FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
Arlington, Virginia
November 10, 2009

FEDERAL REMEDIATION TECHNOLOGIES ROUNDTABLE MEETING
Arlington, Virginia
November 10, 2009

ACTION ITEMS

- ► Anyone interested in participating in the Green and Sustainable Remediation Subcommittee should contact Carol Dona or Kirby Biggs.
- ► Volunteers interested in helping review and update the FRTR *Field Sampling and Analysis Technologies Matrix* should contact Jean Balent.
- ► Recommendations for agency representation at a SERDP/ESTCP vapor intrusion (VI) technical exchange workshop planned for spring 2010 should be sent to Andrea Leeson.
- ► Helen Dawson will prepare a conceptual basis for collaboration on VI issues and population of EPA's Vapor Intrusion Database. The concept will be disseminated to FRTR participants to determine level of interest and potential level of participation.
- ► Carol Dona will follow up with Army participants not present at the meeting to determine their interest in joining a collaborative VI effort.
- ► Any member interested in taking the lead to establish the agenda for the spring 2010 meeting should contact John Kingscott or Marti Otto.

WELCOME/INTRODUCTION

Arnold Layne, Director of the 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 39th meeting of the Federal Remediation Technologies Roundtable (FRTR). He provided a brief overview of the agenda and noted that the meeting was broadcast live via the Internet. Attendees were given the opportunity to announce any events or activities relevant to FRTR interests.

Tom Nicholson (U.S. Nuclear Regulatory Commission) reported that the 2009 Fall Meeting of the American Geophysical Union (AGU) would be held 14-18 December in San Francisco, California. The Nuclear Regulatory Commission, International Atomic Energy Agency, and Lawrence Berkeley National Laboratory have organized sessions on environmental remediation and confirmatory monitoring. Approximately 53 papers will be presented, covering a wide range of organics, metals, and radionuclides contamination issues. The abstracts will be available on the AGU Web site (www.agu.org/meetings/).

Carol Dona (U.S. Army Corps of Engineers) said that the Green and Sustainable Remediation Subcommittee is working on defining what constitutes the environmental footprint of a cleanup and the metrics involved. The group is seeking new participants, and those interested can contact Dona or Kirby Biggs (EPA/OSRTI) for additional information. In addition to Dona and Biggs, the subcommittee's agency points of contact are Carlos Pachon (EPA/TIFSD), Erica Becvar (Air Force Center for Engineering and the Environment [AFCEE]), Karla Harre and Issis Rivadineyra (Naval Facilities Engineering Service Center), Beth Moore (U.S. Department of Energy), and Kevin Roughgarden (U.S. Army).

Kim Brown, Naval Facilities Engineering Command (NAVFAC), disclosed that the Navy is developing green and sustainable remediation case studies, and the NAVFAC Optimization Workgroup is incorporating a section on green and sustainable remediation into its guidance.

David Carrillo (U.S. Air Force) noted the release of a request of inputs for the development of the Defense mission needs requirements for a wide range of research and development initiatives, including energy impacts and environmental remediation. Results should be consolidated by February 2010.

Anna Willett of the Interstate Technology & Regulatory Council (ITRC) announced that ITRC is offering 2-day classroom training on the VI pathway. The classes include interactive presentations, hands-on exhibits, informative handouts, and problem sets. The 2010 sessions are scheduled for March 22-23 in Norfolk, Virginia, July 12-13 in a location not yet determined, and October 4-5 in Atlanta, Georgia. The classes are not free, but scholarships are available to federal agency staff. The ITRC membership process begins November 16, and technical experts from federal and state agencies are welcomed. A new team focused on environmental molecular diagnostics will begin work in 2010 to gather and organize information concerning advanced diagnostic techniques, such as molecular biological tools that can identify and quantify key microorganisms and their genes, and compound-specific isotope analysis, a chemical method that measures the relative abundance of different isotopes. Information on training opportunities and the project teams is available on the ITRC Web site (www.itrcweb.org).

Jeff Heimerman (Deputy Director, EPA/TIFSD) informed the assembly that the Strategic Environmental Research & Development Program (SERDP) released its annual Core and SEED solicitations for FY 2011 on October 29, 2009. Funds are available through a competitive process to both federal and private organizations to perform environmental research and development. For the Core solicitation, pre-proposals from the non-federal sector are due January 7, 2010, and federal proposals are due March 11, 2010. In addition, SEED Statements of Need (SON) were released for several focus areas. All SEED proposals are due March 11, 2010. Detailed instructions and the SONs are available on the SERDP site under the "Funding Opportunities" link (www.serdp.org/funding/). A webcast, *SERDP Funding Opportunities*, conducted by SERDP's Executive Director, Dr. Jeffrey Marqusee, will be archived for viewing on Clu-In (www.clu-in.org/conf/tio/serdpfunding_111309/) following its November 13 presentation. The briefing provides information for those interested in responding to new funding opportunities available through SERDP in Fiscal Year 2011.

FRTR ADMINISTRATIVE AND BUSINESS ISSUES

Jean Balent (EPA/TIFSD) described plans to update the 1998 FRTR *Field Sampling and Analysis Technologies Matrix* (archived at www.frtr.gov/site/samplematrix.html). Work will commence in December 2009, aiming for completion by June 2010. The project will involve reviewing the technology descriptions, reevaluating the current resources, identifying new resources, and updating the matrix to reflect current practices. Volunteers interested in helping review and update the matrix, or to provide comments on the update, should contact Balent.

John Kingscott (EPA/OSRTI) drew attention to the new *Federal Remediation Technologies Roundtable Annual Summary of Activities: September 2009* (www.frtr.gov/publib.htm). The summary format has been expanded to include highlights from the presentations on green remediation that were given at the December 2008 FRTR meeting. The fact sheet also summarizes activities of FRTR member agencies and describes the status of cost and performance resources, including recently completed case studies and reports. Hundreds of reports are available in the searchable Cost and Performance Case Studies Database (www.frtr.gov/costperf.htm).

Kingscott also announced that a representative from each member agency present would be asked to cast a ballot to select a topic for the technical session at the spring 2010 Roundtable meeting, with the results to be announced at the end of the meeting.

MEETING OBJECTIVES: INTRODUCTION

Arnold Layne reviewed the overall objectives for the meeting:

1. Improve communication and common understanding of vapor intrusion (VI).
2. Share experience and lessons learned in advancing best practices.
3. Outline key issues and develop shared strategies to address them.
4. Develop a "charge" for future FRTR action in VI.

He introduced Dr. Elizabeth Southerland, the Director of the Assessment and Remediation Division in OSRTI. Dr. Southerland has worked for EPA in both the Water and Superfund programs as well as in state government and private consulting.

MEETING OBJECTIVES: PERSPECTIVES

Dr. Elizabeth Southerland said that sites originally listed for groundwater problems now are being revisited to determine if the sites have VI problems—a huge undertaking for the Superfund Program. EPA's Hazard Ranking System does not provide for recognition of VI pathways, but it is understood that VI characterization probably will be required at the time of listing for sites having volatile organic compounds (VOCs) in the groundwater. She listed the top five things known about VI across all the federal agencies:

- Once organic compounds have been introduced into the subsurface, very complex fate and transport processes can move them aboveground into buildings.
- No single set of monitoring data is sufficient to indicate that a VI problem exists; multiple lines of evidence are needed with data for groundwater, soil gas, sub-slab gas, and indoor air.
- A site team should consist of a remedial project manager (RPM) or on-scene coordinator (OSC) as project manager, a risk assessor, a hydrogeologist, an attorney, and lab experts. The team needs a good conceptual site model to help them design the sampling program and define the sampling strategy and data quality objectives.
- To derive appropriate VI cleanup levels, assessors have begun focusing on inhalation dosimetry methodology rather than route-to-route extrapolation from ingestion pathways.
- Practical experience has shown that certain mitigation approaches seem to work better for new construction, and other approaches work better for existing buildings.

Southerland then identified five major VI knowledge gaps:

- Accurate prediction of VI with fate and transport models is lacking, hence the need for actual monitoring data in multiple lines of evidence.
- Streamlined monitoring to identify a complete pathway has not been achieved—it is so expensive to identify a complete pathway that it can be cheaper to install a mitigation system than to undertake full VI characterization and monitoring.
- It is still unclear which mitigation methods are most cost effective. Sub-slab depressurization is currently considered the dominant method, but depending on the site, other mitigation methods may be more appropriate.
- Implementing VI monitoring where homeowners are reluctant to accept the intrusion is a challenge, especially when dealing with a transient population concerned primarily with property values. Community engagement techniques are needed to facilitate in-house monitoring.
- Evaluating and implementing the best institutional controls to address VI is difficult, especially considering the need for flexibility to adapt to future land uses.

VAPOR INTRUSION TOPIC INTRODUCTIONS

U.S. EPA

Helen Dawson (EPA/OSRTI) identified VI resources recently issued by EPA (Attachment A):

- The presentations from the January 2009 National Forum on Vapor Intrusion have been posted on the EPA Web site (www.epa.gov/osp/hstl/viforum09.htm).
- An Engineering Issue, *Indoor Air Vapor Intrusion Mitigation Approaches* (EPA/600/R-08-115), was published in October 2008. www.clu-in.org/issues/default.focus/sec/Vapor_Intrusion/cat/Overview/
- In April 2009, EPA released OSWER 9200.2-72, *Operational and Functional Determination and the Transfer of Fund-Lead Vapor Intrusion Mitigation Systems to the State* (http://epa.gov/superfund/policy/pdfs/VaporGuidance04092009.pdf).

EPA currently has many resources under development:

- Three technical reports: 1) *Indoor Air Background Levels of Contaminant Vapors*, 2) *U.S. EPA's Vapor Intrusion Database: Preliminary Evaluation of Attenuation Factors*, and 3) *Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils.*
- The Vapor Intrusion Database (http://iavi.rti.org/).
- Several policy documents: *Toxicological Review of Trichloroethylene* (re-released November 3, 2009, http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=215006) and a policy statement on when to address VI in non-residential settings.
- A set of 55 frequently asked questions (FAQs) for VI considerations in the Superfund Program are divided into seven categories: general information, site assessment, sampling and analytical considerations, risk assessment and toxicology, mitigation, post-construction management, and community involvement and outreach.
- A VI roadmap.
- A spreadsheet version of the Johnson and Ettinger model that will incorporate regional screening levels and the new method for calculating the toxicity.

EPA is developing a response to the draft report on VI issued in July 2009 by the Office of Inspector General. The draft report contained two recommendations: quickly release a document that says what is applicable and what is outdated in EPA's 2002 *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils*, and finalize the draft VI guidance and expand its scope. The document addressing the first recommendation should be issued in the summer of 2010. Several more years will be required to finalize a VI guidance. The VI roadmap is designed to serve as a functional guidance document. It will restate the relevant parts of the 2002 guidance, while updating others. The roadmap will cover hazard identification, vapor source screening, exposure assessment, and risk decision making.

Question: Will the updated VI guidance discuss intrusion of radionuclides, such as tritium, radon, and carbon-14?
Answer: That has never come up in the workgroup discussions.

Comment: At the U.S. Geological Survey's Aramagosa field site, research on movement of water, gas, and chemicals (tritium, radiocarbon, VOCs, and mercury) through the unsaturated zone is being supported by multiple lines of data. This work has revealed the potential for organic compounds to convey radionuclides, particularly carbon-14.

Question: How does the roadmap deal with feasibility studies and remedial investigations? Are VI remedies packaged with the remedy for groundwater?
Answer: The FAQs rather than the roadmap discuss how to approach characterization and remediation of groundwater and minimization of the VI pathway. In some instances, VI mitigation has been implemented as a temporary measure during the design of the groundwater remedy. This issue will be addressed in the final guidance.

Question: Will the recently revised TCE toxicity values drive the concentration level down in terms of acceptable level of risk?
Question: If the draft values that are in the ORD reassessment and the standard exposure parameters that are used to calculate EPA's other screening levels are applied, then the answer is yes, but first it will have to undergo a lengthy review process.
Question: Then fast-forwarding 3 or 4 years, will remedies that currently meet protective levels have to be revisited in light of the change to lower protective levels?
Answer: Superfund uses the 5-year review process to respond to these kinds of changes.

U.S. Air Force

David Carrillo (U.S. Air Force) said that the Air Force had learned from dealing with radon migration issues to put in a generic design requirement for a passive mitigation system in new buildings. Movement of vapors outside the base boundary, however, is a major concern that requires the involvement of the Surgeon General's office.

U.S. Navy

Kim Brown (NAVFAC HQ) reported that the Navy has found about 59 potential VI sites contaminated with chlorinated VOCs and eight affected by petroleum-related VOCs (Attachment B). Several efforts are underway to support environmental RPMs addressing the VI pathway. The Navy's efforts focus on providing RPMs with consistent and technically defensible closure-oriented strategy and resources for VI assessments, such as the Navy's 2008 VI policy, the 2009 DoD VI handbook, a VI focus group, the Navy Best Practices Project, a Navy VI conceptual site model checklist, and a Navy background VI document. The VI focus group brings together VI technical leads from NAVFAC, the Naval Facilities Engineering Service Center (NFESC), the Navy Marine Corps Public Health Center, Navy contractors, and industry experts.

The goal is to provide technical expertise to RPMs in support of VI-specific projects, develop decision tools for VI investigations that address confounding issues with background indoor air sources, soil gas/air temporal and spatial variability, and attenuation factor variability. The Best Practices Project, funded by the Navy Research Program, supports research to identify improved assessment strategies for VI that will minimize the need for intrusive sub-slab samples, identify sampling methods to improve exposure estimates, and identify methods for indoor air source separation to tease out background contributions. Passive adsorptive samplers and pressure cycling have been selected for demonstration. NFESC has developed a VI conceptual site model checklist and is collaborating with the focus group to develop a VI Web tool. Following three earlier documents on background analysis (soil, sediments, and groundwater, respectively), the Navy is developing a fourth volume in the series. The VI background analysis guidance focuses on exploratory data analysis methods, forensic methods, and statistical methods.

Links to the *DOD Vapor Intrusion Handbook* and the *Review of Best Practices, Knowledge and Data Gaps, and Research Opportunities for the U.S. Department of Navy Vapor Intrusion Focus Areas* can be found in Clu-In's Vapor Intrusion Issue Area (www.clu-in.org/issues/default.focus/sec/Vapor_Intrusion/cat/Overview/).

U.S. Army Corps of Engineers

Mark Fisher (U.S. Army Corps of Engineers) explained that the Army is in the process of updating the Interim Vapor Intrusion Policy of November 6, 2006 (Attachment C). The final VI policy is expected to be signed in the near future (Fall/Winter '09/'10). The policy will address the Army's position on regulatory drivers that guide the use of environmental funding; the use of existing technical guidance; VI pathway assessment procedures; considerations for buildings, undeveloped property, and transferred property; and 5-year review considerations. The U.S. Army Corps of Engineers' Environmental and Munitions Center of Expertise (EM CX) has started a process by which CERCLA and RCRA documents are reviewed for vapor intrusion concerns and vapor intrusion technical assistance is provided to all EM CX customers.

SERDP/ESTCP

Andrea Leeson (SERDP/ESTCP [Environmental Security Technology Certification Program]), gave an overview of SERDP/ESTCP VI initiatives undertaken since 2001 to develop an improved understanding of the vapor intrusion pathway from chlorinated solvent-contaminated groundwater plumes (Attachment D). Current projects build upon the knowledge gained from the earlier work. Two ongoing VI projects are funded under SERDP:

- Project ER-1686, "Integrated Field-Scale, Lab-Scale, and Modeling Studies for Improving the Ability to Assess the Groundwater to Indoor Air Pathway at Chlorinated Solvent-Impacted Groundwater Sites"
- Project ER-1687, "Vapor Intrusion from Entrapped NAPL Sources and Groundwater Plumes: Process Understanding and Improved Modeling Tools for Pathway Assessment."

ESTCP has three current VI projects:

- Project ER-0702, "Application of Advanced Sensor Technology to DoD Soil Vapor Intrusion Problems"
- Project ER-0707, "Protocol for Tier 2 Evaluation of Vapor Intrusion at Corrective Action Sites"
- Project ER-0830, "Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling Techniques"

Several VI projects have been selected for funding in 2010, but contracting procedures have not yet been implemented for these starts. During a VI technical exchange workshop planned for Spring 2010, the SERDP/ESTCP-funded researchers will exchange information with people dealing with VI issues in the field. Leeson is seeking representatives from EPA, the services, and other agencies to invite to the meeting, and she urged the Roundtable attendees to send her their recommendations for meeting participants.

VAPOR INTRUSION TOOLS AND TECHNIQUES

Improved Investigation Methods to Distinguish Vapor Intrusion from Indoor Sources of VOCs

Tom McHugh (GSI Environmental, Inc.) described the challenges involved in distinguishing between indoor organic contaminant sources and the intrusion of contaminated vapors from outside sources (Attachment E). Indoor sources of VOCs are ubiquitous, resulting in detectable concentrations in indoor air, often at concentrations above regulatory screening levels. At VOC-contaminated sites with potential VI concerns, the presence of indoor VOC sources (e.g., glues, plastics, cleaning products, lubricating sprays) significantly complicates the exposure pathway investigation. McHugh identified a variety of common household products that contain tetrachloroethene.

Because of the frequent presence of indoor sources, the detection of a site-related VOC in a potentially affected building at a concentration above the regulatory screening level does not necessarily indicate a VI impact. Instead, additional analysis is required to determine the sources of the detected VOCs. Multiple approaches are available to distinguish between VI and indoor sources of VOCs: 1) real-time onsite analysis using a field-portable gas chromatograph/mass spectrometer (GC/MS) to evaluate the distribution of VOCs within a building and to identify specific indoor sources of VOCs; 2) collection of indoor air and sub-slab soil gas samples under controlled negative building pressure conditions designed to maximize vapor intrusion and controlled positive building pressure conditions designed to inhibit vapor intrusion; and 3) use of compound-specific stable isotope analysis to determine the original source of VOCs detected in indoor air samples.

Although real-time onsite analytical methods can be very useful for identifying indoor sources, the limitation of all the real-time approaches is that they are expensive. A HAPSITE® GC/MS sells for about $125,000, and a TAGA unit costs about $10,000 per day. Although each of these methods has proved useful in distinguishing between VI and indoor sources of VOCs, access to them is limited by their cost.

Under natural conditions, building pressure can vary between positive and negative. Most houses are negatively pressured because they leak. Building pressure can be manipulated: controlled negative building pressure maximizes VI, and controlled positive building pressure turns off VI; however, sampling under controlled building pressure conditions may not be feasible in very large or very leaky buildings. Sampling indoor air under controlled pressure is being examined under ESTCP Project ER-0707, "Protocol for Tier 2 Evaluation of Vapor Intrusion at Corrective Action Sites." This work has in part involved characterizing building foundation permeability through induced depressurization using indoor radon concentration as a tracer.

Compound-specific stable isotope analysis (CSIA) can be used to determine the original source of VOCs detected in indoor air samples. Isotopes have the same number of protons (an identical atomic number), but a different number of neutrons (different atomic mass). Stable isotopes, such as carbon-13 (^{13}C), do not undergo radioactive decay. Differences in isotope ratios between samples can indicate different sources. A small proof-of-concept study was conducted at Hill Air Force Base (AFB) using this technique to measure four indoor sources, three subsurface samples, and two indoor air samples. Part of the study involved placing a never-used spray can of gun cleaner consisting of 100 percent trichloroethene (TCE) in a sealed flask and measuring the air in the flask after 20 minutes. Over 1 ppm of TCE had built up in the jar during that brief period of time. ESTCP Project ER-201025, starting in early 2010, will support the full validation of the CSIA method.

Multiple approaches—a range of methods likely to vary in cost, complexity, equipment—are recommended to distinguish between VI and indoor sources of VOCS. The "best" method is likely to vary by chemical and by building. It is helpful to have protocols for each of the approaches so that all participants can agree on the amount and kind of data needed, as well as its interpretation and validation.

Question: With reference to the use of the radon tracer, how long was it necessary to pump clean air into the room to achieve a low radon concentration?

Answer: Pumping started 12 hours prior to sample collection—essentially overnight. In even a tight building under normal ventilation, expect at least six air exchanges per day. Twelve hours of pumping is a minimum of three air exchanges, which achieves about 90 percent of a new steady-state condition.

Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling Techniques

Todd McAlary (Geosyntec Consultants, Inc.) identified the effects of spatial and temporal variability on the sampling data as one of the major challenges encountered when characterizing a VI pathway (Attachment F). The work conducted under ESTCP Project ER-0830 is designed to demonstrate the applicability of lower-cost alternatives for sampling and analysis of VOCs in indoor air and soil gas during investigation of subsurface VI to indoor air. Laboratory analysis of indoor air, outdoor air or soil gas samples by EPA Method TO-15 is currently the most common method used for VI assessments, but it typically costs $250 to $400 per sample, depending on the reporting limit required. Passive diffusive sampling and analysis can be 30 to 50 percent less expensive. The passive samplers also have at least three technical benefits: 1) they can be used consistently by different operators with minimal training, 2) they can be deployed over relatively long periods of time, which would provide a long-term average concentration more suitable for assessing risks over long exposure periods and minimizing temporal variability inherent in shorter-term samples, and 3) they are significantly smaller and less obtrusive than SUMMA canisters, and hence less disruptive to building occupants. In the radon field, the preferred sampling duration is greater than three days and some methods collect samples over one year. Long-term average concentrations are more representative for risk assessment. Short-term variability can lead to requests for more monitoring with no real benefit gained.

Four types of passive diffusive samplers (gas/solid absorption)—SKC Ultra II Badge, ATD tube sampler, PDMS sampler, and Radiello sampler—will be tested against SUMMA canisters (whole-gas sample) and ATD tubes (active gas/solid adsorption), two conventional active gas sampling methods. Each of the passive diffusive samplers contains solid adsorbent media that trap VOCs over time during exposure of the sampler to indoor air or soil gas. Each has different materials of construction and geometries that make them sufficiently different to justify comparative testing. None were designed specifically for soil gas monitoring; however, the benefit of having data from both soil gas and indoor air is very attractive for VI assessments, so the proposed research is designed to test their applicability to soil gas as well.

Ten target compounds were selected for the controlled laboratory experiments to span a range of compounds of interest for VI studies: benzene, carbon tetrachloride, naphthalene, 1,1,1-trichloroethane, 1,2,4-trimethylbenzene, 1,2-dichloroethane, 2-butanone, n-hexane, PCE, and TCE. The testing will include controlled laboratory experiments at 1, 50, 100, 1,000, 10,000, and 100,000 parts per billion by volume at various temperatures, relative humidities, and wind speeds. The laboratory experiments are expected to be underway within the next month. Field testing will be conducted as early as spring 2010 at one or more DoD sites. Ideally, the field testing will be able to piggyback on sites with existing data or data to be collected because that will reduce the cost of providing control data. Sites with high concentrations are preferred to minimize the number of non-detect results and thereby maximize the statistical power of the data sets.

Question: Please comment on the effect of indoor relative humidity on volatile compounds.

Answer: Relative humidity is key when using adsorptive sampling techniques. Its effect can be managed in one of two ways, either by reducing the volume of air flowing through the sampler or increasing the total amount of absorbent medium. Relative humidity can vary from 20 to 95 percent in outdoor air, although the indoor range is usually subject to control and tends to be narrower than the outdoor range. Relative humidities of 30, 60 and 90 percent will be tested during the laboratory phase of this project. Conventional methods like SUMMA canisters are less sensitive, although it may be necessary to add moisture to the canister to facilitate recovery of more sorptive compounds like naphthalene.

Detailed Indoor Air Characterization and Interior Source Identification by Portable GC/MS
Kyle Gorder (Environmental Restoration Branch, Hill Air Force Base, Utah) summarized the methods and challenges of the Hill AFB Vapor Intrusion Program, described the successful use of the portable Inficon HAPSITE® GC/MS for locating interior sources, and provided examples of indoor air investigations (Attachment G).

Traditional sampling of indoor air with off-site analysis typically involves the collection of one to three indoor air samples, sometimes in conjunction with one or more sub-slab samples. Although the distribution of VOCs within and below a building may be suggestive of the source, the results obtained from traditional indoor air sampling and analysis methods are rarely definitive. The time and expense associated with off-site analysis of indoor air samples limits the ability to identify the source of VOCs detected in indoor air samples definitively.

Gorder said that VI assessments tend to follow either a bottom-up investigation strategy, which proceeds from assessments of contaminant concentrations in the groundwater or soil gas, or a top-down strategy, which focuses first on determining indoor sources. Hill AFB has favored the top-down approach primarily because indoor air samples are a direct measurement of potential exposure point concentrations. Samples are collected over a period of 24 hours using SUMMA canisters. The samples are analyzed using method TO-15. Prior to sampling, samplers conduct a detailed chemical inventory and product inspection to identify background sources in the home. The chief disadvantage of the top-down approach is that it does not distinguish between vapor sources.

A portable GC/MS can be used to conduct detailed indoor air characterizations for the assessment of potential VI and for the identification of interior sources. The chief advantage of using onsite analysis is that the rapid analytical results can be used to guide the collection of additional samples. This real-time feedback allows the investigator to focus additional sampling on the specific portion of the building that exhibits the highest VOC concentration. Within a few rounds of sampling and analysis, the investigator often can identify a specific indoor source or VI entry pathway. The ability to identify a specific interior source minimizes the frustration of affected residents and prevents unnecessary mitigation. On the other hand, if specific routes of VI are identified, mitigation measures can be evaluated and implemented to prevent future VI.

TCE present in the groundwater affects seven cities that surround Hill AFB. Approximately 2,900 homes have VI potential. Gorder offered several case studies that illustrated both public relations issues and techniques for conducting detailed indoor air characterization. At one residence where installation of a vapor remediation system (VRS) had not reduced indoor TCE below its action level, sampling results suggested the garage as a source. Further investigation revealed sources consisting of a TCE-containing tire repair kit and a pair of gloves stained with an oily substance. The samplers suggested the homeowners move these objects from the garage to the backyard storage shed. Follow-on sampling showed no change in the TCE levels because the homeowners declined to remove the items.

Question: What was behind the policy decision to use a top-down approach rather than bottom-up? It requires a lot of time, effort, and resources to identify and separate out background sources rather than verifying VI is occurring. Will the base continue to follow this approach?

Answer: Many factors went into making the decision, but the primary driver was public relations. It is easier to communicate the findings. Inside sources have been discovered in 15 to 18 homes, while VRS mitigation in nearly 100 homes has successfully fixed their indoor air problems. The conclusion from those homes is that VI likely was occurring. A widespread VI problem clearly is associated with the Base, but the presentation was intended to highlight the potential of interior sources to affect indoor air.

Question: What are the elements that go into the cost estimate of $45,000 per sub-slab VRS?

Answer: The main cost element is monitoring, assuming quarterly measurements will be collected over the long term. The estimated timeframe for cleaning up these very large, dilute plumes of chlorinated solvents is 75 to 80 years, during which time monitoring would continue. Hill AFB offers to compensate homeowners for mitigation system electrical costs.

Question: Please comment on the VI experience at Hill AFB in light of the conventional but sometimes unrealistic guidance to remove all indoor sources from the house before sampling.

Answer: It is a good idea if it can be done, but staff employed to do routine sampling regularly find and remove obvious chemical sources. Residents are often unaware of what kinds of chemical products might constitute a contaminant source.

Question: Was the VI program at Hill AFB implemented in response to health complaints?

Answer: No, this VI program started in response to a question at a public information meeting. A member of the audience asked if his house could be tested. The incident occurred before VI became a major area of concern, but measurements showed TCE at 16 ppb_v, indicating that there might be a problem. A single resident asking for sampling essentially kicked off the program.

Site Investigation Issues

David Mickunas (U.S. EPA/Environmental Response Team) described his experiences with EPA's Trace Atmospheric Gas Analyzer (TAGA) mobile laboratory (Attachment H). The TAGA laboratory has provided analytical data at numerous sites around the country to help identify and resolve VI concerns. The mobile laboratory contains a Perkin-Elmer/Sciex® API TAGA IIe, which is a triple quadrupole mass spectrometer. The TAGA is a direct air monitoring instrument capable of detecting, in real time, trace levels (points per trillion) of many organic compounds in ambient air. The TAGA can be operated in a stationary or mobile mode. In the stationary mode, the TAGA mass spectrometer/mass spectrometer (MS/MS) system uses a 400-foot Teflon tube to sample indoor air from rooms within and outdoor air adjacent to the potentially impacted structures. The TAGA has the unique capability to locate and differentiate lifestyle sources of toxic gases (emissions from solvents, paints, gasoline) from the outside ambient air and/or emissions from subsurface gases. In the mobile mode, the TAGA can isolate sources that are polluting the outside ambient air by driving along roads and lanes adjacent to structures.

The TAGA mobile laboratory also has an Agilent® 7890A gas chromatograph and 5975C mass spectrometer. This GC/MS system can perform VOC analysis of outdoor and indoor ambient air samples or sub-slab and soil gas samples collected in Tedlar® bags. The Tedlar® bags can be introduced via an OI 4660 purge-and-trap sample concentrator or a loop-injection 10-port valve. Additionally, an Agilent® MicroGC is on board the laboratory. The MicroGC is a gas chromatograph fitted with dual columns and thermal conductivity detectors for the analysis of permanent gases (O_2, N_2, CH_4, CO, and CO_2). The permanent gas data are particularly informative when investigating vapor intrusion as a result of gaseous migration from landfills. The field analyses provide many benefits that are not available from a traditional fixed laboratory and standard sampling techniques. The TAGA mobile laboratory provides real-time or near real-time information with known data quality to permit good decision making in the field with the added benefit of considerable cost savings. Utilizing the capabilities associated with the TAGA mobile laboratories has produced data to eliminate many of the ambiguities associated with other VI investigation approaches.

In an occupied building, the use of sampling equipment from the TAGA laboratory typically accomplishes similar analytical results from a single sampling episode as those achieved using 24-hour time-weighted-averaged SUMMA canister samples, which requires two entries to deposit and retrieve. For indoor air analysis onsite using the TAGA, one minute of monitoring within each room of a structure gave immediate results similar to those from the SUMMA canisters. For sub-slab air analysis onsite using GC/MS analysis with the concentrator (45 minutes per sample), a one-minute grab Tedlar® bag sample gave results similar to those from the SUMMA canisters. For sub-slab air analysis onsite using GC/MS analysis with the loop injector (6 minutes per sample), a one-minute grab Tedlar® bag sample gave results similar to those from the SUMMA canisters. The equipment from the TAGA lab provides information in the field for real-time decision making and can minimize inconvenience to residents and reduce overall expenses.

Mickunas detailed several case studies—one of monitoring for subsurface intrusion source of TCE in Region 2 and the other of monitoring for signature compounds to determine subsurface gas intrusion at a chlorinated solvent site in Region 1—in addition to citing numerous examples and comparisons of techniques from other case studies. Experience with the TAGA technology has shown that it can provide quantitative and qualitative information to isolate confounding factors involved in VI studies. The interfering sources may be related to lifestyle products/operations, accidental/intentional releases, ambient air impacts, geological anomalies, or other factors. The TAGA mobile laboratory has demonstrated its utility for resolving the problems associated with the VI matrices.

Question: How many TAGA units does EPA have?
Answer: Three in buses, one in Las Vegas, two in Edison, New Jersey, and one in a cart in a trailer at Research Triangle Park, North Carolina.

Question: Have you calculated a limit to the size of the room in which the 150 liters per minute that the TAGA is pulling would cause significant depressurization?
Answer: No, but likely it would be the same type of depressurization that would result from operation of a vent in a bathroom, kitchen, or clothes dryer.

Question: Is an instantaneous TAGA reading taken indoors really comparable to a long-term 24-hour integrated SUMMA canister sample measurement?
Answer: The result from a 1-minute average taken with the TAGA is comparable to a 24-hour SUMMA measurement.

Question: Are more studies planned to correlate the results of long-term and short-term sampling?
Answer: The Emergency Response Team is data-mining the results from all the TAGA lab sites visited in the past. If good correlations are found, the study can move forward.

Microfabricated GC for Sub-ppb$_v$ Determinations of TCE in Vapor Intrusion Applications
Jim Reisinger (Integrated Science and Technology, Inc.) described the development of a fully functional microfabricated gas chromatograph (µGC) for the determination of low-/sub-ppb levels of TCE in indoor air for VI applications (Attachment I). This effort is funded under ESTCP Project ER-0702, "Application of Advanced Sensor Technology to DoD Soil Vapor Intrusion Problems."

The essential components of the µGC are a micro-preconcentrator/focuser (µPCF), micro-columns for chromatographic separations, and an integrated array of four chemiresistor (CR) microsensors for detection. The combination of chromatographic retention time with the response patterns for each analyte provided by the CR array increases the reliability of TCE determinations in the presence of co-contaminants. To achieve the low sub-ppb TCE detection limits in an approximate analysis timeframe of 15 minutes required for some VI applications, a high-volume sampling tube packed with 100 mg of Carbopack X has been added to the front end (prior to the µPCF). In addition, a pre-trap is being tested to preclude the intrusion of semivolatile compounds. On the basis of calibrations performed from 2 to 20 ppb of TCE in air, the calculated TCE detection limit is 0.06 ppb$_v$ (20-L sample). TCE can be separated from 9 common co-contaminants in less than 2 minutes. The µGC also can be adapted to the analysis of other VOCs of VI concern.

Two µGC prototype configurations are being developed. The portable µGC unit is designed for analyzing multiple samples at different locations throughout a home during a single site visit to evaluate potential sources of TCE in a forensic, site assessment-type mode; this unit can be used to assess potential indoor sources of TCE. The fixed µGC unit is designed for long-term operation (weeks, months) with wireless communications in a single location with multiple samples throughout each day for exposure and/or mitigation system performance assessments.

The project is being conducted in three phases. The SPIRON µGC sensor technology was selected in Phase I, which involved the screening of existing and emerging vapor detection technologies to determine the most promising technologies for VI applications. Phase II involves prototype construction and testing of the portable and fixed units. Extensive field demonstration of the portable and fixed prototypes will be conducted at Hill Air Force Base in Utah during Phase III to evaluate the practical use of the µGC for TCE determinations in various VI applications. The field demonstrations are planned for the summer of 2010.

Question: Do you envision the µGC unit as being compatible with the normal electrical supply found in a home?
Answer: Yes, in its fixed, "smoke detector" configuration.

Question: How hot does that unit become?
Answer: Because the system is low in mass and the cooling is focused, the heat is wasted quickly and the exterior does not become very hot.
Question: What is the interval for integrating the sample?
Answer: The quantitation would be a function of the signal represented by the peak. It is a matter of selecting a preconcentration volume and looking at that as the peak—probably a couple of minutes to get the detection limit.

Question: Has a path for commercial technology deployment been worked out?
Answer: The team is looking at technology transfer and working with people who have taken technologies to commercialization. Several instrument manufacturers are showing interest, but it is unlikely to happen by next year.

Question: Is the µGC a VI screening tool or a quantitative instrument for defensible decision making?
Answer: The µGC is an instrument that can be used by a trained field technician—no need for a high-powered chemist to operate the instrument. It will generate data that could be used with confirmation for TO-15 analysis, calibration, etc.

VAPOR INTRUSION CASE STUDIES AND LESSONS LEARNED

Air Force Strategy for Vapor Intrusion Pathway Evaluation

Cornell Long (AFCEE/TDV) provided a historical perspective on (Attachment J) Air Force response to VI concerns. The Air Force began evaluating the VI pathway in the mid-1990s using simple tools, such as the Farmer model, box model, and the earliest versions of the Johnson & Ettinger (J&E) model. Investigation of the VI pathway was neither uniform nor widespread at Air Force installations and guidance was lacking. As the regulatory community became more informed about the pathway and began to request VI assessments, the Air Force began to develop internal guidance to help RPMs address the pathway at their numerous chlorinated solvent and jet fuel-contaminated sites. As more sophisticated techniques became available, each of the services, in turn, began to develop service-specific guidance and technical approaches. In January 2009, the Office of the Secretary of Defense released the *DOD Vapor Intrusion Handbook*, a product of the Tri-Service Environmental Risk Assessment Workgroup. The Handbook was developed to serve as a resource for RPMs needing to investigate the vapor intrusion pathway at Defense sites. The handbook provides a general framework for conducting these investigations under the Defense Environmental Restoration Program and discusses both residential and occupational exposure scenarios that might occur on a DoD installation.

Long highlighted the elements of the handbook and compared it to guidance issued by U.S. EPA and the Interstate Technology Regulatory Council. He described specific Air Force approaches to address VI-related risk management and policy issues using a case study from Lowry AFB for illustration. The investigators used SUMMA canisters (Method TO-15) to take indoor air samples, one sample every two months for one year. Crawlspace air samples were also taken with SUMMA canisters. Sub-slab soil gas was collected at the end of the indoor air study, and groundwater monitoring results were used for J&E modeling. Concentrations were 100 to 1,000 times higher in sub-slab soil gas than in crawlspace air, and the VOCs had higher attenuation factors than those in indoor air. The crawlspace air TCE concentrations generally decreased through summer and early fall. Indoor air also showed a pattern—higher TCE levels in cool months, lower levels in warmer months.

Two houses exceeded CDPHE target risk level for TCE, but one residence was discounted due to indoor air contributing sources. The use of multiple lines of evidence allowed identification of the indoor air sources (furniture refinishing). The target risk level for indoor air was exceeded at one residence. The state required remedial action, and an active sub-slab depressurization system was installed. Only 13 of the 21 homes in study area could be sampled. Tentative plans were made to contact remaining owners and residents in the study area.

An AFCEE Broad Agency Announcement award was made in FY09 for "Validation of New Tools to Better Manage Vapor Intrusion Liability." This project will develop a set of tools to discriminate between indoor and subsurface sources of VOCs in buildings and document biotic and abiotic destructive processes occurring in the vadose zone that prevent or minimize VI impacts. Hill AFB has been selected as a demonstration site. (See additional project information at https://newafpims.afnews.af.mil/shared/media/document/AFD-091028-106.pdf)

Question: Did the J&E model use any information from the site geology?
Answer: Yes, data from the boring logs.

Question: How did the model prediction compare to the actuality?
Answer: It varied from house to house, comparing well at some houses and less well at others. Overall, it was a good guide and potentially a valuable screening tool when used with other information.

Comment: To capture the behavior of the soils, modelers at this site found closer values using the coarser-grained sediments as input to the model rather than those found in borings near the building.

Vapor Intrusion Pathway: A Practical Guideline

John Boyer (New Jersey Department of Environmental Protection) discussed the significance of the ITRC's national technical and regulatory guidance, *Vapor Intrusion Pathway: A Practical Guide* (www.itrcweb.org/guidancedocument.asp?TID=49), from the perspective of a state regulator (Attachment L). The document outlines the ITRC approach, and represents many of the lessons learned by regulators about this complex pathway over the last decade. The guide is the result of a combined effort of more than 100 professionals from state and federal regulatory agencies, consultants, environmental vendors, industry, and community stakeholders.

In 2004, only eight or nine states had developed or adopted VI regulatory guidance documents, but by 2009, 24 states had specific guidance. Because various states express a wide range of comfort about the data types that are acceptable for assessing a site, the ITRC approach is not prescriptive as to the specific investigative tools or technical methodology appropriate, but rather is intended to assist the investigator in understanding the factors and techniques that can be used to assess the VI pathway. The document also stresses the importance of using multiple lines of evidence (e.g., soil gas data, indoor air data, temporal patterns, background sources) when conducting a VI investigation. The text includes a comprehensive directory of mitigation methods, with detailed information on passive and active building control remedies, institutional controls, ongoing monitoring and maintenance, site-wide approaches and closure.

Boyer stressed that when discussing VI activities, it is important for all parties involved to use the same units (e.g., micrograms per liter, parts per million by volume) and to understand what they mean. This understanding is particularly vital to communication strategies for public relations, risk communication, and potential litigation.

Question: Is it possible to differentiate between the relative contributions from soil and from groundwater?

Answer: VI effects from contaminated soil can be addressed with remediation, because the soil can be removed or treated fairly quickly, whereas contaminated groundwater tends to call for VI mitigation over an extended period of time. Because these media are addressed differently, their relative contributions generally are not considered.

A Navy Vapor Intrusion Case Study Post-Mitigation

Dan Waddill (NAVFAC Atlantic) described a VI mitigation project that did not proceed as expected despite a textbook plume and excellent site characterization (Attachment L). An off-site VI investigation was conducted in a residential area adjacent to a Navy site based on results of a soil gas survey at the Navy property line. This fence-line soil gas survey was conducted following identification of VOCs in soil and groundwater, five-year operation, and then shutdown of an onsite soil vapor extraction system. An offsite phased VI investigation was conducted with soil gas sampling in neighborhood right-of-ways, followed by sub-slab soil gas, indoor air, and outdoor air sampling of residence overlying the identified vapor plume.

Mitigation systems were installed in homes with concentrations of VOCs in indoor air above state screening criteria. Mitigation consisted of the installation of portable activated carbon air purifying units (APUs) in basements and sub-slab depressurization (SSD) systems. With lower than expected reductions of VOCs in indoor air in some homes based on post-mitigation sampling results, the Navy has conducted additional post-mitigation sampling and is evaluating factors contributing to system performance and options for system adjustments, as the Navy works to continue to improve the indoor air quality of affected homes. The investigators noted that some residents were turning down the fans on the indoor mitigation units because they found the fans too noisy. The Navy continues to work in partnership with regulatory agencies throughout the VI investigation and mitigation process.

Question: What was the decision basis for installing an APU versus an SSD system?

Answer: Both types of systems were installed, but an APU system allows a very rapid response and decreases the indoor concentrations quickly, whereas installation of an SSD system requires contracting and mobilization in the field.

Question: How can appropriate functioning of the APUs be determined, as in knowing when to change the carbon. Is that determined from the indoor air measurements?
Answer: The carbon is changed on a regular cycle based on the manufacturer's recommendations. The APUs were intended to run only until an SSD could be installed to control the VI, after which the APUs were to be removed.

Question: If the APU is more effective in these houses than the SSD, is it not likely that there is an indoor source?
Answer: Given the high level of contamination in the sub-slab air, it seems unlikely that an indoor source is responsible for the high indoor levels.

Vapor Intrusion: Lessons from Radon Studies

Henry Schuver (U.S. EPA) pointed out that lessons learned during nearly 30 years of dedicated independent scientific study of the migration of naturally occurring radon gas into indoor air of residential structures are relevant to characterizing and mitigating the intrusion of chemical vapors (Attachment M). Schuver and co-author Ron Moseley (EPA/ORD) reviewed the literature on the radon studies for their relevance and possible future use in developing improvements in the confidence and efficiency of assessing anthropomorphic chemical-contaminant VI. Their findings are available in a paper[1] that formed the basis of the keynote presentation at the 2009 Vapor Intrusion meeting of the Air & Waste Management Association.

Much of the research of radon intrusion into indoor air, particularly in the early years, was presented in conferences and is documented in conference proceedings; however, thousands of relatively recent articles have been published. He discussed papers that appear to be particularly relevant to chemical VI.

Schuver briefly summarized the lessons from three types of radon studies:

- External-based studies: To know what is in indoor air, measure indoor air.
- Indoor air-based studies: The longer indoor air is measured, the better.
- Health outcome-based studies: Radon is a significant health risk and actions to reduce it may be health decisions of the utmost importance.

Question: The presentation slides show a map of areas at high risk for radon intrusion. What general fraction of the homes were tested for radon?
Answer: The numbers were rather low; however, of the houses that tested above the standard, about half took additional steps, such as more testing, and about half of those undertook mitigation measures.

Question: Do background sources complicate the assessment of radon as much as products containing volatile organic compounds complicate vapor intrusion studies?
Answer: There is evidence that some building materials—bricks, granite, marble—might provide a source term, but the influence of these materials as major radon contributors has been discounted.

---

[1] Schuver, H.J. and R.B. Mosley. 2009. Investigating vapor intrusion with confidence & efficiency (some observations from indoor air-based radon intrusion studies). Vapor Intrusion 2009. AWMA. http://secure.awma.org/presentations/VaporIntrusion09/Papers/Keynote.pdf

Question: Are there lessons learned from radon mitigation that might be applicable to mitigation of VOCs?

Answer: Yes. David Folkes of EnviroGroup Limited wrote a paper[2] about the effect of radon mitigation systems on levels of VOCs at the Redfield site located in Denver, Colorado, where a residential/commercial neighborhood lies over a chlorinated solvent plume. He concluded that careful installation of a standard radon mitigation system can be expected to achieve up to three orders of magnitude reduction in VOC concentrations about 70 percent of the time, depending on site-specific conditions.

Question: Testing for radon is relatively cheap. Are there any studies where testing for radon has been used as a surrogate for VI testing?

Answer: Tom McHugh[3] has co-authored a paper on it. Where there are multiple chemicals in the subsurface, EPA has used the chemicals that do not have common indoor sources as surrogates for the ones that do have common indoor sources. Radon can be used in the same approach to assess migration of gases through a slab foundation. In the simplest case, indoor radon concentrations that are in line with ambient concentrations suggest that vapor migration is not a problem. Even areas with very low levels of radon have enough to use it as a sensitive tracer for soil gas.

Question: Does the body of work on intrusion and mitigation of radon and VOCs appear to have had any effect on new home construction?

Answer: Although we have not evaluated any potential effects on new home building techniques, the *Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment* (http://www.brownfieldstsc.org/pdfs/BTSC%20Vapor%20Intrusion%20Considerations%20for%20Redevelopment%20EPA%20542-R-08-001.pdf) recommends proactive consideration of the potential for vapor intrusion by incorporating mitigation strategies into plans for new construction. Installing piping for air quality management in a new building is much less expensive than retrofitting an existing building. In northern New Jersey where radon levels typically are high, new buildings commonly include these piping systems. In some instances, EPA has included VI mitigation systems in the institutional controls specified for a site. Installation of mitigation systems in new and existing structures is also addressed in the 2008 ASTM standard (ASTM E2600), *Standard Practice for Assessment of Vapor Intrusion into Structures on Property Involved in Real Estate Transactions*.

Comment: VI mitigation systems can fail due to seismic shifts, high water tables, or flooding. Failure of a sump pump can invalidate the system. Common home modifications, such as installation of a new stove hood, also can affect mitigation system performance adversely. Maintaining the VI mitigation system requires long-term

---

[2] Folkes, D.J. 2002. Design, effectiveness, and reliability of sub-slab depressurization systems for mitigation of chlorinated solvent vapor intrusion. Presentation for U.S. EPA Seminar on Indoor Air Vapor Intrusion. http://www.envirogroup.com/publications/folkes_epa_seminar.pdf

[3] McHugh, T.E., D.E. Hammond, T. Nickels, and B. Hartman. 2008. Use of radon measurements for evaluation of volatile organic compound (VOC) vapor intrusion. Environmental Forensics 9(1):107-114. http://www.gsi-net.com/files/papers/McHugh_Env_Forensics_Radon.pdf

due diligence in revisiting the system periodically to look for changes in performance.

FOLLOW-UP FOR VAPOR INTRUSION SUBGROUP

The participants agreed that a collaborative FRTR VI subgroup similar to the subgroup for green remediation would provide useful regular input on the topic. Several people supported adding data to the VI database as a good starting point for collaboration. Development of a flow diagram for decision making was proposed as a sensible and effective approach that would work for the majority.

Helen Dawson volunteered to prepare a conceptual basis for collaboration on VI issues and population of the VI Database (http://iavi.rti.org/OtherDocuments.cfm?PageID=documentDetails&AttachID=369). The concept will be disseminated to FRTR participants to determine level of interest and potential level of participation.

Carol Dona volunteered to follow up with Army participants not present at the meeting to investigate their interest in joining a collaborative VI effort.

BALLOT RESULTS & WRAP-UP

Balloting for the next FRTR meeting topic indicated that low-energy technologies for groundwater and soil remediation is the topic of greatest interest to member agencies. Decision support tools also received a significant number of votes, with handwritten notes indicating specific needs for tools for dealing with uncertainty, sustainability, green remediation, and cost estimating.

John Kingscott suggested that useful products could be developed from meetings on these topics, such as a small handbook or brochure that summarizes low-energy technologies or decision support tools, with a bibliography indicating available resources. Any member interested in taking the lead in establishing the agenda for the spring 2010 meeting should contact Kingscott or Marti Otto.

Helen Dawson expressed the desire for a follow-on to radionuclide intrusion into indoor air and its applicability to chemical VI, and David Mickunas said that incorporating isotope ratios into the ongoing comparison studies of sampling approaches had intriguing potential.

Tom Nicholson suggested future attention to migration of tritium, carbon-14, and radon; the conveyance of carbon-14 and tritium by organic chemicals; microbial geochemical and hydrologic processes in the smear zone; and estimating radon flux rates from depleted uranium sources.

Jeff Heimerman saluted Erica Becvar in absentia and Marti Otto for putting together the agenda and thanked the speakers and participants for attending. The meeting was adjourned.

ATTACHMENTS

A. U.S. EPA Vapor Intrusion Update
B. NAVFAC Vapor Intrusion Activities
C. U.S. Army Corps of Engineers Vapor Intrusion Update
D. Overview of SERDP & ESTCP Investments in Improving Our Understanding of Vapor Intrusion
E. Improved Investigation Methods to Distinguish Vapor Intrusion from Indoor Sources of VOCs
F. Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling Techniques
G. Detailed Indoor Air Characterization and Interior Source Identification by Portable GC/MS
H. Site Investigation Issues
I. Microfabricated GC for Sub-ppb_v Determinations of TCE in Vapor Intrusion Applications
J. Air Force Strategy for Vapor Intrusion Pathway Evaluation
K. Vapor Intrusion Pathway: A Practical Guideline
L. A Navy Vapor Intrusion Case Study Post-Mitigation
M. Vapor Intrusion: Lessons from Radon Studies