing GSR.
- Efficiency of performance-based contracts.
- Remedy optimization.
- Barriers and incentives to site closeout from a risk-based perspective.

Kim Parker Brown, Naval Facilities Engineering Command (NAVFAC), described the Navy's recently posted Green and Sustainable Remediation Web portal (www.ert2.org/t2gsrportal/). A group led by Karla Harre from the Port Hueneme office helped to develop the new Web portal. NAVFAC has an optimization workgroup with participants from all of the field offices. The workgroup plans to update the Navy's GSR guidance and finalize it by the end of the year. Many of the optimization guidance and policy documents also will be updated to incorporate GSR principles. Additionally, training on the SiteWise™ Sustainable Environmental Remediation (SER) Tool, which is run through the Navy's field offices, is scheduled to be offered in the DC area in early June. Anyone interested in the training can contact Kim for information on the course schedule.

Chuck Reeter, Naval Facilities Engineering Service Center, said that Karla Harre has recently been selected to fill his former position as Branch Manager for Technology Applications. She also will transition to fill Reeter's role in FRTR activities.

Elizabeth Southerland (EPA/OSRTI) pointed out that many of the states are currently in budget crisis, which makes it difficult for them to find the 10 percent share of capital costs for groundwater cleanup at Superfund sites, and more so when they must take over 100 percent of the operation and maintenance costs when the sites are transferred from EPA to state oversight. This budget crisis increases the importance of emphasizing optimization of groundwater treatment systems to ensure that operations at the sites EPA transfers to cash-strapped states are as efficient and cost effective as possible. Although EPA's optimization emphasis has so far focused on groundwater systems, new work is under way to expand optimization review to other remedies. In response to interest expressed by EPA's new Assistant Administrator, Mathy Stanislaus, a new interim soil dioxin preliminary remediation goal (PRG) was issued on December 30, 2009 (epa.gov/superfund/policy/remedy/sfremedy/remedies/dioxinsoil.html). EPA accepted comments on the draft dioxin PRGs until April 2, 2010, and plans to issue the final dioxin PRGs by the end of August 2010.

FRTR Subgroup Reports

Helen Dawson (EPA/OSRTI) announced that a new workgroup for vapor intrusion (VI) was launched in March. It is coordinated by Steve Chang (EPA/OSRTI) and meets on the second Thursday of every month. Membership includes the Navy, Hill Air Force Base, the Agency for Toxic Substances and Disease Registry (ATSDR), the Strategic Environmental Research and Development Program (SERDP), USACE, and EPA, as well as the states of California, New York, and Wisconsin. The goal is to expand the VI database and increase knowledge of VI processes and mitigation. A pilot study is proposed that will couple ArcGIS technology with the database to depict data in three dimensions, which should help with the visualization of VI processes and verification of numerical models.

Carlos Pachon reported that green remediation activities are increasing across the agencies and seem to be moving along parallel tracks. The FRTR Subcommittee on GSR will look at common metrics and approaches and useful tools, and regular conference calls will help the subgroup coordinate its efforts. Carlos would like to see more policy-neutral case studies that illustrate how to determine the environmental footprint of different remedies and the actions that can be taken to reduce the footprint. New tools, such as SiteWise™ and Sustainable Remediation Tool™ (SRT), will facilitate this purpose. Two new green remediation fact sheets have been issued on building and operating specific remedies—bioremediation and soil vapor extraction/air sparging (www.clu-in.org/greenremediation/). A draft fact sheet on clean diesel is being coordinated with EPA's Office of Transportation and Air Quality. Carol Dona added that the next workgroup conference call will take place on June 24, 11:00 Eastern time. Current participants will be notified, and anyone not yet involved who would like to participate can contact Carol for the call-in information.

Meeting Objectives

John Kingscott went over the ballot of potential topics for the Fall 2010 FRTR meeting and asked that a representative from each member agency present cast a ballot and return it after the lunch break, with the results to be announced at the end of the meeting.

Kingscott recognized Kim Parker Brown, Carol Dona, Erica Becvar, Beth Moore (U.S. Department of Energy), and Marti Otto and thanked them for their efforts in planning and coordinating the meeting. He then introduced the meeting's technical program moderators: Carol Dona for the first session, Erica Becvar for the second session, and Kim Parker Brown for the final part of the program.

LOW-ENERGY TREATMENT TECHNOLOGIES FOR GROUNDWATER AND SOIL: AGENCY PERSPECTIVES

Energy Considerations at Navy Restoration Sites

According to Kim Parker Brown, the Navy's Environmental Restoration program faces both opportunities and challenges in using alternative and reduced energy approaches in site cleanup (Attachment A). The major benefits include minimizing the environmental footprint of the remedy and analyzing new ways to reduce the costs of remedial action operations. Consumption of energy from non-renewable versus renewable sources is important because of the need to conserve the U.S. energy supply and reduce dependence on foreign sources of energy. Energy consumption also results in the generation of greenhouse gases (GHGs).

In light of these needs, the Navy is increasing its emphasis on evaluating energy usage not only from a cost perspective, but more importantly from an environmental sustainability perspective. The Department of the Navy Optimization Workgroup is tasked with developing guidance for remedial project managers seeking to improve the sustainability of Navy environmental cleanups. This guidance will include recommendations for planning and operating remediation systems in addition to information specifically related to minimizing energy usage, reducing natural resource consumption, and minimizing GHG emissions.

Navy sites have implemented the use of wind power, solar energy applications, and pressure-driven applications in the operation of groundwater remediation systems, free-product recovery systems, and bioventing applications. Brief overviews were provided of five energy study projects:

- SiteWise™ analysis of energy use in different remediation scenarios at Naval Air Station (NAS) Alameda
- Use of wind turbines and photovoltaics to provide energy at a former munitions live impact area in Vieques, Puerto Rico
- Bioventing of petroleum hydrocarbons at NAS Whidbey Island, Washington
- Energy generation via mobile wind turbines for remediation at the former Adak Naval Complex, Alaska
- Phytoremediation of PCE in groundwater at Naval Training Center Orlando

Among the lessons learned from the energy studies, the importance of planning to meet energy needs in a worst-case scenario was underscored when some of the mobile wind turbines at the remote Adak site were damaged when gale-force winds unexpectedly swept the area.

Kim also described the Navy's Technology Validation Program (TechVal), which focuses on transitioning energy-efficiency technologies from the demonstration stage into agency-wide application. TechVal was started because the Navy saw a need for accelerating technology adoption to meet its energy saving goals. The program identifies potential technologies for energy savings within the Navy, works with facilities on validating technology performance to reduce the economic risk of investing in the acquisition of new technologies, and promotes the wider application of those technologies with proven performance and potential. The program categorizes the technologies it investigates by the potential return on investment. Green-light technologies are expected to prove cost effective in less than 10 years; the money saved from installation costs and energy savings will pay for green-light technologies in this timeframe. The savings on yellow-light technologies should be realized in 10 to 15 years, and red-light technologies would take longer than 15 years to pay for themselves.

Question: Does the Navy's GSR guidance outline any specific requirements or does it just encourage awareness of sustainability issues?

Answer: As there are no specific regulatory requirements at the present time, the guidance makes recommendations for evaluating different technologies with attention to GSR early in the process, even during the remedial investigation phase.

Low Energy Technologies at U.S. Air Force Sites

Erica Becvar discussed the energy costs borne by the Air Force (Attachment B). Although energy consumption is decreasing, energy costs are increasing because the cost of fuels is going up—the Air Force spent over $9 billion on energy in 2008. Energy goals include an outlay of $2.3 billion over the next six years on energy and water conservation and expanded use of renewable energy projects. This capital investment strategy is expected to reduce energy intensity at Air Force facilities by 30 percent by 2015, reduce potable water usage by 16 percent, increase on-base renewable energy to 3 percent of all electricity use, and increase renewable energy to 10.5% of all electricity.

The Air Force is the largest user of liquid fuels within the Department of Defense (DoD), with aviation comprising 84 percent of its energy consumption. Although the Air Force is the largest consumer of energy due to fuel use, it also is an EPA Green Power Partner and the number-one purchaser of green power within the federal government. The Air Force has met every energy conservation goal since 1975.

The Air Force's Environmental Restoration Program has a FY2010 budget of $414 million for the three sub-programs that lie within it: the Installation Restoration Program (IRP), the Compliance Restoration Program (CRP), and the Military Munitions Response Program (MMRP). In 2010, the IRP has 572 open sites that were identified prior to 1986. Over 90 percent of the IRP sites have been cleaned up: 6,078 sites have achieved a status of closed, response complete, or response in place (RIP). About 40 percent of the open sites are estimated to need some sort of remedial action, and about 30 percent are likely to need removal. Compliance cleanup sites in the CRP are affected by post-1986 releases, and as of 2009, 952 sites are still open. The MMRP, which involves cleanup of non-operational ranges, has 455 open munitions response sites, and its goal is to achieve RIP/response complete by 2020.

Based on the FY2008 EDITT system inventory as of 15 March 2010, the Air Force has 381 remedial systems in operation. Approximately 38 percent are high-energy systems for free-product recovery, soil vapor extraction (SVE), pump and treat, and 'other.' About 48 percent are passive or low-energy systems: enhanced bioremediation, treatment walls, and monitored natural attenuation. Pump and treat consumes over half (52 percent) of the annual remediation energy costs. The high-energy systems consume two-thirds of the remediation energy budget, whereas the low-energy systems use only 28 percent.

Key elements of the GSR initiative in the Air Force are to minimize energy use for treatment systems, water use and impacts on water resources, material consumption and waste generation, impacts on land and ecosystem, and air emissions. Incorporation of GSR technologies as part of a holistic approach to optimize cleanup is a major goal, which the Air Force has developed several tools to support:

- SRT™, which among other uses can estimate total energy consumed during a remediation project http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation/srt/index.asp
- An alternative energy Microsoft® Excel-based tool under development that will help identify whether it makes sense on a ROI, LCA basis to provide renewable energy to remediation systems
- Environmental Decision Information Tracking Tool (EDITT), a system for the Air Force and its contractors that includes the Performance Tracking Tool (PTT) http://www.afcee.af.mil/resources/restoration/editt/index.asp

The Air Force invests in innovations to achieve efficient environmental cleanups through its Broad Agency Announcement (BAA) solicitations for cost-effective innovative remediation technologies. The primary FY2008-2009 BAA technology improvement investment areas were enhanced bioremediation, long-term monitoring technologies, sustainability/optimization, and emerging contaminants. The technology investment goals are to accelerate greener RIP, augment current remedies to achieve response complete, lower capital and operation and management (O&M) costs, move from energy-consumptive to energy-efficient technologies, and promote education and transfer of successful solutions and lessons learned.

Erica offered examples of Air Force use of low-energy technologies:

- Emplacement of a biowall to dechlorinate a TCE plume at Altus AFB, Oklahoma;
- Installation of a solar-powered extraction well at the base boundary at Travis AFB, California;
- Optimization of systems within the central treatment plant at Travis AFB;
- Implementation of an in situ bioreactor as a solar-powered biogeochemical source area treatment system at Travis AFB;
- Phytoremediation involving planting of 380 eucalyptus trees across a solvent plume at Travis AFB; and
- Installation of a wind turbine that is expected to generate 25 to 30 percent of the total electrical requirement for the treatment systems at the Massachusetts Military Reservation.

Question: Was the Travis AFB bioreactor that used solar-powered recirculating wells a demonstration or a full-scale project?

Answer: That project is being proposed as part of the remedy at Travis, based on feedback from the regulators. It is the third bioreactor project following a pilot study and a full-scale system at Altus AFB, OK.

Permeable Reactive Barriers – A Green Technology

As a member of the Interstate Technology Regulatory Council (ITRC), Kimberly Wilson (South Carolina Department of Health & Environmental Control) participates on the ITRC Permeable Reactive Barrier (PRB) Technology Update Team (Attachment C). Formed in 2009 in partnership with AFCEE, the PRB update project is scheduled to conclude in 2011. The team plans to issue a technical regulatory guidance document in early 2011 that will update the information in ITRC documents published in 1999, 2000, and 2005. Internet-based training also should begin in 2011.

PRBs, once considered a novel remedial method, have been installed to intercept and treat contaminated groundwater at polluted sites throughout the world for many years. PRBs that contain iron are now widely accepted as a conventional treatment technology, and other reactive media are gaining acceptance rapidly. With the recent emphasis on low-energy or green remediation technologies, PRBs are recognized as a sustainable remedial technology.

Compared with more traditional remediation technologies, PRBs conserve physical and financial resources; they generally are more durable and longer lasting than conventional remedial methods and typically require little, if any, O&M. Because of recent interest in climate change issues and resource-intensive remediation technologies, EPA and many state environmental agencies are emphasizing green remediation practices that focus on water conservation and lowering energy consumption and emissions of greenhouse gases. PRBs combine all three green practices and might be considered a cornerstone of the green remediation movement.

PRB technology has expanded in recent years with respect to the reactive media used to treat contaminants, the contaminants that can be remediated, and installation methods used. New installation techniques have been developed and older ones have been improved. Installing a PRB no longer means digging a trench, installing reactive material, and backfilling it to surface. Installation methods have advanced to include continuous trenching techniques, long-arm excavators and biopolymer slurries, injection of materials, fracturing (pneumatic or hydraulic) and injection, and augured boreholes or caissons. Novel reactive media are being used today, such as zeolites to address radioactive isotopes, organophillic clays to prevent NAPL migration, and combined media (e.g., eZVI® and EHC®) to address multiple contaminants.

Question: If the barrier's reactive material has to be replaced periodically due to a factor such as a challenging geochemistry, is there a balance point that can be used to determine if the project is energy inefficient?

Answer: From a performance standpoint, it would seem preferable to use a different technology.

Question: Have you experienced any need to restrict activities that would diminish hydraulic flow?

Answer: Although that is an element to consider, it has not arisen so far.

Comment: At the ITRC meeting in April, Doug Downey (CH2M Hill) of ITRC's GSR team made a presentation that compared the environmental footprint of a biowall to pump and treat. The AFCEE biowalls are installed using perforated pipe that allows periodic addition of a vegetable oil substrate to rejuvenate biological activity. A biowall is expected to maintain biological activity for three to five years, but if substrate had to be added every two years, the environmental footprint would approach that of pump and treat. Calling a technology "green" is very specific to the site, the technology's design and installation process, and how well it performs. That is why it can't be said that all PRBs are green.

Comment: PRB longevity is an issue for which there is no good answer as it depends on the reactive media used and the character of a site's groundwater, both the chemistry and the hydraulics. At a site with optimum conditions, the right barrier might last as long as 30 years, while at another site, a PRB will have a much shorter life. From a GSR standpoint, however, an issue that needs more attention is the carbon footprint of the manufacturing process for the material used in the barrier. It is necessary to add that information to the installation and O&M data to derive an overall carbon footprint that allows for accurate comparison of a PRB against other technologies.

Comment: The Air Force biowalls are able to use waste materials from facility landscaping maintenance activities, composted Christmas trees, and waste materials from local industry, such as a cotton gin.

Comment: It would provide a useful study to revisit the iron PRBs that are 10 years old or older and to compare the present permeability and flow against initial operation and to investigate issues that might have emerged over time.
Answer: That is part of the ITRC PRB project approach. The original installers on the update team are revisiting some of the older systems.
Comment: EPA's Office of Solid Waste and Emergency Response is funding an Air Force study of older biowalls to assess performance, levels of total organic carbon, and ways to add different materials.

Large, Dilute Solvent Plumes

Jim Cummings (EPA/Technology Assessment Branch/OSRTI) described the challenges that attend remediation of large, dilute plumes of chlorinated solvents, which are a prevalent, problematic remediation problem set. (Attachment D). The plumes are heterogeneous rather than uniform, and 90 percent of the contaminant mass may be sorbed to the matrix in the volume commonly thought of as "dissolved phase". This configuration manifests as early "spikes" in contaminant concentration, sometimes greater than initial concentrations, following in situ chemical oxidation (ISCO) as contaminants desorb from the matrix.

Pump-and-treat remedies are coming under increasing scrutiny due to efficacy constraints and sustainability considerations. In some cases, particularly where source(s) have been addressed, monitored natural attenuation might be sufficient to allow resource restoration in a reasonable timeframe. In other cases, closed exposure pathways or threats can require some level of intervention. Given the areal extent of many solvent plumes and the large quantities of water affected, solution sets require least-cost additives/reagents and least-cost delivery mechanisms.

At the Hopewell NPL site in Hopewell Junction, New York, EPA and DOE have collaborated on efforts to address a 7,000 foot long solvent plume. Despite maximum concentrations generally less than 100 parts per billion (ppb), the plume is causing maximum contaminant level (MCL) exceedances in drinking water wells and vapor intrusion exceedances in residences. An additional complication is that aerobic conditions of the shallow plume appear to preclude reductive dechlorination remedies. As a result, the innovative technology aerobic co-metabolic bioremediation is the leading remedial candidate. Indigenous microorganisms in the aquifer would consume organic substrates and oxygen under aerobic conditions and produce an enzyme that can destroy TCE without the generation of toxic byproducts, such as vinyl chloride. Aquifer conditions at the site are favorable for reduction of the site contaminants through this technology. Discussion continues on what kind of substrate to use and how and where to inject it to achieve the most effective substrate distribution. Pilot work is likely to begin within the next year.

Aerobic co-metabolic bioremediation has not been widely used due to its relatively slow degradation rates. Additionally, the enzymatic process is uncomfortable to microorganisms, and there is natural selection away from the desired organisms; hence, the process can "burn out" when too few of the organisms needed to maintain it are present. Recent work had been done at DOE's Savannah River Site on substrates that increase biodegradation rates. At least one commercial firm—CL Solutions—has done work at the field scale using *Pseudomonas* bioaugmentation with addition of dextrose substrate. Across the country, 80 to 100 percent of the wells at most sites screen positive for significant numbers of the organisms that express the enzymes necessary for cometabolism. Cometabolism is occurring in all of the aerobic plumes tested to date. Current research focuses on how the organisms manage to live in oligotrophic aquifer systems.

Question: At the public meeting last year to present EPA's preferred remedy, how did the public react to the idea of injecting a gas into a site where vapor intrusion is an issue?

Answer: They were more concerned about the production of vinyl chloride during treatment but were reassured to learn that unlike enhanced reductive dechlorination, the proposed co-metabolic process does not involve the formation of vinyl chloride. Injection of benign gases was not perceived to be a problem, but injectants that were perceived to be more like a toxic substance, such as toluene or phenol, generated a higher level of concern. The public's greatest concern was the provision of an alternative water supply.

Question: What is your feeling regarding the potential of the oxygenate enzymes in co-metabolic reduction to degrade tetrachloroethene (PCE)?

Answer: Engineering and technical challenges involved with using this treatment for TCE in large dilute plumes—biofouling, competitive inhibition, deactivation—remain to be resolved. After we elucidate the mechanisms for TCE, we can focus on whether PCE can or cannot be degraded using this approach.

Question: Given a heterogeneous subsurface, how are appropriate locations for substrate injection identified?

Answer: The contaminated zone is mapped on slide 8, showing a large area of lesser contamination and a central zone of higher contamination. If injection occurs below the zone of highest contamination, the treatment performs almost like a reactive barrier. Another approach is to inject into the heart of the contaminated zone. The two approaches could be combined to address the source and use the flow of groundwater to help distribute the amendments. Another challenge is determining the effect of the till mound that bifurcates the plume geometry because it might be a TCE repository, a source of contaminant back-diffusion.

Question: During the public meeting, was there any discussion of aerobic co-metabolic bioremediation being a lower energy approach compared to pump and treat?

Answer: There was a general understanding that pump and treat would move a great deal of water but very little contamination. Energy issues were not discussed in the meeting, but the feasibility study evaluated pump and treat and dismissed it for reasons of energy consumption and efficiency.

Environmental Remediation Energy Calculators

Carol Dona discussed how to calculate the amount of energy a remediation project will consume over its lifetime using the Air Force SRT™ and the Battelle SiteWise™ Sustainable Environmental Remediation (SER) Tool (Attachment E). Both tools calculate energy use, as well as greenhouse gas emissions. The Battelle SiteWise™ (SER) has been purchased jointly by the Army and Navy, and both tools are publicly available on line (www.ert2.org/t2gsrportal/tools.aspx). The presentation provides several examples of energy consumption for different remediation technologies, components (and change-out of components) of existing remedies, and commonly used site investigations procedures. The results of conventional and renewable energy calculations are related to greenhouse gas emissions.

AFCEE's SRT™, designed in Microsoft Excel®, allows evaluation of particular remediation technologies on the basis of sustainability metrics. This tool facilitates sustainability planning and evaluation and is intended to support decision making. The SRT™ allows users to estimate sustainability metrics for specific technologies for soil and groundwater remediation. The SRT™ currently incorporates modules for excavation, soil vapor extraction, pump and treat, enhanced bioremediation, in situ thermal treatment, ISCO, permeable reactive barriers (including biowalls), and long-term monitoring/monitored natural attenuation. In 2010, the SRT™ will be interfaced with the Remedial Action Cost Engineering and Requirements (RACER™) cost modeling tool, which will provide users with an estimate for sustainability alongside the budgetary cost estimate.

Sitewise™, a sustainable environmental remediation tool developed jointly by Battelle, USACE, and the U.S. Navy, is designed to calculate the environmental footprint of remedial alternatives. The tool is a series of Excel spreadsheets that provide a detailed baseline assessment of several quantifiable sustainability metrics: energy usage, water usage, greenhouse gases, particulates, air pollutants (e.g., sulfur oxides, nitrogen oxides), and accidental risk. The tool uses a modular approach to conduct sustainability assessments by considering the activities with environmental impact that are involved in well installation; soil/groundwater monitoring; system monitoring;

system start-up, operations, and maintenance; and decommissioning. The tool supports both a comparison of the remedial alternatives and a detailed breakdown of the environmental footprint for each alternative. It can be applied at remedy selection, design, or implementation stage, as well as for remedy optimization.

Training on both tools is offered at the 2010 Battelle Monterey Conference, and USACE is also planning Web-based training on SiteWise™.

Question: SRT™ incorporates costs calculation, but SiteWise™ does not. Is that likely to change?

Answer: It is beyond SiteWise™ at this point in time. When a project team is approached about taking part in the study, they immediately ask two questions: 1) What are the cost impacts? and 2) Will it affect the project schedule? Cost and schedule are very important factors, and SRT™ has the advantage in that it allows calculation of costs along with technology sustainability metrics; however, it is more difficult to model the technology using SRT™ than using SiteWise™.

Comment: Modules do not exist for every possible technology. The SRT™ works well when the technology or combination of technologies to be used is known. SiteWise™ allows easier development of a module when the technology is not yet determined or is not commonly used. The SRT™ can calculate costs while SiteWise™ cannot. The next-generation SRT™ will interface with the RACER™ software, allowing what is built within RACER™ to be used for a sustainability analysis within the SRT™. The SRT™ allows the user, if desired, to normalize metrics such as carbon dioxide, technology cost, greenhouse gases, and energy and then compares the technologies using the normalized values. The SRT™ also has a virtual roundtable that allows weights to be assigned to the normalized metrics to identify the factors of greater decision-making importance in attaining the cleanup goal.

Question: So SRT™ works better if the technology has already been selected, but with SiteWise™ the technology can be unknown?

Answer: SRT™ is not a design tool. The program works in the FS stage using Tier 1, and it works well in Tier 2 when systems have been designed or are already in place. It is important to remember that both tools look at energy requirements over the life of the project, the overall operation of the system, and are not designed to provide a snapshot in time.

Pilot Scale Testing of Swellable Organosilica-Nanoparticle Composite Materials for the In Situ and Ex Situ Remediation of Groundwater Contaminated with Chlorinated Organics

Dr. Paul Edmiston, an associate professor of chemistry at the College of Wooster in Wooster, Ohio, introduced a new class of chemically inert, nano-engineered, silica-based material that swells to eight times its dry volume in organic liquids (Attachment F). About five years ago, he serendipitously discovered a material with unique properties while working on another project. The material, a swellable, organically modified silica (SOMS), can capture organic compounds found as neat liquids, as vapors, or dissolved in water. The expanding nanoporous matrix can lift >10,000 times it own weight upon expansion.

SOMS is known commercially as Osorb. Although Osorb does not swell in water, it swells in the presence of organic gas or liquid, including organics dissolved in water. Osorb floats on water, which makes it useful for recovery of oil spills. Organics trapped in the glass matrix can be recovered by exposing the product to heat (60 to 110°C), upon which the sorbed compounds evaporate. Incorporating nanoscale zero-valent iron (nZVI) into Osorb produces Iron-Osorb, which is effective for treatment of chlorinated contaminants, such as TCE. Iron-Osorb can be injected directly into aquifers, where it extracts TCE from the water and captures it in the Iron-OsorbTCE matrix, forcing the contaminant into contact with ZVI. Dechlorination intermediates (e.g., vinyl chloride) are fully destroyed by complete reduction to chloride and ethane. The glass matrix serves to concentrate the chlorinated solvents and protect the embedded metal particles from deactivation by dissolved ions. The material can be milled to a particle size that will either allow or prevent movement in a flowing subsurface zone. Deployment of Iron-OsorbTCE is done in very small amounts compared to standard ZVI treatments (<10 percent by mass). This inert, sand-like silica can be left in place. When in contact with a DNAPL zone, the swelling of the glass will immobilize and lock away all TCE contacted. Iron-OsorbTCE density can be optimized to target certain depths in a groundwater aquifer.

In conjunction with laboratory testing, three pilot projects were carried out in central Ohio at industrial sites with groundwater contaminated by either TCE or PCE. Composite materials were injected into the aquifer to create a soft curtain up-gradient from monitoring wells. Soil testing was used to determine the distribution of the material post injection using fluorescently labeled particles. Chlorinated solvent concentrations were measured as a function of time to assess the effectiveness. Results from these studies indicate that injection methods and soil composition are important considerations for the treatment design.

The pilot tests have shown that when the glass is properly placed, steep declines in chlorinated solvent constituents follow. The work has enabled a basic understanding of what types of injections work and shows that the material can be dispersed over a long distance. Clay must be treated in addition to the water. Upcoming projects will employ blends of high reactivity and low reactivity SOMS-nZVI emplaced using custom-designed injection tools. The goal is to hit targets <5 ppb and develop systems that work over both short and long timescales.

In a separate set of tests and pilot projects, SOMS with embedded nanoscale palladium (Pd) particles was used as a replacement for air sparge towers in the ex situ treatment of groundwater contaminated with chlorinated solvents. Reduction was accomplished by dissolved hydrogen gas. The system has been shown to be effective in dechlorinating TCE and PCE from levels exceeding 20,000 ppb to less than 1 ppb. In addition, SOMS-Pd is effective at reducing trinitrotoluene, atrazine, and triclosan in water. The presentation slides provide data from bench- and pilot-scale tests.

Question: Can the material be used for arsenic?
Answer: No.

Question: Can you provide any cost figures?
Answer: The cost for remediation with Iron-Osorb is comparable to other technologies. The active lifetime of Iron-Osorb can be longer than other technologies.

Question: Does the glass exert any pull on the contaminant, or is it completely passive?
Answer: There is a sponge effect. The partitioning coefficient for binding PCE is 20,000, and the glass has a capacity eight times its own volume. It essentially will scavenge any organic material it contacts. Diffusion will migrate the contaminants to the glass, and as the glass absorbs them, the concentration gradient will draw in additional material. Because the glass is hydrophobic, it doesn't travel down gradient with the flow of groundwater. Once the surfactant slurry used for injection is gone, the glass's hydrophobicity keeps it locked in place.

Question: What happens to the hydraulic conductivity of the aquifer post injection?
Answer: The quantity injected is small, with a goal of roughly 10 grains per cubic foot. All the aquifers visited for the pilot tests are high permeability aquifers, and the injections had no observable effect on the hydraulic conductivity.

Question: TCE in the presence of iron undergoes abiotic reductive dechlorination, producing ethane. Is the ethane retained?
Answer: Ethane is a gas at room temperature, and the glass does not hold on to a gas as strongly as it holds on to species with a higher boiling point. Ethane can be sequestered temporarily, but it will eventually leach out of the glass.

Question: What is the hydraulic conductivity of the aquifer below which this technology will not work, and is it effective for radioactive contaminants?
Answer: I don't know the answer to the first question, because all the field work so far has been done in high-permeability systems. With regard to radioactive contaminants, if a chelating agent is added to the glass or to the surrounding matrix, then a metal ion that can be chelated with an organic chelating group is also absorbed by the glass.

Question: The glass has been tested on solvent plumes so far. Do you plan to test it on the pure DNAPL phase?
Answer: Because a very large amount of iron would be needed to dechlorinate DNAPL, the development of a configuration of glass that resembles a straw is being considered. Can we build a straw-like system that will cause the DNAPL to percolate upward into either a place on the surface or into some kind of container? The goal is to extract the DNAPL from the subsurface.

Question: How far from commercialization is the technology?
Answer: The glass is already in commercial production.

Question: Do you plan to demonstrate the technology in the Environmental Technology Verification Program under EPA's Office of Research and Development?

Answer: If information about the program is made available, I will be interested in following up on it.

Question: Will you comment on how the glass will work on oil spills?
Answer: Oil spill cleanup is easy for this glass because once it absorbs the oil it assumes a semi-solid gel-like state that floats on the water. The gel can be recovered, the oil extracted, and the glass reused.

Question: Will it work on 1,4-dioxane and NDMA?
Answer: The glass has a high affinity for 1,4-dioxane in water. It hasn't been tested on NDMA, but given its chemical structure, the glass should absorb it.

CASE STUDIES AND LESSONS LEARNED

Small Renewable Energy Systems: Performance versus Prediction

Dr. Curt Elmore, Missouri University of Science and Technology, described several experiences and lessons learned with wind turbines and photovoltaic systems (Attachment G). These small renewable energy systems have the potential to offset energy costs at remediation sites while providing good opportunities for offsetting power plant emissions and attracting positive public interest. The small renewable energy systems will almost always "work," but they may not deliver energy in appropriate amounts or in a fashion that suits the need. The models used to predict wind turbine performance and solar panel output are straightforward, but the reliability of the performance predictions are sensitive to the earth resource data that are used as input. Given the data sources—publicly available resource maps and databases and site-specific data collected for individual applications—an engineer can generate more than one performance prediction for any given system. The performance predictions are further complicated by the inherent random variability of wind velocities and solar irradiation.

Wind data collected in the vicinity of the former Nebraska Ordnance Plant Superfund site were used to select a wind turbine system to provide a portion of the energy necessary to power a groundwater circulation well located in an area of high TCE groundwater contamination. With utility power already installed at the remediation system, a 10-kW grid inter-tie wind turbine system was added to supplement the utility system without requiring batteries for energy storage. The wind turbine output was about 30 percent below that predicted by the vendor's wind turbine production model, given the wind data collected at the site. Investigation showed that the vendor's power rating curve was for a newer, more-efficient generation of wind turbine airfoils than the unit actually purchased. Although the wind turbine did not produce enough energy to power all of the primary electrical components, it was sufficient to power the submersible pump as a part of an off-grid active remediation system, and environmental value of the system was considerable. The final report for this project is available on EPA's Clu-In Web site (cluin.org/greenremediation/docs/Mead_Final_Report_Rev_0.pdf).

A renewable energy feasibility study was undertaken for Sacala las Lomas, a small village in the rural highlands of Guatemala. A relief agency proposed the drilling of a deep groundwater well to supply the community with a good supply of clean drinking water. A multi-staged pumping system was proposed to transfer water from a surface storage tank near the well to a surface storage tank above all residences in Sacala. From the storage tanks, the water would be distributed by gravity to the homes. The feasibility study showed that renewable energy pumps could not supply enough power to meet the dynamic head and water demand needed for the submersible pump, so the focus switched to evaluating renewable energy for the transfer pumps. A weather station was erected to collect site-specific data. The collected data and models were used to predict the renewable energy generation rate and evaluate the potential to use a photovoltaic array or a wind turbine. The analysis revealed that the energy required to power the transfer pumps was too great for a renewable energy system to be feasible—the number of energy structures needed to meet the demand (a considerable expense in itself) would have covered all the farmland.

During the planning for a renewable energy project it is a good idea to ask "Is this too good to be true?" because sometimes it *is* too good to be true. It might be necessary to temper participants' expectations—renewable energy is not a silver bullet.

Question: Do you take power loss into account?
Answer: Yes, the measurement number includes calculation of loss—turbulence and degrading factors must be taken into account. On slide 14, the difference between the measurement and the actual represents the calculation of loss. The calculation was made using a commercial product, the WindCad Turbine Performance Model. The same calculation was used for the other measurements.

Question: How do you know what height is most appropriate for a wind turbine?
Answer: The wind map will show the best height. The towers are designed in standard heights: 30, 50, 60, 100, or 120 feet.

Low-Energy Technologies and Uncertainty Analysis
Via remote broadcast, Dr. Sam Brock (AFCEE/TDV) explained that uncertainty analysis is undertaken to identify the qualitative and quantitative important sources of uncertainty (Attachment H). Risk can be calculated by multiplying the likelihood of occurrence by the consequences of occurrence. Better data can reduce uncertainty, but it cannot reduce variability, which can be defined as the real identifiable differences between individual cases. A single action or approach to reduce risk is not optimal in every case. In environmental restoration, risk can be managed by a course of action that addresses all risks related to the remediation process, i.e., the risks associated with site investigation, remedy selection, implementation, and close-out. The Air Force has developed several programs that support this effort.

AFCEE's Environmental Restoration Program Optimization (ERP-O) program is a strategic effort geared towards improving Air Force environmental cleanup strategies, systems, and programs at bases across the country. The program was created for the specific purpose of supporting the optimization of the Air Force Wide Environmental Restoration Program, and it has grown in the areas of energy and greenhouse gas assessment, strategic communications, and performance tracking. ERP-O provides for a comprehensive and systematic review of an installation's cleanup activities, first to ensure remedy effectiveness, and then to optimize remedy efficiency. The program encompasses three environmental program processes: investigation process optimization (IPO), remedial process optimization (RPO), and post-closure care.

The ERP-P process uses various tools to estimate and manage uncertainty. The SRT™ helps drive and influence GSR technology selection, aids in future planning and optimization of existing systems, provides lifetime sustainability assessment, works in concert with Performance Tracking Tool (PTT) to evaluate performance and reduce time to site closure, and provides a virtual roundtable for all-party consensus. It estimates sustainability metrics for eight specific technologies concerning carbon dioxide emissions, total energy consumed, change in resource service, and safety/accident risk. Fifteen sustainability assessments have been performed over the past eight months.

For example, the tool allows consideration of risk to workers with reference to an evaluation of resources being protected, as well as consideration of a particular treatment technology and the energy required to implement it. It enables the project team to determine whether active remediation is really justified and then to consider what the alternatives to remediation might be. Slide 18 provides an example matrix for evaluation of risk level.

To manage risk effectively during the remediation process, it is important to address the site life cycle early in the process. It is also necessary to analyze performance and generate performance data throughout the project. The development of performance measures allows leveraging of experience and lessons learned. Risk estimates should improve until risk is below the decision criteria, and the acquisition of additional knowledge does not change the estimated risk: i.e., the consequences are not high enough to warrant further work.

Dr. Brock offered the following philosophy: We cannot be perfect. As humans, we don't have perfect knowledge of what is going to happen, but we can pursue excellence, and we can do a good job through application of the best science we have, employing the continuous improvement loops and continuing to respond to experience and science as it becomes available to us.

Question: Who performs the uncertainty analysis, the project team or an outside group?

Answer: It is implemented through the CERCLA process using the base team, the contractors, and the feasibility study, and also undergoes the project review and validation process, which is centralized at AFCEE for the larger projects. In addition, teams of seasoned experts visit the facilities. About 42 bases have been evaluated, reflecting about 90 percent of cost to complete. Some of the analyses have been done by these optimization teams, and the results have been correlated with review of projects and funding requests after the optimization visit to verify that the projects are in line with the recommended conceptual approaches. The analysis involves a multifaceted approach.

Question: With respect to risk to workers on slide 15 and considering voluntary versus involuntary risk, is active remediation justified when the risk is high?

Answer: We are advocating doing a better job of estimating the short- and long-term effects and the implementability to make a more informed decision in selecting a remedy for a site where a remedy is warranted.

Integrated Wind and Solar Powered Free-Product Recovery System at Former St. Croix Alumina Site in St. Croix, U.S. Virgin Islands

Timothy Gordon (EPA/Region 2) described the use of renewable energy at the former St. Croix Alumina site (Attachment I). A recovery system was required under a 2001 RCRA Corrective Action Order to clean up a plume of light non-aqueous phase liquids (LNAPLs), comprised mostly of diesel, on the groundwater underlying the bauxite refinery facility. Because the facility was closing and there was no existing hookup to the local power grid, the Respondents Group recommended installation of a free-product recovery system utilizing pneumatic well pumps powered by 4 wind turbine compressors (WTCs). The WTC-powered system was estimated to cost about one-third of the cost to connect to the power grid, which provided an economic advantage to using alternative energy instead of additional construction to provide conventional power.

The WTCs are mounted on masts and resemble the windmills used on farms. The 4.33 foot blades begin rotating at a wind speed of 4 mph. When wind speed exceeds 30 mph, the blades furl and turn out of the wind. The air compressor is located directly behind the windmill. The combined blade/compressor unit is on a hinged tower, and can be lowered to the ground for maintenance or protection in case of a hurricane. Each WTC is designed to generate approximately 45 psi of operating pressure. The capital costs for the initial power system (installation of 4 WTCs and masts) totaled approximately $20,000), which does not include the cost of the fluid recovery gathering and compressed air distribution systems.

The initial WTC-powered pneumatic-pump system came on line in early 2002. Between 2004 and 2007, electric total-fluid and skimmer pumps powered by solar panels and wind electric generators (WEGs) were added to enhance recovery. The electrical pumps are powered directly, on demand, from an integrated power supply system consisting of eight solar panels and four WEGs, with no batteries involved. The no-battery electrical system was chosen because access to the site is not well controlled, and potential theft of batteries was considered a major problem. The downside is that no pumping occurs when there is insufficient wind and sunlight. This consequence was acceptable because the plume is relatively stable, and the groundwater is not utilized down-gradient of the site. Through December 31, 2009, a cumulative total of 347,676 gallons of free product has been recovered, and as of that date the estimated in-place remaining free product is 832,000 gallons.

The total capital cost for alternative power equipment (WTCs, WEGs, solar panels, and system integrator controllers) was approximately $50,000. The total cost for 11 pumps was $20,400, which does not include costs for well drilling and completion and installation of the gathering system (flow lines, separators, tanks). The current capital cost for a similar wind/solar powered system and a recovery pump is estimated at $13,800 each well.

Comment: The mechanical windmills have multiple purposes—a RCRA site in New Jersey used pneumatic pumps for a similar process, running a soil vapor extraction system to create a vacuum and then putting the gas through granular activated carbon before releasing it to the atmosphere.

Response: The company that manufactured the equipment used at St. Croix went out of business, but a company in California, Airlift Technologies, is now making similar equipment.

An Innovative Low-Energy Technology Application at Marine Corps Base Camp Pendleton

Arun Gavaskar, Naval Facilities Engineering Command, described the Navy's efforts to implement low-energy alternatives for managing the Site 7 Landfill at Marine Corps Base Camp Pendleton, California (Attachment J). The construction of a corrective action management unit next to a housing complex and elementary school on open municipal landfill eventually resulted in a lawsuit, the only toxic tort case in the Navy's history. The area continues to be a source of concern to state agencies as monitored methane gas levels fluctuate in and out of compliance.

A basic evapotranspiration cap covers the 28-acre landfill. To gain better control of methane generation and migration from the landfill, the Navy is replacing the existing flare with a microturbine capable of generating 30 kW of electricity. A microturbine is a small gas turbine generator that turns methane into electricity. Microturbine technology is well suited for sites that produce low methane flow rates or have limited space for flare facilities. Microturbines will operate on landfill gas methane concentrations as low as 7 percent, and the system selected is adaptable to low methane production and to fluctuations in gas volumes. At the Camp Pendleton landfill, a 30 kW microturbine is connected to methane gas collection wells, and the energy produced is fed into a photovoltaic panel system. The microturbine is the size of an industrial refrigerator. The unit is not visible from the housing complex or the school, and it runs quietly without a flare.

In addition, the installation of 220 photovoltaic cells (solar panels) will generate another 1.5 MW of electricity. Because supports cannot be sunk into the landfill cover, the solar panels are placed on self-ballasted, non-penetrating foundations on top of the cover to avoid any negative effect on the current cover and drainage collection system. The limitation of the support system means that the panels cannot rotate all day to follow the sun; rotation is limited such that each panel has a fixed 15° tilt, a 190° orientation. The Record of Decision (ROD) for the site was not amended, as this GSR project was considered a land-use change rather than a remedy change, but an Explanation of Significant Differences was added to the current ROD. This project is being implemented with funds from the American Recovery and Reinvestment Act.

Comment: Many landfills were written off years ago as non-recoverable for energy uses, but as this presentation points out, now that microturbines operate on gases down in the concentration range of 7 percent versus the earlier 40-percent range, opportunities for energy recovery are greatly expanded. Microturbines that combine heat and power can add to the efficiency, especially in urban areas, where there is potential commercial use for the heat.

Response: The next big technological push will have to increase the efficiencies of the microturbines and solar panels. Conversion efficiency is about 24 percent for microturbines and about 20 percent for solar panels, but manufacturers are working to improve them.

MEETING WRAP-UP/NEXT MEETING AGENDA

Balloting for the next FRTR meeting topic indicated fractured rock characterization and remediation as the topic of greatest interest to member agencies. The U.S. Geological Survey will take the lead in developing the agenda and coordinating the Fall 2010 FRTR meeting with John Kingscott and Marti Otto.

The next meeting will be scheduled in November or December. Kingscott thanked everyone for attending, and the meeting was adjourned.

ATTACHMENTS

A. Energy Considerations at Navy Restoration Sites
B. Low Energy Technologies at U.S. Air Force Sites
C. Permeable Reactive Barriers – A Green Technology
D. Large, Dilute Solvent Plumes
E. Environmental Remediation Energy Calculators
F. Pilot Scale Testing of Swellable Organosilica-Nanoparticle Composite Materials for the In Situ and Ex Situ Remediation of Groundwater Contaminated with Chlorinated Organics
G. Small Renewable Energy Systems: Performance Versus Prediction
H. Low-Energy Technologies and Uncertainty Analysis
I. Integrated Wind and Solar Powered Free-Product Recovery System at Former St. Croix Alumina Site in St. Croix U.S. Virgin Islands
J. An Innovative Low-Energy Technology Application at Marine Corps Base Camp Pendleton