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Note: biographies may be viewed online at www.aehsfoundation.org (see online program)

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Session 01: Environmental Issues Associated with the Cannabis Industry

What's all the Buzz and Environmental Concerns Regarding the Cannabis Industry?
Sam Williams, Geosyntec Consultants, San Diego, CA

Cannabis and Environmental Impacts: The Applicant's Perspective
Jessica McElfresh, McElfresh Law, Inc., Solana Beach, CA

A Cannabis "Consultant Turned Regulator" Perspective
Samuel LoForti, Nu Consulting Services, Aptos, CA

An Accredited Cannabis Testing Lab Perspective
Jeremy Sackett, Cascadia Laboratories, Portland, OR

Local Requirements for Cannabis Production Facilities
**Not available at the time of publication*

What's all the Buzz and Environmental Concerns Regarding the Cannabis Industry?

Sam Williams

Since the legalization of cannabis for recreational use in many states, numerous challenges have resulted from this growing industry. While local regulations regarding cannabis use have been relaxed, many companies doing work regulated by the Federal government are still required to comply with Federal requirements. Cannabis is a Federal Schedule I drug, meaning it has a high potential for abuse and no medical value according to the US government.

With the approval of the Adult Use of Marijuana Act in 2016 and subsequent legalization on January 1, 2018, cannabis cultivators in California are required to enroll in several environmental permits. This presentation will describe environmental compliance challenges and impacts considering the current legalization status of cannabis in the State. Of interest is the State Water Resources Control Board's new Cannabis Cultivation Program, approved in December 2017. This program addresses potential water quality and quantity issues related to cannabis cultivation and requires all cultivators to apply for coverage under the Cannabis Cultivation General Order. Additional interest areas include the requirement of permits for facilities not connected to municipal water supplies; compliance with the Stormwater Industrial General Permit; air permitting related to carbon filtration and odor control; and analytical requirements for potency, contaminants, and specific terpene signatures. Lastly the business opportunities and risks associated with the cannabis industry will be discussed.

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Presenting Author: Sam Williams

Cannabis and Environmental Impacts: The Applicant's Perspective

Jessica McElfresh

Since the passage of the Medical Marijuana Regulation and Safety Act in 2015 and Proposition 64 in 2016, California's cannabis industry has undergone true state regulation for the first time, and local regulation at a growing pace and level. Historically, local governments had focused on storefronts, or dispensaries. From 2015 onward, local governments and the state have begun to recognize and permit the supply chain, from seeds and clones to sale to a consumer. Along with enhanced consumer protection and transparency has come environmental regulation. Applicants must now deal with the California Environmental Quality Act as they seek licenses and they must follow ongoing, stringent state and local rules for water sourcing and usage, power, and pesticides. For many applicants, this is their first significant contact with local and state government regulation at this level, regardless of their background.

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A Cannabis “Consultant Turned Regulator” Perspective

Samuel LoForti

As the Cannabis Licensing Officer for Santa Cruz County, my goals are to assist with the creation of a legal cannabis market while stewarding changes to local regulations to align with the State while meeting the goals of the Board of Supervisors. As a previous consultant to the industry I worked multiple use permits, implemented track and trace programs for cultivators, manufacturers and distributors. I have gained a working knowledge of all aspects of the industry through this work and now, sitting on the other side of the table, I feel I have a well-rounded view of the permitting and enforcement process. The presentation will focus on common deficiencies in use permit applications, the lack of understanding some land use consultants have of the industry and the way that this impacts operators through the permitting process, and the value of a well-informed regulatory agency. Common deficiencies I’ve noticed are poor odor control plans and erosion control plans written to local regulations that do not take into account the Cannabis General Permit requirements.

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An Accredited Cannabis Testing Lab Perspective

Jeremy Sackett

Historically, medical cannabis programs at a State level have not had extensive controls in place for product quality. As legalization and regulation of cannabis items continues, the requirement of quality control testing is now recognized as a critical component of the expanded programs. Though there are new quality control testing regulations in some jurisdictions, there is still a gap in the availability of standardized reference methods. Additionally, many of the contaminates being regulated have not been studied for toxicity when introduced by inhalation, making the establishment of sound action levels for regulatory ‘pass/fail’ limits challenging. Furthermore, regulatory agencies have been faced with limited resources, which can lead to gaps in enforcement.

This presentation will be from the perspective of an accredited laboratory operating in Oregon and California cannabis markets. The presentation will provide a summary of the technical challenges faced by the laboratory and what typical testing regulations encompass, including points where improvement is needed.

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Session 02: Environmental Forensics

Rewind the Clock: Use of Environmental Forensics to Investigate Timing of Release
Lydia Dorrance and Adam Love, Roux Associates, Inc., Oakland, CA

Forensic Analysis of Perchlorate Sources Using a Three End Member Mixing Model Analysis (EMMA)
Michael Foster and Lindsay Ellingson, Kleinfelder, San Diego, CA

Using Sub-Slab Soil Gas Data in Lieu of Indoor Air Data to Evaluate the Effectiveness of a Passive Vapor Mitigation System
Matthew Hall, Terracon, Nashville, TN; Robert Roth, Terracon, Wheat Ridge, CO; Casey Portela and Michael Jordan, Terracon, Raleigh, NC

Navigating Site Redevelopment with an Off-Site Plume of Unknown Source – A Vapor Intrusion Case Study
Hilary Nevis, Avery Whitmarsh, and Doug Bablitch, Wood Environment and Infrastructure Solutions Inc., Oakland, CA

Lines of Evidence to Distinguish Indoor Source Effects from Preferential Pathway and Conventional Vapor Intrusion
Jennifer Simms, Jacobs, Indianapolis, IN; Christopher Lutes, Jacobs, Raleigh, NC

Source Evaluation for Per- and Polyfluoroalkyl Substances (PFAS)
Ioana Petrisor, ToxStrategies, Mission Viejo, CA

Rewind the Clock: Use of Environmental Forensics to Investigate Timing of Release

Lydia Dorrance and Adam Love

One of the most frequent, and often most confounding, questions asked about contaminated sites is: when were the contaminants released to the environment? Given the costs of environmental cleanups, the answer to this question can have critical impacts on the liabilities of the associated parties. Timing of release can result in the identification of responsible parties (RPs), factor in the allocation of cleanup costs among RPs, and determine whether the release falls within a RP's insurance policy period. While we often imagine a single, readily identifiable, moment when the contaminants of concern entered an environmental matrix, we will discuss the numerous ways in which timing of release can be assessed and how multiple lines of evidence can be used to provide further confidence in such assessments. Technical environmental forensic methods can be drawn from site operational history, chemical fingerprints, fate and transport and degradation pathways to hone in on the "when" of a contaminated site. However, even when combining multiple lines of evidence, caution must be applied, as an overly specific release timing can be at best difficult to defend and at worst undermine the credibility of an otherwise sound application of environmental forensics. Use of environmental forensics with an understanding of its limitations is needed to establish defensible conclusions regarding the timing of release.

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Forensic Analysis of Perchlorate Sources Using a Three End Member Mixing Model Analysis (EMMA)

Michael Foster and Lindsay Ellingson

Stable isotopes of oxygen and hydrogen in groundwater have been used to help better understand the recharge sources of groundwater downgradient of the Stringfellow Superfund Site in Jurupa Valley, West of the City of Riverside in California. The results indicated that recharge sources varied spatially with some areas having isotopically heavier groundwater as a result of hill-front runoff and recharge of local precipitation. Other areas with isotopically light groundwater reflect a component of recharge from water imported from adjacent basins recharged with water from the San Bernardino and San Gabriel Mountains.

A three end-member mixing model was used to estimate the proportions of perchlorate in groundwater originating from i) synthetic, ii) agricultural and/or iii) natural background sources. Multiple permutations of stable isotope combinations were used including $?^{17}O$, $?^{18}O$, $^{36}Cl/Cl$, $?^{37}Cl$ present in dissolved perchlorate in groundwater samples. The mixing model results are being used to differentiate perchlorate contaminated groundwater originating from the Stringfellow Superfund Site from other perchlorate present in groundwater in the Jurupa Valley. Other potential sources not from the Stringfellow Superfund Site include perchlorate containing nitrate fertilizers and imported water from other groundwater basins.

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Using Sub-Slab Soil Gas Data in Lieu of Indoor Air Data to Evaluate the Effectiveness of a Passive Vapor Mitigation System

Matthew Hall, Robert Roth, Casey Portela and Michael Jordan

Environmental investigations at a redevelopment site with historical dry cleaning and auto repair facilities detected tetrachloroethylene (PCE) and trichloroethylene (TCE) in soil gas at concentrations (up to 1,750 µg/m^3 and 165 µg/m^3, respectively) exceeding the US Environmental Protection Agency (EPA) residential vapor intrusion screening levels (VISLs) of 360 and 16 µg/m^3, respectively. Prior to construction of a mixed-use development, the site was entered into the state voluntary cleanup program (VCP), and a passive vapor mitigation system (VMS) was recommended to protect future residents from vapor intrusion risks. The VCP regulator approved the VMS, and required indoor air monitoring prior to occupancy and continued post occupancy air monitoring. Given that indoor air samples are easily biased by sources not related to intrusion through the slab, a system of sub-slab monitoring points was designed to evaluate sub-slab concentrations at various points of construction. The results indicated that the system was effectively mitigating the accumulation of vapors beneath the slab, and the concentrations were below the EPA residential VISLs for indoor air in each of the events. An argument was put forth to the VCP regulator that, given the sub-slab data collected during the monitoring events, indoor air testing was not required. This case study aims to demonstrate alternatives to indoor air sampling, which could lead to detections of alternative indoor air sources, and, ultimately, cause delays in occupancy or later evacuations of newly constructed buildings.

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Navigating Site Redevelopment with an Off-Site Plume of Unknown Source – A Vapor Intrusion Case Study

Hilary Nevis, Avery Whitmarsh and Doug Bablitch

Just prior to redevelopment of a former auto body shop in the greater San Francisco Bay Area into residential apartments, the unexpected discovery of tetrachloroethene (PCE) and other chlorinated volatile organic compounds in groundwater and soil gas at the site nearly derailed the redevelopment. Not previously considered constituents of concern, the local environmental regulatory agency required further investigation to evaluate the extents of the groundwater and soil gas impacts. One potential buyer fell through and the consultants who identified the impacts were held to the fire. Additional investigation indicated that the PCE was related to an off-site, upgradient source, but finding the source in an area with multiple historical dry cleaners and a web of utility lines seemed unlikely. The redevelopment was able to proceed, with the addition of a permeable reactive barrier (PRB) at the upgradient boundary to reduce PCE mass flux into the site and a vapor mitigation system (VMS) beneath the new buildings over the vapor plume. While the PRB was not expected to reduce on-site PCE concentrations in groundwater in the short term, it was hypothesized that PCE concentrations in soil vapor would decline significantly following removal of utility lines during site demolition. Once the VMS, which included a vapor membrane and a passive sub slab venting system (with the potential to be converted to an active system), was operational the vapor concentrations in the vent risers corroborated this. The buildings are now becoming occupied and ongoing operations and maintenance activities require coordination with the local air board, environmental regulatory agency, developer, property manager, and tenants, all of which have separate objectives. This presentation will provide a summary of historical site characterization results, PRB and VMS design specifics, lessons learned from working with multiple stakeholders, and two years of operational and monitoring data collected post redevelopment.

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Lines of Evidence to Distinguish Indoor Source Effects from Preferential Pathway and Conventional Vapor Intrusion

Jennifer Simms and Christopher Lutes

Distinguishing the effects of indoor sources of volatile organic compounds (VOCs) from intrusion of site-related vapors has been challenging since the advent of vapor intrusion (VI) investigation, but it has recently become more challenging as the understanding of preferential pathways has developed. Case studies continue to arise showing vapor transport into buildings through preferential entry points, or direct off-gassing from contaminated groundwater that has entered the building. It was previously generally accepted that low VOC concentrations in subslab soil vapor indicated that VI was unlikely; however, it is no longer that simple due to the potential for unusual transport mechanisms. There is a greater need for multiple lines of evidence to evaluate the source of elevated indoor air VOC concentrations. This paper will discuss different methods that have been used to identify indoor VOC sources and preferential vapor transport including:

- Conducting building surveys
- Identifying and removing potential indoor VOC sources and sampling indoor air again
- Identifying indoor VOC sources with a real-time monitoring instrument (ppbRAE or HAPSITE) and removing them before indoor air sampling
- Sampling radon as a tracer gas
- Differential pressure measurements
- Comparison of constituent ratios
- Screening potential preferential vapor entry points with a ppbRAE or HAPSITE
- Sump water sampling or screening head-space air in sump pits with a ppbRAE or HAPSITE
- Sewer gas sampling
- Indoor air sampling under induced pressure conditions from a blower door

The effectiveness of each method to distinguish between indoor sources, conventional VI, and preferential pathways will be discussed. Methods will be compared with regard to their implementability, costs, invasiveness, and other considerations. Examples and lessons learned from field investigations will be shared while keeping those sites confidential. Examples will be discussed where multiple methods were applied and thus their probative value can be intercompared.

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Source Evaluation for Per- and Polyfluoroalkyl Substances (PFAS)

Ioana Petrisor

Per- and polyfluoroalkyl substances (PFAS) are undoubtedly some of the “hottest” and most challenging emerging contaminants worldwide. This group of compounds comprises potentially thousands of individual substances, with a large range of properties and environmental behaviors and potential to create issues at very low levels. Our current detection ability is limited to a small number of individual compounds, making environmental characterization, risk assessment, and remediation challenging. However, the fact that PFAS include a large number of complex compounds creates multiple forensic opportunities for source evaluation through chemical fingerprinting.

Fingerprinting techniques available to date include using the proportions of detected individual PFAS compounds to link samples to potential sources, evaluating isomer profiles (branched vs. linear compounds) and homologue patterns, and analyzing fluorotelomer sulfonates and total oxidizable precursors (TOPs). The data from chemical analyses can be evaluated using various graphical, statistical, or geospatial techniques. In addition, PFAS manufacturing history and the composition of different commercial formulations may provide potential useful signature chemicals (e.g., impurities or additives) for source identification on a case-specific basis. Fingerprinting data should be interpreted in light of the potential for differential transformation that may occur during environmental transport between potential sources and sampling points. This presentation will review the available fingerprinting methods and applications to source evaluation, and will provide representative examples from several case studies.

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Session 03a: Urban Runoff

PCBs Updated Regulations and its Implications to Industry
Michelle Rosales, Forensic Analytical Consulting Services, Rancho Dominguez, CA; John Martinelli, Forensic Analytical Consulting Services, Citrus Heights, CA

Non-Point Source Pollution and Infiltration of Stormwater Due to Low Impact Development Regulations
Kelly Steffen, TRC Solutions, San Diego, CA

PCBs Updated Regulations and its Implications to Industry

Michelle Rosales and John Martinelli

Buildings constructed, renovated and/or repaired between 1950 and 1979 are likely to have a variety of building materials containing polychlorinated biphenyl's (PCBs). The environmental health risks associated with PCBs in dielectric oil spills, fires, and waste sites where PCBs spills have occurred are well documented. However, recent studies show that the environmental health risks due to PCBs in building materials such as exterior caulks and sealants is not as well defined. Enforcement actions by US EPA 40CFR761 in relation to PCBs in building materials are continually evolving and it is sometimes described as a moving target; in addition, other regulatory agencies are now becoming more aware and setting their own rules (e.g. Storm Water Management Agencies) and proposing significantly more stringent testing protocols. Identifying locations of PCB containing building materials, their impact to the substrates with which they contact, their impact to the soils onsite, and to storm drains and water ways nearby can be a complex and controversial process. The need to manage these materials safely until they are removed is often in conflict with the onerous regulatory requirements that come in to play once the materials have been tested and found to contain PCBs. In May 2017, EPA published the *"PCB Facility Approval Streamlining Toolbox - A Framework for Streamlining PCB Site Cleanup Approvals",* to assist in expediting the process. However, theory versus real world situations continues to muddy the waters. To further complicate processes, poorly defined terms such as "no unreasonable risk" have begun entering the language of the regulators.

This session will discuss the key components of the May 2017 toolbox and draft guidance standards proposed by storm water management agencies, along with ongoing operational concerns associated with renovation and demolition projects where PCBs are present in building materials.

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Non-Point Source Pollution and Infiltration of Stormwater Due to Low Impact Development Regulations

Kelly Steffen

Urban stormwater is a leading source of contaminants to coastal oceans and inland waterways. Water quality and nonpoint sources in urban watersheds include vehicle emissions and applications of pesticides and fertilizers around homes and in public areas. Cities within municipal separate storm sewer systems (MS4s) are working towards reducing the total maximum daily load (TMDL) of pollutants that are discharged from MS4s to surface waters by implementing regional watershed best management practices (BMPs) that reverse the effects of urban hydromodification. More recently, required BMPs include implementation of low impact development (LID) concepts which aim to offset discharges to the MS4 so that stormwater can be retained and/or infiltrated through soils at the point of origin. Stormwater infiltration practices reduce runoff peak flows and volumes, promote groundwater recharge, and can mitigate the transport of non-point source pollutants to surface water bodies. Typical urban runoff contaminants include nutrients (i.e., phosphorus and nitrogen), heavy metals, suspended solids, petroleum hydrocarbons, pesticides, pathogens (i.e., bacteria and viruses), and chloride. Because southern California has infrequent rainfall, pollutants may accumulate on impervious surfaces, especially from “hot spots” such as roads, parking lots and industrial areas. There has been concern that pollutants present in discharges could contaminate groundwater and soil as a result of infiltration practices. The municipal ordinance enforces the LID practice of infiltration of stormwater, however the MS4 effluent limitations and discharge specification excludes groundwater as a receiving water, and therefore discharge to groundwater is unregulated, as described in Section II.F, MS4 Discharges within the Coastal Watersheds of Los Angeles County 2015. This presentation examines priority pollutants present at typical southern California parking lots, and evaluates LID techniques for stormwater management based on its ability to minimize risk to groundwater.

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Session 03b: Site Investigation

Evaluating Saltwater-Freshwater Dynamics in Coastal Aquifer Conceptual Site Model Development and Groundwater Management
Sean Culkin, Integral Consulting Inc., San Francisco, CA

Advantages of Passive Sampling as a Decision Making Tool
Michael Healy, Jeff Roberts, and Sandra Dworatzek, SiREM, Guelph, ON, Canada; Jason Conder, Geosyntec, Huntington Beach, CA; Matt Vanderkooy, Geosyntec, Guelph, ON, Canada

Phase II Site Investigation with Vapor Intrusion
Denise Yaffe and Mark Drollinger, Citadel Environmental Services, Inc., Glendale, CA

Evaluating Saltwater-Freshwater Dynamics in Coastal Aquifer Conceptual Site Model Development and Groundwater Management

Sean Culkin

Saltwater-freshwater dynamics have received increasing attention in coastal aquifer systems. Typically, these dynamics are studied with respect to seawater intrusion, which has been specifically categorized as an undesirable result in the California Sustainable Groundwater Management Act. However, understanding these flow dynamics also has implications for groundwater contaminant transport and remediation, as well as disposal of industrial wastewater in coastal areas. Variable-density groundwater models provide a flexible platform to evaluate saltwater-freshwater interactions on a site-specific basis; herein we present three different applications of model investigations for coastal groundwater remediation, industrial development, and sustainable groundwater management. The first case is a peninsular coastal aquifer system impacted by solvents. Previous conceptual site models did not accurately represent the nature of discharging contaminated groundwater. Evidence that seawater intrusion had a major impact on the transport of contaminants was corroborated by groundwater modeling coupled with direct observations of tidal saltwater dynamics at the site. The second case is a proposed discharge location for heated industrial water from a clean energy site in a productive coastal aquifer. Groundwater models were used to show that the discharge area for heated groundwater was constrained by intruding saltwater, which was used to evaluate the impact area to sensitive offshore habitat. The third case is an example of a modeling exercise to develop long-term management goals for mitigating seawater intrusion in a coastal aquifer system in central California in combination with various emerging remote sensing technologies. These examples collectively demonstrate the necessity of accurately estimating the location of the saltwater-freshwater interface in coastal aquifers for a variety of applications, and the utility of groundwater models to support these investigations.

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Advantages of Passive Sampling as a Decision Making Tool

Jeff Roberts, Jason Conder, Matt Vanderkooy, Sandra Dworatzek and Michael Healey

Passive sampling devices (PSDs) present numerous advantages over conventional sample collection methods for quantifying hydrophobic organic compound (HOC) availability in sediment, soil, surface water and storm water. PSDs can provide superior convenience, cost and data quality compared to conventional grab or mechanically-extracted samples. A major advantage of PSDs is their property of quantifying only the freely-dissolved, bioavailable, fraction while not measuring the sorbed, or non-bioavailable fraction. Measuring only bioavailable contaminants with PSDs provides a better measure of actual toxicity for environmental receptors and a lower tendency towards toxicity overestimation than conventional sampling methods.

This presentation will highlight examples where PSDs have been used in the laboratory and in the field for decision making in site investigation and remediation, including techniques and advancements that simplify and improve ease of sampling, increase data quality and lower costs. We will demonstrate how a rapid (2-week) passive sampling deployment was used to evaluate polychlorinated biphenyl (PCB) and polycyclic aromatic hydrocarbon (PAH) availability and associated risks at an active shipyard. A laboratory treatability case study will highlight the use of PSDs to evaluate the effectiveness of different levels of activated carbon to immobilize PCBs. The study reduced the remedial budget significantly by avoiding the addition of excess activated carbon amendment at this sediment site. A third case study will highlight the *ex situ* application of PSDs to evaluate the digestive availability of benzo(a)pyrene in soils contaminated with clay targets, using the results to derive an alternate human health risk-based cleanup levels that account for the low availability of clay target-associated benzo(a)pyrene.

Additionally, the presentation will review our recent advances in deploying samplers without the use of scuba divers, optimizing *ex situ* passive sampling with small sediment and soil samples, and the evaluation of new analytes.

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Phase II Site Investigation with Vapor Intrusion

Denise Yaffe and Mark Drollinger

Citadel performed a supplemental phase II site investigation that included a human health risk assessment from potential vapor intrusion at a commercial facility located in California. A dry cleaning business occupied one of the suites from approximately 1991 to 2002. A Phase II Environmental Site Assessment, conducted in 2000 reported concentrations of PCE and TCE in soil. However, groundwater and soil vapor samples were not collected. To delineate the extent of the contamination, Citadel advanced four soil borings at the Site for the purposes of collecting soil, groundwater and soil vapor samples. Levels of PCE, toluene, trichlorofluoromethane, chloroform, TCE and 1, 3, 5-trimethylbenzene were detected in soil vapor. Soil sample analysis resulted in one detection of chloroform at 0.0020 mg/kg and one detection of PCE at 0.0031 mg/kg. Groundwater samples had detections of chloroform, cis-1, 2-dichloroethene, PCE and toluene. Based on the findings, Citadel advanced three additional soil borings in the alley behind the Site for collecting soil vapor samples with the objective to evaluate the lateral extent of PCE in soil vapor to the hydraulically downgradient side of the building. Citadel also collected ambient air samples to evaluate the indoor air quality with respect to potential vapor intrusion. The Johnson – Ettinger Model was used to assess the human health risk from potential vapor intrusion. A carcinogen risk of 4.1E-06 for PCE at two feet was calculated. The cancer risk result is in the acceptable EPA cancer range for a positive risk management decision in a commercial setting. Concentrations of PCE observed in soil and groundwater are not residual sources for replenishing PCE in the vapor phase. The indoor air samples indicate that subslab concentrations of PCE are not impacting indoor air quality. Based on these results, Citadel recommended no further investigations with respect to soil, groundwater, soil vapor and indoor vapor.

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Presenting Author: Denise Yaffe

Session 04: A Renaissance in the Use of Horizontal Wells

Soil Vapor Extraction Using a Horizontal Remediation Well – Pilot Test to Full-Scale Operations
Sam Bailey, Kleinfelder, Riverside, CA

The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In Situ Remediation: Design, Implementation, and Sustainability Considerations
Craig Divine, Arcadis, Irvine, CA; Jeff McDonough, Arcadis, Newtown, PA; Michelle Crimi, Clarkson University, Potsdam, NY; J.F. Devlin, University of Kansas, Lawrence, KY

New Perspectives on Horizontal Wells for Assessment and Remediation
Erik Piatt, EN Rx, Inc, Flower Mound, TX; Stephen Koenigsberg, EN Rx, Inc., Irvine, CA; Lance Robinson, EN Rx, Inc., Parrish, FL; Wes Wiley, EN Rx, Inc., Denver, CO

Site Remediation Using Segmented Horizontal Well Systems in Areas without Ready Access
Glen Vallance, CGRS, Fort Collins, CO

Reconsidering Horizontal to Vertical Well Ratios for Site Clean-up
W. Richard Laton, California State University, Fullerton, CA

Distribution of Permanganate via Deep Horizontal Well Injection and Recirculation
Monica Fulkerson, Jacobs, Charlotte, NC; Matt Louth, Jacobs, Virginia Beach, VA; David Cleland, NAVFAC, Norfolk, VA; Charity Delaney, MCB Camp Lejeune, Jacksonville, NC

Soil Vapor Extraction Using a Horizontal Remediation Well – Pilot Test to Full-Scale Operations

Sam Bailey

Background/Objectives: At a site undergoing environmental investigation and remediation for petroleum-hydrocarbon impacts, the effectiveness of a horizontal remediation well (HRW) was evaluated to remove biogenic methane and petroleum hydrocarbon VOCs from the vadose zone. The first phase of remediation (Phase I), consisting of a traditionally configured soil vapor extraction (SVE) system with 15 vertical wells and a thermal oxidizer, had removed approximately 370,000 pounds of methane and VOCs, since October 2014. The conceptual approach for the second phase of remediation (Phase II) originally consisted of approximately 32 additional vertical SVE wells. This approach was modified to evaluate an optimized configuration consisting of HRWs that would limit near surface infrastructure and potential conflicts related to future site redevelopment.

Approach/Activities: A pilot test for evaluating the HRW was installed using entry/exit well directional horizontal drilling along sandy layers at a depth of 30 to 35 feet.

Testing performed during the HRW pilot test included:

- 3-dimensional field vacuum response and parametric data collection followed by pore velocity modeling to estimate influence at three depth intervals; and
- evaluation of methane and VOC response during pilot testing and estimation of the full-scale methane and VOC removal rate.

This presentation will discuss the installation and operation of the pilot HRW, the results of the pilot HRW operation and comparisons to the Phase I vertical well operations. The presentation will also discuss the design and operation of the full-scale system which consists of 21, HRWs with 100-foot screen intervals connected to a larger Phase II SVE treatment system.

Results/Lesson Learned: Based on the pilot test results, it was determined that a HRW could effectively remove methane and VOCs while limiting near surface infrastructure that could inhibit future redevelopment of the site.

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The Horizontal Reactive Media Treatment Well (HRX Well®) for Passive In Situ Remediation: Design, Implementation, and Sustainability Considerations

Craig Divine, Jeff McDonough, Michelle Crimi and J.F. Devlin

A new in-situ remediation concept termed a Horizontal Reactive Media Treatment Well (HRX Well) is presented that utilizes horizontal wells filled with reactive media to passively treat contaminated groundwater in-situ. The approach involves the use of large-diameter directionally-drilled horizontal wells filled with solid reactive media generally installed parallel to the direction of groundwater flow. The design leverages natural “flow-focusing” behavior induced by the engineered contrast in hydraulic conductivity between the high in-well reactive media and the ambient aquifer hydraulic conductivity to passively capture and treat proportionally large volumes of groundwater within the well. Clean groundwater then exits the horizontal well along its down-gradient sections. Many different types of solid reactive media are already available (e.g., ZVI, GAC, biodegradable particulate organic matter, ion exchange resins, zeolite, apatite, slow-release oxidants). Therefore, this concept could be used to address a wide range of contaminants. The approach requires no above-ground treatment or footprint and requires limited ongoing maintenance. This presentation will discuss in detail the results of the modeling, tank tests, and field-scale implementation. In general, the results demonstrate that capture and treatment widths of tens of feet can be achieved for many aquifer settings, and that reductions in down-gradient concentrations and contaminant mass flux are nearly immediate. Furthermore, the results confirm that the HRX Well concept addresses many of the challenges/limitations inherent to remediation including: (1) costs and time requirements associated with hydraulic containment (2) delivery of injected reagent-based strategies in complex hydrostratigraphy, and (3) up-front costs and long-term hydraulics in flow-through permeable reactive barrier (PRB) treatment schemes. For many sites, it is increasingly recognized that contaminant mass flux and discharge may represent the most appropriate measure of plume strength and potential migration risk, and therefore remedial objectives and technologies focusing primarily on long-term mass discharge reduction

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New Perspectives on Horizontal Wells for Assessment and Remediation

Stephen Koenigsberg, Erik Piatt, Lance Robinson and Wes Wiley

Some remediation technologies can be established but not prevalent, however; they can still be subject to the forces of change. In some cases, creative economics can open up new uses, but also process improvements can drive new applications and levels of acceptance.

This is what is happening with the deployment of horizontal wells for site assessment and remediation. In essence, decreasing costs, as well as strategic shifts, which can be characterized as “initiating greater flexibility”, are two factors that have brought about a resurgence of horizontal well systems. The latter is specifically tied to moving from monolithic single well systems, which are subject to preferential path distortions, to segmented well systems.

A case will be made for how this forms a next generation advancement in site assessment and remediation. As one example, nested, discrete horizontal profiling brings additional accuracy to assessment at sites, especially those challenged by access issues and also provides more directed treatment operations with a unique flexibility in dynamic groundwater systems. Also, with horizontal nested well systems, CSMs can be significantly enhanced with new perspectives and, on a case by case basis, there can be significant economic advantages in deployment.

Lastly, this technological advancement creates a new paradigm in contrast, or rather as an adjunct to, vertical profiling and high resolution site characterization (HRSC). In fact, it opens up a new strategic approach that can be called high resolution contaminant distribution (HRCD); because flexible horizontal segmented well systems can be used to navigate “up the spine of the plume” providing discretized data sets that illuminate contaminant locations in new ways. Several case studies will be presented that illuminate the advantages of horizontal segmented well systems, that also incorporate miniaturization and nested bundling methods into the process. The improved flexibility and the integrity of the data sets that are collected and the ability to deliver reagents with improved precision will be illustrated.

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Site Remediation Using Segmented Horizontal Well Systems in Areas without Ready Access

Glen Vallance

Horizontal well systems provide a means to intersect the strata of most plumes efficiently while providing more linear contact area than vertical wells. New segmented horizontal well systems offer discrete control over pre-defined intervals, filling data gaps and allowing for adjustments as needed. The flow rate to or from each segment can be individually controlled, allowing for variable treatment thus improving remediation efficiency.

A site in Greeley, Colorado, was impacted with diesel and gasoline range organics in a dissolved phase and LNAPL configuration. A segmented horizontal well system was installed to remediate the site utilizing air sparging (AS) and soil vapor extraction (SVE). Installation went under highways, roadways, and complex infrastructure, maintaining full operational status of the business and traffic movement. The system became fully operational in March 2018. The first quarterly sampling event was conducted in June 2018 and demonstrated significant reductions in measurable LNAPL and the dissolved contaminant plume. The second quarterly sampling event was performed in September 2018 and results documented additional reductions in measurable LNAPL and dissolved contaminants below target cleanup levels under active remediation conditions. Results of the third quarter sampling event performed in November 2018, documented the absence of measurable LNAPL and additional reductions in dissolved contaminants which were maintained below target cleanup levels.

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Reconsidering Horizontal to Vertical Well Ratios for Site Clean-up

W. Richard Laton

Directional drilling has been used for a variety of purposes; utilities, dewatering, and remedial activities. Cutting costs for remedial activities is always of consideration. The costs to clean-up a site via traditional vertical extraction wells, versus the use of a horizontal well system, need to be reconsidered based upon todays remedial challenges. Traditionally, it has been stated that a single horizontal well is worth 4-11 vertical wells. This seems arbitrary, in that both depth of the system and hydrogeological conditions play a large role that is not considered. A better way to evaluate the cost benefit of one system over another is to base it on the number of vertical wells per linear foot of directional well, and base it more on zone of influence of both designs.

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Distribution of Permanganate via Deep Horizontal Well Injection and Recirculation

Monica Fulkerson, Matt Louth, David Cleland and Charity Delaney

Background/Objectives: In situ chemical oxidation (ISCO) via injection of permanganate through horizontal directionally drilled (HDD) wells is the selected remedy for groundwater treatment at a former dry cleaning facility. Groundwater is impacted by tetrachloroethene (PCE) at concentrations nearing 300 parts per million (ppm) at depths up to 115 feet (ft) below ground surface (bgs). A pilot study was conducted in 2016 to evaluate permanganate distribution both with and without recirculation through an HDD injection well. Results of the pilot study were analyzed to optimize the full-scale remedial design.

Approach/Activities: During the study, an HDD injection well was installed with a 500-foot screened interval to a depth of 100 ft bgs. The study was conducted in two phases. During Phase I, approximately 100,000 gallons of 2 percent permanganate were injected through the HDD well. In Phase II, an extraction/recirculation system was employed for one month. Performance monitoring and geophysical mapping were conducted to assess whether recirculation significantly improved permanganate distribution, allowing for optimization of the design for full-scale remedy implementation.

Results/Lessons Learned: The study proved that recirculation via the HDD injection well is an effective method to distribute substrate in the subsurface. Lateral distribution up to 33 feet and vertical distribution up to 25 feet from the injection well were observed. During the study, PCE concentrations were observed to decrease up to 97 percent, with an overall reduction of constituents of concern of up to 82 percent. Critical design parameters required for a full-scale design, such as injection/extraction well spacing, oxidant dosage, injection rates, and recirculation rates, will be detailed during the presentation. The presentation will also review challenges encountered during implementation and how the full-scale design will overcome those challenges.

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Session 05: Remediation

Eight Years, Ten Villages, and Five Thousand Children: Adapting Superfund Methodologies to Remediation in Nigeria
Casey Bartrem, Simba Tirima, Ian von Lindern, and Margrit von Braun, TerraGraphics International Foundation (TIFO), Moscow, ID

Anaerobic BTEX Bioaugmentation Approaches
Sandra Dworatzek, Jennifer Webb, and Jeff Roberts, SIREM, Guelph, ON, Canada; Elizabeth Edwards, Nancy Bawa, Shen Guo, and Courtney Toth, University of Toronto, Toronto, ON, Canada

Horizontal Remediation Well Technology Applications for Successful In-Situ Chemical Oxidation and In-Situ Anoxic Biodegradation
Kyle Carlton, Directional Technologies, Inc., Miramar Beach, FL; Michael Sequino, Directional Technologies, Inc., Wallingford, CT

When a Temporary Solution Becomes a Long-term System
Kevin Lienau, Groundwater & Environmental Services, Inc., Eagan, MN; Rich Evans, Groundwater & Environmental Services, Inc., Exton, PA

Tracking Full-Scale Performance of an Injectable Sorptive Biobarrier – One Year and Beyond
Jack Sheldon, Antea Group, West Des Moines, IA; Dacre Bush, Antea Group, Long Beach, CA; Craig Sandefur, Regenesis, San Clemente, CA; Dan Nunez, Regenesis, La Mirada, CA

Benefits of Combining Alkaline Activated Persulfate with In Situ Stabilization and Solidification
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Thermal Enhanced Recovery for Phthalate-Cutting Oil Mixture Treatability Study – Former Plastic Manufacturing Facility
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Eight Years, Ten Villages, and Five Thousand Children: Adapting Superfund Methodologies to Remediation in Nigeria

Casey Bartrem, Simba Tirima, Ian von Lindern and Margrit von Braun

Background: Since 2010, TerraGraphics International Foundation (TIFO) has collaborated with federal, state, and local governments as well as international and national NGOs to address epidemic lead poisoning associated with artisanal, small-scale gold mining in northern Nigeria, where more than 400 children died and thousands of people have been severely poisoned. Project activities in ten villages have included emergency soil remediation based on US superfund protocols to reduce unprecedented exposures, chelation treatment, and programs promoting safer mining practices. During the response, five remedial effectiveness evaluations (REEs) were implemented to: assess the efficacy of remediation in reducing blood lead levels (BLLs); the degree of recontamination; the effectiveness of institutional controls in sustaining the remedy; and the capacity of Nigerian governments to prevent and respond to future crises.

Methods: Remediation protocols were adapted to local social and economic contexts. After remediation, REEs were completed in six of ten villages. Homes and public areas throughout the villages were assessed and discussions were held with multiple levels of leadership. Retrospective (ex-post) social impact assessment (SIA) was used to analyze interview and observation results.

Results: Significant differences were found between pre- and post-remediation lead levels in all villages. BLLs are progressing satisfactorily in four villages while soil recontamination and persistently high BLLs persist in two villages. Six categories of SIA variables show intentional and unintentional project impacts and the influence of social factors on the long-term project sustainability. REE results were used to modify response protocols and support institutional controls as the project evolved.

Conclusions: The environmental health response substantially reduced exposures and BLLs in all villages, but further support of institutional controls is needed. Technical response capacity has grown considerably and efforts to prevent resumption of processing activities and para-occupational exposures are ongoing.

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Anaerobic BTEX Bioaugmentation Approaches

Sandra Dworatzek, Jennifer Webb, Jeff Roberts, Elizabeth Edwards, Nancy Bawa, Shen Guo and Courtney Toth

The degradation of benzene, toluene, ethylbenzene and xylene (BTEX) by microorganisms is a significant process that is now known to occur in diverse environments. Understanding this process has important implications for the application of bioremediation technologies at BTEX-contaminated environments. While aerobic microbial processes can degrade BTEX at faster rates than anaerobic processes, aerobic bioremediation is not feasible at all sites (i.e., deep anaerobic aquifer systems where oxygen application would be challenging and expensive). In these instances, anaerobic approaches can be used to better address BTX contamination.

Over the past 20 years, anaerobic (methanogenic) enrichment cultures capable of complete degradation of benzene, toluene and *o*-xylene to carbon dioxide and methane have been developed at the University of Toronto. The cultures have recently been characterized using next-generation DNA sequencing technologies and other genomic tools that have helped identify the key organisms associated with benzene, toluene and xylene degradation (Luo et al, 2015).

SiREM and University of Toronto have collaborated to scale up an anaerobic benzene bioaugmentation culture from research to commercial volumes through a 3-year research project. The culture has been used in multiple laboratory treatability studies to evaluate its performance to remediate a variety of hydrocarbon-contaminated materials from field sites. The growth of the benzene-degrading microbes was tracked by quantitative polymerase chain reactions to establish correspondence between the growth of these organisms and benzene degradation. Information developed from this testing includes cell density requirements, degradation rates and the range of geochemical conditions required for optimal performance, which are being used to design field pilot trials. These laboratory studies have also been used to validate molecular biomarkers used to monitor *in situ* biodegradation activity.

This presentation will present results of laboratory treatability studies and discuss lessons learned as we move towards field application of these promising anaerobic bioaugmentation cultures.

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Horizontal Remediation Well Technology Applications for Successful In-Situ Chemical Oxidation and In-Situ Anoxic Biodegradation

Kyle Carlton and Michael Sequino

Horizontal Remediation Well (HRW) technology continues to make major strides for the environmental industry by enabling in-situ remediation of sites previously considered unfeasible. Installation of horizontal injection wells with horizontal directional drilling (HDD) accesses contaminated areas beyond the reach of vertical drilling techniques, significantly diminishing overall remedial duration and long-term costs. Whether target remediation zones are beneath storage tanks, buildings, roadways, waterways, and other difficult areas to access, HRW/HDD technology facilitates injection beneath all types of surficial obstructions and activities. This presentation will detail HRW/HDD technology and the processes associated with successful horizontal injection implementation. Case studies for horizontal in-situ chemical oxidation (ISCO) and anoxic biodegradation sites will be presented describing the HRW layouts, horizontal well screen designs, and installations, along with remediation system operational data and contamination reduction results.

Case Study 1: Potassium Permanganate Injection Beneath Active Redevelopment Project:

A major redevelopment project at a former shopping mall faced significant environmental challenges due to a dry-cleaning facility that operated on the property for 60 years. The chlorinated solvent plume extended 1,600 feet and caused extensive soil and groundwater contamination. An in situ chemical oxidation system needed to be installed while construction activities were ongoing. Directional Technologies, installed 10 single-entry horizontal permanganate injection wells under the future building sites, and 5 single-entry horizontal soil vapor extraction (SVE) wells under the active dry-cleaning facility. The horizontal injection wells delivered over 1 million gallons of KMNO4 solution within a 26-day period.

Case Study 2: In-Situ Anoxic Biodegradation of Perchlorate:

Industrial process wastewater leaking from a drain line contributed to perchlorate concentrations in the groundwater ranging from 10 to 500 mg/L and the estimated mass on the order of 1,500 pounds of perchlorate. Two HRWs installed beneath a parking lot and building injected a soluble carbon source to facilitate anoxic biodegradation of the perchlorate.

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When a Temporary Solution Becomes a Long-term System

Kevin Lienau and Rich Evans

Initial response and interim remedial measures may result in the construction and installation of a system designed to operate for a short period of time – typically a few months and up to a year. Due to the quick response nature of these systems, the equipment is often based on what was available at the time, oversized, and automation/safety measures are replaced with dedicated on-site personnel presence. These measures are installed with good intentions to remove contaminant mass and protect receptors. However, we often find these temporary remedies continuing to operate for years beyond their expected life cycle. Years after start up, we find ourselves operating these systems at a high cost with constant "band-aid" fixes and high site oversight staffing to keep them running. How do we recognize this and how to we address the situation?

When an aged "temporary" system continues to operate, the first step is to evaluate the system for critical safety and compliance issues. After resolving any imminent risks, a holistic view of the temporary remedy should be performed. Identify the original purpose, design basis, receptors, site use and condition, and regulations. With that information in hand, the need for continued active remediation can be evaluated. This detailed analysis is necessary to ensure that objectives are achieved in a safe and cost-effective manner.

We continue to find these "temporary to permanent" remediation systems in operation. The effort and cost to operate are often key factors that necessitate these technical reviews. However, while we wait for the financial spend to drive a response, the system operators face daily challenges to safely operate aged equipment while avoiding non-compliance conditions.

The presentation will provide examples of aged temporary systems that remain in operation without corrective actions and examples where corrective actions have been implemented.

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Tracking Full-Scale Performance of an Injectable Sorptive Biobarrier – One Year and Beyond

Jack Sheldon, Dacre Bush, Craig Sandefur and Dan Nunez

This presentation describes the full-scale results for an injectable sorptive biobarrier downgradient of a service station site impacted with methyl tertiary- butyl ether (MTBE) and tertiary butyl alcohol (TBA). The results span more than one year post-injection of an injectable activated carbon amendment, PlumeStop® Liquid Activated Carbon. The product was applied to address off-site migration of MTBE/TBA in groundwater at multiple barrier locations. The site is located in Daly City, California and historically the on-site area had active remediation that led to significant reduction in gasoline constituents. Biodegradation played a key role in the on-site remediation and continues to play a key role in the off-site reduction of MTBE and TBA concentrations. The migration of MTBE further downgradient was a primary regulatory issue because a municipal water well was present. Retardation of the plume became paramount if site closure were to be achieved.

The following aspects of the project will be discussed in this presentation: a summary of on-site/off-site microbial profiling of MTBE-degrading bacteria and gene functions coding for biodegradation, the value of in-well microcosms evaluating amendments plus geochemistry, contaminant concentrations, and stable isotope probing (SIP) using radio-labelled MTBE to differentiate incorporation of ^{13}C into biomass and dissolved inorganic carbon as evidence of biodegradation of MTBE, a summary of pilot test results including contaminant reductions and changes in microbial profile and geochemistry/field parameters, the challenges encountered during injection, the results from multiple performance monitoring wells more than one year post-injection of the PlumeStop® Liquid Activated Carbon, and two of the monitoring wells that were part of the pilot test and have data that spans more than two years. Longevity of injectable activated carbon products is of importance to the industry to verify that rebound is not occurring because biological mechanisms are continuing to regenerate sites on the carbon particles.

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Benefits of Combining Alkaline Activated Persulfate with In Situ Stabilization and Solidification

Brant Smith, Stacey Telesz and Brianna Desjardins

Background: In situ chemical oxidation (ISCO) and in situ stabilization and solidification (ISS) technologies are two established remediation technologies that have been used to treat a wide assortment of environmental contaminants of concern around the world. ISCO is a contaminant mass destruction technology that is effective when contact with a sufficient dose of activated oxidant for the contaminant mass is established. ISS decreases the contaminant flux by decreasing the hydraulic conductivity of the source area soils.

These two technologies can be combined into a single application using the inherit alkalinity within Portland cement and hydrated lime can also create alkaline activation conditions for persulfate. Other benefits include establishing contact between the reagents and the contaminants in both permeable and low permeable soils with in situ soil mixing and controlling the various reagents dose to control the site's post application geotechnical characteristics.

Activities: The objective of these studies was to demonstrate the effectiveness of combining ISS and ISCO with alkaline activated persulfate. The studies evaluated contaminant mass reduction as well as key geotechnical parameters. Further, this study expanded on empirical observations that reducing contaminant mass with ISCO enhances the cementitious process of ISS.

Both the bench and field scale evaluations to be presented evaluated adding various doses of hydrated lime and Portland cement with activated Klozur persulfate to treat contaminated soil samples. In situ soil mixing was utilized in the field and simulated in the laboratory to ensure complete mixing of the contaminated soils with the reagents.

Results: In addition to treatment of the contaminants of concern, the data show a trend of decreasing hydraulic conductivity and decreasing leachate concentrations with increasing dosages of persulfate. The addition of persulfate typically decreased hydraulic conductivity by an order of magnitude or greater. Dose response curves and treatment efficacy will be presented.

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Thermal Enhanced Recovery for Phthalate-Cutting Oil Mixture Treatability Study – Former Plastic Manufacturing Facility

David Winslow, Zhan Shu and Benjamin Romagnoli

Separate, dissolved and adsorbed phase DEHP and DOP contamination are present at the former Nuhart Plastic manufacturing facility in Brooklyn, New York (the Site). In order to evaluate whether in-situ thermal conductive heating combined with in-situ chemical oxidation would be an effective remedial technology at the Site, we conducted a bench scale treatability study. Soil, groundwater and LNAPL samples were collected from areas representing worst case scenarios. Soil samples were homogenized in the laboratory and tested for particle size, moisture content, bulk density, specific gravity and calculated porosity. In addition, untreated samples were analyzed for VOCs, SVOCs, TPH and Walkley Black TOC. LNAPL was tested for viscosity differences at temperature. LNAPL from the source area behaved as expected with a decrease in viscosity with temperature from 460 mPa-s at 10^{o}C to 28 mPa-s at 88^{o}C. Samples were treated with three different thermal treatments: Thermal Conductive Heating to 100^{o}C; Hot Water Flush with water at 80 to 90^{o}C; and, Steam Enhanced Extraction (SEE). The physical flushing combined with heat in the SEE treatment proved most effective on this material and would likely be most effective and practical in a full-scale setting. During the test, steam displaced LNAPL in the column after a few minutes. In addition, the SEE resulted in a decrease in adsorbed phthalates with reductions of 47% to 66%. Thermally treated samples were then further treated with heat-activated sodium persulfate. At 50?C and a 15 g/kg persulfate dosage, a reduction of up to 45% of BEHP concentrations was achieved from the heat-activated persulfate oxidation process. The results also indicate that another 44% of BEHP reduction may have been achieved through abiotic processes such as hydrolysis during prolonged heating (4 days at 50?C). Overall reductions of 90% were observed using the two treatment technologies.

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Session 06: Regulatory Programs and Policies

Why Do Contaminated Site Closures Take So Long? A Regulatory Perspective
Nick Amini, Santa Ana Regional Water Quality Control Board, Riverside, CA

Site Cleanup Subaccount Program: Better Groundwater Through Grants
Kathryn Dominic, State Water Resources Control Board, Sacramento, CA

Proposition 1 Groundwater Grant Program Funding – Protecting Groundwater Quality
Chad Nishida, SARWQCB, Riverside, CA

State Water Board's GeoTracker Database
Matthew Cohen, State Water Resources Control Board, Sacramento, CA

The Santa Barbara County Response to the Thomas Fire and Montecito Debris Flow Disasters
Thomas Rejzek, Paul McCaw, Steve Nailor, and Marissa Censullo, Santa Barbara County, Santa Maria, CA

Nearly 20 Years of Environmental Screening Levels (ESLs): Where Have They Been and Where Are They Going?
Nicole Fry, Ross Steenson, and Cheryl Prowell, San Francisco Bay Regional Water Quality Control Board, Oakland, CA

Findings of the 2018 Science Advisory Panel on CECs in Recycled Water
Claire Waggoner and Tessa Fojut, State Water Resources Control Board, Sacramento, CA

Why Do Contaminated Site Closures Take So Long? A Regulatory Perspective

Nick Amini

As California's economy gains momentum, more and more infrastructure projects are being implemented throughout the State. One of the major markets for these types of project is the redevelopment of brownfields. These properties are typically impacted with known contaminants as a result of historical activities in place. Cleanup of impacted properties is typically required before their redevelopment in order to secure funding from banks or other investors. For these cleanups to meet the requirements stipulated in the California Health and Safety Code or California Water Code, the responsible parties would need oversight by a State or local regulatory agency. After the environmental work at a site is completed, according to the applicable requirements and to the satisfaction of regulators, a no further action (NFA) determination (or site closure) is typically granted for the site.

Obtaining an NFA for such sites is characteristically a thorough, step-by-step and thus, a costly process. Additionally, there is a variety of factors that could readily impact the pace of this process, resulting in further delays in its completion. Some of these factors include:

- Non-cooperative responsible party
- Insufficient funds
- Consultant issues
- Difficulty of access to impacted areas on-site
- Difficulty of access to adjacent properties
- Fear of litigation with third parties
- Existing litigation with third parties
- Insurance funding preferences
- Comingled plumes
- Technical impracticability
- Inexperienced regulator

This presentation will focus on a number of these factors that are more prevalent and discusses some of the potential solutions to minimize delays and streamline the closure process.

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Site Cleanup Subaccount Program: Better Groundwater Through Grants

Kathryn Dominic

The Site Cleanup Subaccount Program (SCAP) was started in 2015 to assist private parties with the cleanup of contaminated sites. The program provides grants for eligible projects that remediate the harm or threat of harm to human health, safety, and the environment caused by existing or threatened surface or groundwater contamination. Now in its fourth year, SCAP has provided grants to over 50 applicants, with a total of over $30 million in funding, for projects including source identification, site investigation, interim remedial action, remediation, and site closure. The SCAP team works collaboratively with each responsible party and regulatory agency case worker to plan projects that drive toward case closure. Their approach is to set up each prospective project for success. Although the majority of funded projects are dry cleaning facilities, SCAP funds projects for a variety of human-made contaminants. Dozens of formerly inactive regulatory cases are starting or resuming long-overdue cleanups as a result of the collaboration among regulators, responsible parties, and SCAP. The case studies provided in this presentation illustrate the variety of projects SCAP has funded as well as SCAP's success in accelerating the pace of cleanups.

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Proposition 1 Groundwater Grant Program Funding – Protecting Groundwater Quality

Chad Nishida

California's groundwater resources are under immense stress due to several factors, including salinization, contamination and rapid depletion. When combined with climate change and population growth, the stresses on groundwater supplies will only be magnified for future generations. The quality of groundwater that is extracted for potable use plays a large role in maintaining the community's high standard of living.

In 2014, the California State legislature approved Proposition 1 allowing the use of state grant funds to prevent and cleanup contamination to aquifers that serve (or has served) as a source of drinking water. The groundwater sustainability chapter includes $900 million in funds to allocate to eligible applicants such as public agencies, non-profit organizations, public utilities, tribes, and mutual water companies. The first round of applicant's projects ranged from planning feasibility studies and remedial investigations to implementation of extraction wells and desalter facilities. These projects have a useful life of at least 20 years and consider the most timely and cost effective prevention and cleanup approaches in compliance with state, federal, and local laws. Grants are awarded on a competitive basis based on specific criteria set by the State Water Board. Environmental regulatory agencies and applicants will collaborate to move the projects forward and provide technical assistance when assessing project feasibility and effectiveness in achieving prevention or cleanup of groundwater. This presentation will discuss the application of this program to protect sources of potable water in Orange and San Bernardino counties.

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State Water Board's GeoTracker Database

Matthew Cohen

GeoTracker is the California Water Boards' data management system for sites that impact groundwater or have the potential to impact groundwater. GeoTracker contains sites that require groundwater cleanup (Leaking Underground Storage Tanks, Department of Defense, and Site Cleanup Program) as well as permitted facilities that could impact groundwater (Irrigated Lands, Oil and Gas Production, Operating USTs and Land Disposal sites.) GeoTracker Secure Portal enables regulators within the Water Boards and local agencies to track project activities, compliance responses, and report and laboratory data submissions. These tools help regulators manage their case load, and schedule and track when deliverables are due from responsible parties.

GeoTracker is a powerful web application is used for secure reporting of laboratory data, field measurement data, documents and reports. GeoTracker public and secure portals retrieve records and view integrated data sets from multiple State Water Board programs and other agencies through an easy-to-use Google maps GIS interface. This allows users to view data in relationship to streets/roads, satellite imagery, and terrain map views as well as other sites that affect groundwater quality and wells and other beneficial uses that may be affected.

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The Santa Barbara County Response to the Thomas Fire and Montecito Debris Flow Disasters

Thomas Rejzek, Paul McCaw, Steve Nailor and Marissa Censullo

The changing climate has led to a drought in California since 2012. This had led to an increase in wildfires and a lengthening of the fire season. The fire season, which typically ended in the early Fall, now extends into the winter months. On December 4, 2017, the Thomas Fire began in Ventura County. By the end of the day, dry hot Santa Ana winds pushed the fire over 50 miles west, destroying homes in suburban areas. The fire continued burning throughout the month, burning north into Santa Barbara County, and ultimately becoming the largest fire in modern California history. The fire burned 440 square miles and destroyed over 1,000 homes.

Climate change has also been associated with increased storm intensity. The first significant rain of the 2017/18 winter season occurred on January 8 and 9, 2018. On January 9, 2018, at 3:30 a.m., the burned hills above Montecito received 0.5 inch of rain within 5 minutes. Due to the lack of vegetation and the burned soil preventing infiltration, the storm generated massive debris flows in Montecito and Carpinteria. The debris flows damaged over 300 homes, killed 23 people, and blocked the main coastal highway, US 101, for 2 weeks.

Santa Barbara County Environmental Health Services (EHS) responded to these disasters by initially evaluating hazardous waste and materials at structures burned by the Thomas Fire. During this process, the Montecito Debris flows occurred which required a change in the mission to collecting and removing the hazardous material from the burn and debris flow damaged areas. This required the assistance of mutual aid from neighboring jurisdictions. During the three week emergency cleanup process, EHS collected over 11,000 pounds of hazardous materials and recovered approximately 4,100 pounds of additional hazardous waste during a post-emergency curbside pickup event.

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Nearly 20 Years of Environmental Screening Levels (ESLs): Where Have They Been and Where Are They Going?

Ross Steenson, Nicole Fry and Cheryl Prowell

In September 2000, the San Francisco Bay Regional Water Quality Control Board first published risk-based screening levels (RBSLs) for 100 commonly encountered chemicals at sites with impacted soil and groundwater. The RBSLs were intended to expedite risk assessments and evaluations of the need for additional work, particularly for small- to medium-sized sites. Following peer review of the 2001 RBSLs by the University of California, the scope was broadened beyond human health risk to include ecological risk, concerns for nuisance and potential presence of separate-phase liquid. This effort culminated in 2003 with the renamed Environmental Screening Levels (ESLs) that added screening levels for surface water, indoor air, and soil gas. Over the last decade, the ESL team has devoted much effort to the vapor intrusion (VI) pathway. The challenge has been whether or not to change the existing soil gas and groundwater VI ESLs based on modeled attenuation factors (AFs) to values based on empirical AFs from the USEPA national VI database. The change is planned for next ESL update, consistent with development of the DTSC-Water Boards Supplemental VI Guidance. Other significant efforts have included adopting a fraction approach for the TPH ESLs in 2013, streamlining of the Workbook (number of tables reduced by about half) and revising the User's Guide in 2016, and developing new functionality (cumulative risk calculator) in 2018.

The ESL team looks forward to updating other components of the ESLs (e.g., soil leaching to groundwater, nuisance, and potentially adding sediment) or adding functionality and is taking stock of priorities. This talk will provide a brief history of the ESLs, introduce the different endpoints and concerns, discuss how they differ from screening levels published by other regulatory agencies, discuss how they should and should not be used, and provide insight on planned updates going forward.

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Findings of the 2018 Science Advisory Panel on CECs in Recycled Water

Tessa Fojut and Claire Waggoner

Recycled water agencies must be able to demonstrate to their customers that their recycled water is safe for all uses. Some customers are concerned with the risks to human health associated with constituents of emerging concern (CECs). Recycled water agencies can improve confidence in the safety of recycled water by: monitoring for CECs that present a potential risk to human health; demonstrating the analytical methods will capture low concentrations of CECs in recycled water; and that the recycled water producer has a framework for initiating actions if CECs are detected at a level of concern. Given that the state of the science around CECs is rapidly evolving, it is important for recycled water agencies to periodically review and update their CEC monitoring programs based on the current state of the science.

In 2017, the California State Water Resources Control Board reconvened the CEC Science Advisory Panel for Recycled Water (Panel), which is composed of subject matter experts, to review the current state of scientific knowledge and monitoring data related to human health risks associated with exposure to CECs in recycled water for all reuse projects allowed under Title 22 in the California Code of Regulations. The Panel developed and applied a risk-based framework and recommended monitoring a targeted list of CECs and using two *in vitro* bioassays to screen for CECs in potable recycled water projects (i.e., groundwater recharge and reservoir water augmentation). State Water Board staff incorporated the Panel's monitoring recommendations in an update to the state's Recycled Water Policy. The Panel made recommendations for programmatic changes for the State Water Board to be able to better respond to CECs and also identified potential research (e.g., non-targeted analytical methods, antibiotic resistance) that could be done to continue to improve confidence in the safety of recycled water.

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Session 08: Vapor Intrusion I

Source Depletion in Petroleum Vapor Intrusion Estimates
George DeVaull, Shell Global Solutions, Houston, TX; Matthew Lahvis, Shell, Spring, TX

Vertical Separation Distance Criteria to Evaluate Vapor Intrusion from Lead Scavengers (EDC and EDB)
Emma Hong Luo and Ravi Kolhatkar, Chevron Energy Technology Company, Houston, TX; Christopher Gaule and Joe Watterson, Chevron EMC, San Ramon, CA

Retrospective MLE VI Assessment to Facilitate Remedial Alternatives Evaluation at a Former Petroleum Dispensing/UST Area
Francis Ramacciotti, GHD, North Wales, PA; Pam Barnett, RACER Trust, Detroit, MI; Rick Galloway, DNREC, Wilmington, DE; Greg Carli, GHD, Niagara Falls, NY

All of These Things are Not Like the Others: Chlorinated Solvent VI Site Variability in the San Diego Region
Sarah Mearon and John Anderson, San Diego Regional Water Quality Control Board, San Diego, CA

Estimates of Volatile Organic Compound Concentrations in Outdoor Ambient Air in California from the GeoTracker Database
Peter Scaramella, GSI Environmental, Irvine, CA; Lila Beckley, GSI Environmental, Austin, TX; Sharon Rauch, GSI Environmental, Houston, TX

Evaluation of Site-Specific Attenuation Factors for Sites in California
Steve Luis, Ramboll, Irvine, CA; Chris Stubbs, Ramboll, Emeryville, CA; Yuan Zhuang, Ramboll, Atlanta, GA

Source Depletion in Petroleum Vapor Intrusion Estimates

George DeVaull and Matthew Lahvis

Measured petroleum constituent vapor concentrations in field sampling near subsurface LNAPL sources may be similar to expected vapor concentrations for unweathered petroleum products but are often much less. This may, in part, be attributed to depletion of the more volatile fraction of the petroleum over time. This presentation, through modeling and measurement, examines volatile source depletion effects and changes in source composition over time, with and without including aerobic biodegradation, and with and without inclusion of the effect of overlying buildings. The effect of this depletion on estimated vapor intrusion risks is evaluated, along with the sensitivity of significant parameters.

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Vertical Separation Distance Criteria to Evaluate Vapor Intrusion from Lead Scavengers (EDC and EDB)

Ravi Kolhatkar, Emma Hong Luo, Christopher Gaule and Joe Watterson

The 2015 petroleum vapor intrusion (PVI) guidance by the USEPA established vertical separation distance criteria for benzene. Based on this guidance, additional PVI investigations were considered unnecessary at certain petroleum underground storage tank (UST) sites if certain vertical separation distance criteria were met (> 6 ft. for dissolved source and > 15 ft. for LNAPL source). However, it identified the presence of lead scavengers, ethylene dichloride (EDC) and ethylene dibromide (EDB) in groundwater as a 'precluding factor' to apply this screening approach. Although EDC and EDB biodegrade under both anaerobic and aerobic conditions, the ubiquity and kinetics of these biodegradation processes in the vadose zone are not well understood. The 2015 USEPA PVI guidance document highlighted this data gap and recommended that the potential for vapor intrusion be evaluated at sites with EDC and EDB detections in groundwater.

The lowest reporting limit for EDB in soil vapor from the available PVI investigation data is higher than the soil vapor screening level for EDB (1.6 µg/m^3 for 10^{-5} incremental cancer risk). Therefore, these data are not adequate to empirically evaluate vertical separation distance for EDB.

This study presents data from 14 UST sites with recent EDC and EDB detections in groundwater exceeding the vapor intrusion screening levels. Concurrent groundwater and soil vapor samples for EDC and EDB were collected. The soil vapor samples were analyzed with a modified EPA TO-15 method using a GC x GC-TOF-MS (two-dimensional gas chromatography-time of flight-mass spectrometer) detector that achieved reporting limits of ^{3} for EDB and < 3.6 µg/m^3 for EDC.

The results suggest that vertical separation distances established for benzene (6 ft. for dissolved source and 15 ft. for LNAPL source) appear to be protective for vapor intrusion from EDB. However, a minimum of 15 ft. of vertical separation distance may be required for EDC.

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Retrospective MLE VI Assessment to Facilitate Remedial Alternatives Evaluation at a Former Petroleum Dispensing/UST Area

Francis Ramacciotti, Pam Barnett, Rick Galloway and Greg Carli

In 2012, releases from a former petroleum dispensing and Underground Storage Tank (UST) area to groundwater were identified at the Former General Motors Corporation Assembly Plant in Wilmington, Delaware property, which is subject to facility-wide investigation. The UST area was adjacent to a dilapidated and unoccupied building and along the downgradient property boundary, which was adjacent to an area being developed for residential use. Groundwater and deep soil gas results exceeded then current vapor intrusion (VI) screening levels and additional investigation was performed consistent with the State VI policy. The prior evaluation concluded that future VI exposures off-site could results in unacceptable indoor air concentrations and that vapors were encroaching on the off-site buildings. To support the evaluation of the final remedial alternatives, the VI evaluation was revisited in light of current USEPA and ITRC guidance on petroleum vapor intrusion (PVI). Using current PVI guidance, the VI pathway would "screen out" using the original groundwater and/or deep soil gas results. However, the results from the remaining media (shallow soil gas and subslab) were also evaluated and risk estimates correlated closely with generic biodegradation rates. The indoor air results were also evaluated in the risk assessment and appear to be significantly influenced by outdoor air and other potential indoor sources. These conclusions from this multiple lines of evidence evaluation resulted in Delaware Natural Resources and Environmental Control (DNREC) and RACER working cooperatively to reevaluate the need for and/or extent of a long term remedy at the UST area. The results were also used to evaluate the potential for significant VI exposure into any new buildings at the Site.

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All of These Things are Not Like the Others: Chlorinated Solvent VI Site Variability in the San Diego Region

Sarah Mearon and John Anderson

The San Diego Regional Board oversees cases with VI concerns across our region. The California Water Boards use policies and published guidance to assist with case management, with the goal of a technically sound, consistent approach across sites within regions and throughout California. The State Water Resources Control Board's Low-Threat UST Case Closure Policy, for example, hinges on the well-documented behavior of petroleum fuels in the environment. Application of this policy allows for methodical and systematic evaluation of petroleum UST sites across the state, including identification of the potential for VI issues. Due to favorable bioattenuation processes, VI is generally less of an issue for petroleum UST sites. Unfortunately this is not the case for chlorinated solvent cases, and is one of the reasons a comparable chlorinated case closure policy has not been developed.

Chlorinated solvent sites potentially pose a bigger threat to human health through the VI pathway than do petroleum sites, necessitating a different approach to case management that does not rely on generalizations. Our review of chlorinated solvent cases in the San Diego Region found that apparent similarities in sites based on geology, groundwater depth, contaminant origin, groundwater plume characteristics, and soil vapor data do not translate to consistency in VI risk. Rather, sites that are superficially similar have vastly different VI characteristics, and require focused, site-specific investigative approaches to evaluate risk and identify potential remedial options. Our assessment indicates that the potential for VI at chlorinated solvent sites needs to be evaluated with special attention to factors such as building slab thickness and condition, piping conduits, pressure effects, building use, and HVAC system operation. These factors rank higher than variables such as soil type and groundwater plume characteristics and, combined with data variability in space and time and other uncertainties, make chlorinated solvent cases consistently inconsistent.

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Estimates of Volatile Organic Compound Concentrations in Outdoor Ambient Air in California from the GeoTracker Database

Peter Scaramella, Lila Beckley and Sharon Rauch

In recent years, federal and state guidance have increasingly emphasized the collection of indoor air data to support vapor intrusion (VI) evaluations. Indoor air data is applied as a line of evidence to evaluate whether VI is potentially resulting in unacceptable indoor air exposures and as a diagnostic test of VI mitigation systems (VMSs). The application of indoor air data for has a recognized short-coming, as volatile organic compounds (VOCs) in indoor air may be related to indoor sources, such as consumer products, or outdoor sources, and not subsurface contamination. Typically, indoor air sampling events include the outdoor ambient air sampling to assess potential outdoor ambient VOC contributions to indoor air. Understanding the magnitude and variability of VOCs in outdoor ambient air is key to understanding limitations in indoor air data as a line of evidence in VI evaluations.

In this study, outdoor ambient air data was mined from the California Regional Water Quality Control Board GeoTracker website. The samples were collected at sites located throughout California, with the final dataset including 650 outdoor air samples collected from 165 sites located in 28 counties. Although the dataset is compiled from sites with potential subsurface contamination, the dataset is representative of sites where vapor intrusion evaluations occur.

In this presentation, summary statistics for outdoor ambient air concentrations, including data available from the EPA National Air Toxics Trends Stations (NATTS) Network, will be reviewed and discussed to provide insight into typical outdoor ambient VOCs conditions. Concentrations vary widely and can exceed indoor air screening levels for VI. Thus, outdoor air may act as a background source of VOCs that could confound interpretation of indoor air data collected for VI assessments or diagnostic testing of VMSs.

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Evaluation of Site-Specific Attenuation Factors for Sites in California

Steve Luis, Chris Stubbs and Yuan Zhuang

The California EPA is developing an approach for evaluating the vapor intrusion pathway in California. As part of this approach, CalEPA has emphasized the use of generic empirical attenuation factors for the purpose of evaluating sites with potential vapor intrusion conditions. Efforts are underway to develop generic empirical attenuation factors for California. Until California-specific attenuation factors become available, CalEPA's generic empirical attenuation factors will be based on USEPA's 2012 empirical attenuation factor study.

As has been pointed out in the literature, vapor intrusion is influenced by a variety of site characteristics that can make the development of empirical attenuation factors challenging. Characteristics influencing vapor intrusion include sampling methodologies, building construction, climate conditions, and occupant activities. To help improve understanding of empirical attenuation factors at typical vapor intrusion sites investigated under agency oversight, the authors will present an analysis of site-specific empirical attenuation factors from sites located in California. At each of the sites considered, paired indoor air and soil vapor samples have been collected. Sample results will be analyzed and site characteristics potentially influencing empirical attenuation factors will be evaluated. As part of the evaluation, the authors will compare site-specific empirical attenuation factors and site-specific attenuation factors calculated using the Johnson & Ettinger model. The relationship between site-specific and generic empirical attenuation factors will be considered. The authors will also provide preliminary thoughts regarding potential roles for site-specific empirical attenuation factors to aid site investigation and development of conceptual site models.

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Session 09: Innovative Soil, Groundwater, and Sediment Cleanup Technology Solutions

Impacts of Site Characteristics on Anaerobic Bioremediation Efficiency for Chlorinated Solvents
Richard Raymond and Michael Lee, Terra Systems, Inc., Claymont, DE

Use of Direct Push HRSC in Remedial Design and QA/QC
Eric Garcia, ASC-HRSC, Rancho Cordova, CA

Managing Environmental Data from the Field to the Map
Dave Rich, Geotech Computer Systems, Centennial, CO

Steam Enhanced Soil Mixing and ZVI Injection Using Large Diameter Auger at a Former Dry Cleaner
Jason Marberry, FECC, Inc., Orlando, FL

Innovative Applications of Surfactants for Successful Combined Remedy Remediation
Paul Dombrowski, ISOTEC Remediation Technologies, Lawrenceville, NJ; Fritz Hostrop, Terra Systems, Inc., Claymont, DE; Karnam Ramanand, Brown and Caldwell, Cherry Hill, NJ

Addressing Contaminated Ground Water to Surface Water Discharge: Application of In-Situ Permeable Reactive Barriers (PRB) to Limit Migration of PFAS
John Collins, AquaBlok, Ltd., Toledo, OH; Richard Stewart, Ziltek Pty Ltd, Thebarton, South Australia, Australia; John Hull, AquaBlok, Ltd., Swanton, OH

Impacts of Site Characteristics on Anaerobic Bioremediation Efficiency for Chlorinated Solvents

Richard Raymond and Michael Lee

Anaerobic bioremediation of chlorinated solvents requires sufficient organic substrate distributed in proximity to the contaminants to overcome the competing electron acceptors and support reductive dechlorination. A neutral pH, sufficient nutrients, and a dechlorinating microbial population are also required. For the past 25 years, Terra Systems has evaluated a large variety of substrate packages to determine optimal injection substrate distribution characteristics, impact of a variety of additives, longevity of the substrates, and the need for bioaugmentation. The impact of site characteristics on the makeup of the substrate package and distribution will be discussed with a review of the lessons learned from the anaerobic bioremediation treatment of over 500 sites including cost implications for substrate selection and distribution.

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Use of Direct Push HRSC in Remedial Design and QA/QC

Eric Garcia

Historically the typical use of direct push High-Resolution Site Characterization (HRSC) technologies such as Membrane Interface Probe (MIP), Hydraulic Profiling Tool (HPT), and Ultra-Violet Optical Scanning Tool (UVOST) has been in the characterization of the subsurface prior to remedial action in order to enhance site details and reduce uncertainties in the conceptual site model (CSM). Current use of these technologies can support the Quality Assurance/Quality Control (QA/QC) function of remedial actions by further refining the CSM and improving the remedial action contemporaneously. Knowing the state of the subsurface environment before and after a remedial action is integral to an effective QA/QC program. These HRSC technologies can be used to verify the presence and/or absence of remedial compounds in-situ through changes in pore space characteristics such as permeability/hydraulic conductivity, and geo/electrochemistry. Additionally, in remedial actions requiring environmental fracturing technologies to enhance or create openings in soil with low effective porosity, HRSC technologies such as HPT and the Optical Image Profiling (OIP) tool can be used to identify and delineate the placement and extent of the subsurface fractures.

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Managing Environmental Data from the Field to the Map

Dave Rich

The amount of data being gathered on water, groundwater, and soil investigation and monitoring projects is growing at ever increasing rates. Action levels are becoming more varied and stringent, leading to more exceedances, and the expectations for using the data are also growing rapidly. Most people recognize the need for efficient tools for managing laboratory and field data for water and other matrices. Tools such as affordable GPS receivers, field data entry devices, target levels (MCLs) available in digital form, and readily available base map data in a variety of formats, are making it easier to manage most or all project data without resorting to paper.

This presentation follows the data through the data management process from the field to the final uses of the data. It covers the various steps in the process, from preparing for a field event, gathering field data, interaction with laboratories, data import, checking and validation, data selection, reporting, and GIS mapping, using both local and cloud systems. It also discusses problem areas and pitfalls in running a data management project, and addresses how to overcome them. We will pay particular attention to the specific problems of managing laboratory data, as well as to issues related to mapping groundwater and related data. Cost savings of 50% or more can be documented resulting from more efficient data management and display, and these savings can result in a high return on investment for software purchases, staff training, and data conversion.

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Steam Enhanced Soil Mixing and ZVI Injection Using Large Diameter Auger at a Former Dry Cleaner

Jason Marberry

Site Background/Objective: Tetrachloroethene (PCE) was released into the subsurface at the site, located in Jacksonville, Florida, during drycleaning activities over a period of approximately twenty years. The suspected former source areas included a former UST, which may have contained spent solvents; a floor drain; the former drycleaning machine; and a former supply well that provided water for drycleaning operations. Site assessment activities reported chlorinated solvent contamination in soil and groundwater to a depth of approximately 70 feet below ground surface (bgs). Solvent contamination in the vadose zone soils (approximately 0 to 8 feet bgs) appears to have been either removed during the UST closure excavations or during soil vapor extraction operations. Previous remedial methods for treating the contaminated groundwater were largely unsuccessful due to the likely presence of dense non-aqueous phase liquid (DNAPL) at varying depths within the saturated soils. The objective of this remedy was to remove the remaining adsorbed, soluble, and potential DNAPL contaminant mass located in the source areas. Funding for this technology was provided by the Florida Department of Environmental Protection, Drycleaning Solvent Cleanup Program.

Approach/Activities: FECC's Chlorinated Source Contamination Removal Technology was used to remove adsorbed, soluble, and DNAPL contaminant mass from the source area of a site impacted with chlorinated solvents. This technology used large diameter auger (LDA) soil mixing equipment to deliver a mixture of high-pressure steam and hot air to volatilize the majority of the contaminant mass, followed by an injection of a zero-valent iron (ZVI) slurry into the thermally-treated soil column to act as a long-term polishing agent for continued treatment of residual chlorinated solvent contamination. A vapor collection system recovered the off-gas stream at the ground surface and transported the mixture through activated carbon beds for onsite treatment. This system allows for real time data monitoring during treatment. Another advantage of this technology is that it combines several well-established treatment processes into a single operation to achieve a rapid cleanup at a competitive cost.

Results/Lessons Learned: FECC's client used the technology's innovative real-time data monitoring system to optimize the remedial process by evaluating trends in contaminant location, depth, and concentration. As a result, the client was able to effectively delineate the horizontal and vertical extent of the source area and quantitatively assess the effectiveness of the treatment. FECC treated 17 LDA soil columns to a depth of approximately 65 feet over a 900 square-foot area. Based on the system operational data and the physical and chemical properties of the contaminants, FECC's client estimated that approximately 361 pounds of contaminants were removed during treatment. Thermal treatment and ZVI costs were approximately $160 per treated cubic yard.

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Innovative Applications of Surfactants for Successful Combined Remedy Remediation

Fritz Hostrop, Karnam Ramanand and Paul Dombrowski

The presence of non-aqueous phase liquids (NAPLs) complicates in-situ remediation. In-situ remediation technologies, including in-situ chemical oxidation (ISCO) and bioremediation, actively react with organic contaminants in the aqueous phase, and a large fraction of contaminant mass may be present as NAPL. In addition, other organic contaminants can dissolve into a NAPL. Surfactants can be used enhance the solubility of organic contaminants and reduce the contaminant mass present as NAPL. This presentation will present on two sites where surfactants were incorporated into the remediation design to optimize the performance of in-situ treatment approaches. Both sites are located within active, urban properties, and identifying a remediation approach that would not interrupt operating businesses was vital.

Former operations at Site 1 resulted in PCE impacting soil and groundwater, including NAPL being present. ISCO using sodium permanganate was selected as the in-situ remediation technology to be facilitated by a surfactant where PCE NAPL and highest soil concentrations were detected. Variable oxidant and surfactant dosages were applied across the site based on PCE mass distribution and concentrations. Injections were performed into 40 saturated zone injection points and 67 unsaturated zone injection points. Nine months after injection PCE concentrations decreased in all 18 wells in the monitoring program, and PCE concentration in the most impacted well reduced from 27,000 µg/L to <20 µg/L. A focused injection was performed one year after the first injection for polishing treatment where PCE still exceeded regulatory criteria. Updated performance monitoring data will be included in the presentation.

At Site 2 soil and groundwater are impacted with cutting oil light non-aqueous phase liquids (LNAPL) and trichloroethene (TCE), cis-1,2 dichloroethene (cis-1,2-DCE), and vinyl chloride. Groundwater is slightly reducing due to the presence of LNAPL, and reductive dechlorination was observed to be occurring to varying degrees. The selected remediation approach is to enhance the naturally occurring biodegradation. Within the delineated LNAPL area, a customized sodium lactate solution was designed to include low surfactant dosage to enhance dissolution of the cutting oil to use the oil as an additional carbon substrate, nutrients, and pH buffer. Outside of the LNAPL area, Emulsified Vegetable Oil (EVO) was selected as the electron donor. Injection was performed into 29 direct-push points and 9 injection wells. Post-injection groundwater monitoring indicates molar concentrations of chlorinated ethenes have decreased markedly. In addition, additional LNAPL recovery has been achieved since the injection. A follow-up injection event is being planned to extend the treatment to the eastern portion of the contaminated area where access was previously not available.

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Addressing Contaminated Ground Water to Surface Water Discharge: Application of In-Situ Permeable Reactive Barriers (PRB) to Limit Migration of PFAS

Richard Stewart, John Hull and John Collins

Background: When contamination in soil or groundwater reaches surface water, the cost and complexity for remediation increases dramatically. At many sites, pump and treat systems have been used to hydraulically control/limit groundwater migration and attempt to reduce contaminant concentrations. However, these systems are expensive to operate/maintain, often less responsive to fluctuating flow rates or levels of contamination, and many have been running for decades without meeting goals or regulatory requirements. As a result, several projects have considered alternative passive designs to reduce costs and minimize/prevent the potential transfer of contamination to surface water. Control of PFAS-impacted groundwater, particularly in areas adjacent to canals, waterways or other bodies of water, is imperative to reducing impacts on water sources and habitat. It has been demonstrated that a permeable reactive barrier (PRB) can intercept and limit the migration of a range of contaminants. Examples include petroleum-related facilities, including pipelines, storage and distribution facilities, and sites where PFAS contamination is present. Such an approach will also protect sensitive ecological areas, including wetlands and stream crossings, in a manner that minimizes the potential impact to the existing habitat.

Approach/Activities: The best available materials and construction methods will be discussed with respect to the design of a PRB to address PFAS in groundwater. Material descriptions, the treatment approach, and the use of a funnel & gate design will be provided. The presentation will provide data and case studies, as well as an overview of materials that have been applied to both isolate (low-permeability) and treat (via adsorptive amendments e.g. RemBind®). Examples will highlight both petroleum and PFAS-related sites and applications.

Results/Lessons Learned: Information available demonstrates that a PRB design can provide a cost-effective, in-situ, passive alternative to pump-and-treat that can minimize the potential movement and impact of petroleum and PFAS contamination from upland areas into surface water.

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Session 10: Innovative Remedial Technologies

Use of Combined Drilling Technologies and Hydraulic Fracturing to Safely Inject into a Low Permeability Zone
Gary Cronk, JAG Consulting Group, Inc., Santa Ana, CA; Todd Hayes, Stratus Environmental, Ventura, CA

Enhancing the Sampling and Analysis Performance on Air/Water/Soil Samples with Innovative Approaches Combined with Thermal Desorption
Jan Peter Mayser, Markes, Llantrisant, UK; Rui Li, Markes, Gold River, CA

Evaluating the Remedial Effectiveness of Four Emulsified Substrates in Anaerobic In situ Bioreactors
Kerry Sublette, University of Tulsa, Tulsa, OK; Eric Raes, Bio-Enhance, High Bridge, NJ; Katherine Clark and Anita Biernacki, Microbial Insights, Knoxville, TN; Brett Baldwin and Dora Taggart, Microbial Insights, Inc., Knoxville, TN

Development of a Fast Titration Process to Evaluate Zero Valent Iron Performance
Patrick Randall, Hepure Technologies, Inc., Hillsborough, NJ

Accelerated Low Temperature In-Situ Removal of Creosote
William Kerfoot, Kerfoot Technologies, Inc., Mashpee, MA; Albert J.W. Smits, NTP ENVIRO Netherlands, Enschede, Ov, Netherlands

The Use of Innovative Characterization Technologies and Novel Amendment Injection Approaches at a Superfund Site
Ryan Wymore and Nathan Smith, CDM Smith, Denver, CO; Michael Smith, Vermont Department of Environmental Conservation, Montpelier, VT

Use of Combined Drilling Technologies and Hydraulic Fracturing to Safely Inject into a Low Permeability Zone

Gary Cronk and Todd Hayes

Low permeability groundwater zones often present a difficult obstacle to the safe and efficient injection of chemical reagents using direct push technology. At a gas station site in Los Angeles County, CA, the target geologic formation for injection was comprised of a dense siltstone and claystone formation (mudstone of the Monterey Formation) with low to moderate fracturing. Many of the fractures were infilled with caliche and gypsum making the formation extremely hard and dense. Advancing direct push rods to 50 to 60 feet in this formation often resulted in refusal (and broken downhole tools), so in order to complete the direct push injections at this depth, a hollow stem auger rig was used to drill through the upper 45 feet and then direct push rods were used from a depth of 46 feet to 62 feet for injection. Upon reaching the target depth for injection, a high pressure (100 to 120 psi) hydraulic fracturing tool was initially used for only a few minutes to fracture the surrounding formation and open up pore space for injection purposes. This initial fracturing procedure allowed for subsequent injection of the chemical reagents using much lower pressures of 30 to 50 psi and also improved the injection flow rates by three-fold. The ISCO reagents used at this site were stabilized hydrogen peroxide and sodium persulfate. Keeping low pressures and low flow rates during injection was instrumental at this site to control chemical daylighting. Overall, a total of 12 direct push injection points and three injection wells were used to complete a Full Scale treatment of the gas station site. The groundwater analytical results after seven months showed that the TPH gas, BTEX compounds, and MTBE were all reduced significantly by ISCO treatment, with contaminant reductions in the range of 60% to 95% across the site. As a result, it is expected the client will be pursuing closure of the site under the Low Threat UST Case Closure Policy of the Water Board.

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Enhancing the Sampling and Analysis Performance on Air/Water/Soil Samples with Innovative Approaches Combined with Thermal Desorption

Rui Li and Jan Peter Mayser

Analysis of volatile and semi-volatile organics (VOCs and SVOCs) and odorants in environmental samples often requires extensive sample preparation and multiple injection techniques to fully characterize a sample. In this work, a new multi-mode sampling and pre-concentration platform, Centri, designed to automate sample preparation whilst maintaining maximum sensitivity and selectivity will be demonstrated for the analysis of VOCs and odorants in environmental samples using multiple techniques including HS-Trap, SPME-Trap and Hisorb methods according to US EPA 524.2 requirements and EU Directive 98/83/EC. Up to four different sampling techniques on one platform can be combined for comprehensive characterization with the capability to use a sorbent-packed, cryogen-free focusing trap for optimum sensitivity and selectivity.

- *Headspace* techniques are widely used for analyzing VOCs in water, soil, and air, but sensitivity is limited in conventional static headspace mode. The cryogen-free focusing trap on Centri enables enhanced sensitivity for headspace.

- *SPME* is a convenient and readily-automated approach, typically used for sampling VOC and SVOC levels in the headspace of food, environmental and clinical samples. Combining SPME with secondary re-focusing on Centri enhances sensitivity by allowing multiple extraction cycles from a single sample to be 'concentrated' in one GC–MS run, thus benefitting peak resolution and chromatographic sensitivity.

- *High-capacity sorptive extraction*: In principle an extension of SPME using larger volumes of sorptive phase for greater sensitivity. Both immersive and headspace sampling modes allows the extraction of components from liquid or solid samples prior to pre-concentration and analysis.

- *Thermal desorption* (TD) has commonly been employed as a 'solvent-free' sampling approach for air monitoring, but has historically been limited in its ability to deal with liquid matrices. New developments in sampling technologies have extended the applicability of TD to liquid and solid samples allowing the extraction of components from within the sample prior to TD pre-concentration and desorption.

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Evaluating the Remedial Effectiveness of Four Emulsified Substrates in Anaerobic In situ Bioreactors

Eric Raes, Katherine Clark, Brett Baldwin, Dora Taggart, Kerry Sublette and Anita Biernacki

Background: In situ bioreactors each equipped to inject four different commercially available emulsified electron donors were used to enhance anaerobic bioremediation at an industrial facility in New Jersey. In addition, the sustained bio-augmentation via the ISBRs was compared to the traditional batch injection of EVO and bio-augmentation culture. Chemical, geo-chemical and microbial analysis were collected from the ten remediation wells and five adjacent monitoring wells.

Approach: ISBRs induce positive shifts in microbial growth and corresponding chemical reductions. The ISBR operates by providing small quantities of electron donor into the absorptive, Bio-Sep media within the ISBR to culture the present indigenous organisms. Four different substrates were used in duplicate to determine the remedial efficacy of each substrate when used in concert with the ISBR. The electron donors utilized at the site were Microemulsion ELS (Peroxychem), emulsified vegetable oil (TerraSystems), EVO (EOS), and ERD Provectus. This study also evaluated the pre-incubation of an ISBR (RIP-9) with commercially available reductive dechlorination culture to compare and contrast vs. the ISBR standard operation of culturing the indigenous microbial community. Lastly, a traditional batch injection of EVO followed by the injection of commercial culture was also evaluated (RIP-10).

Results: Significant growth in key microbial communities was observed in the first sampling event (90 days) after the commencement of remediation with all electron donor products. The most positive initial shifts were observed in the PCE and TCE respiring bacteria (Dehalobactor, Desulfitobacterium, etc.), populations increased up to six orders in magnitude. Small shifts Dehalococcoides were observed in select wells. Corresponding chemical reductions were also significant, as PCE levels were reduced from 130,000 to 16,200 mg/L. Results from 3, 6, 9 and 12 month sampling events will be compared and contrasted.

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Development of a Fast Titration Process to Evaluate Zero Valent Iron Performance

Patrick Randall

Purpose: Current methods to evaluate Zero Valent Iron (ZVI) performance require days or weeks and are very expensive. This paper presents the development of a fast titration method which can estimate reactivities, total treatment capacity, and longevity to best compare ZVI products for a project. This testing can be performed in hours without additional laboratory analysis costs.

Method: A known molar solution containing a ZVI product is stirred and a known molar permanganate solution added. The permanganate is introduced in small batches in order to record the required reaction time; initial tests may be needed to determine the optimum amount. The reaction is complete when the purple permanganate color is no longer visible. Applications are continued until timing becomes difficult, usually due to length of time to fully react and/or the interference of floc in reading the solution color. Two plots of the data are needed, the reaction rate for each application vs. the total time, and cumulative moles treated vs. total time. Regression equations are fitted to these plots and from the equations molar reaction rates, total molar capacity, and longevity can be determined.

Results: Initial testing of the titration method has been able to show the advantages and disadvantages of fine and coarse ZVI. Fine ZVI had higher initial reaction rates, however, the advantage was short lived. The coarse ZVI displayed greater overall treatment capacity and longevity. This initial evaluation can be important in finding potential ZVI products for full bench scale testing. Ongoing research is looking at correlating batch and column test data with this method.

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Accelerated Low Temperature In-Situ Removal of Creosote

Albert J.W. Smits and William Kerfoot

In 2013 a pilot test injection of a peroxide-coated micro to nanobubble ozone (Perozone®) was performed into soil capillaries containing adsorbed creosote in soils at a railway sleeper plant. The contaminated area was approximately 6,000 m2 with more than 90 tons of creosote. A low temperature reaction resulted in pushing fine bubbles of reduced mass alkanes into adjacent monitoring wells with cubic meters of product being recovered daily from certain wells. Initially, mineral oil (alkane) fractions were present at 5 µg/L and rose to over 190,000 µg/L with pure recoverable product exceeding cubic meters per day. The separated aqueous fraction was very bacteriologically activatable. The full-scale design was estimated from the seven-month pilot test to reduce the influent concentrations by more than 85% within 2.5 years.

From 2014 to 2016, the full-scale remediation with a conceptual in-situ model of the site near the railroad tracks and operational facilities was conducted. The facilities were able to stay operational during ozone remediation treatment, as compared to operational interruption during heat injection treatment. Chemical and bacterial action was intense on the shortened alkane (mineral oil) fractions. After high product recovery, the groundwater was sent through an above-ground bioreactor to reduce water concentrations from 272,000 µg/L to less than 7,000 µg/L and then recharged in a radial containment array with central recovery wells. Greater than 85% of naphthalenes were removed in a cost-effective manner within the 2.5-year remedial period. Certain regions had 90 to 99% removal. No odors or sound nuisance were present, and the procedure was deemed profoundly suitable for the site. Preliminary costing showed eight times less costly than other alternative techniques. This meets the remediation objective; preventing the spread of naphthalene through mass removal and in-situ treatment, based on a cost-effective approach.

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The Use of Innovative Characterization Technologies and Novel Amendment Injection Approaches at a Superfund Site

Ryan Wymore, Nathan Smith and Michael Smith

The Commerce Street Plume Superfund Site in Williston, Vermont is contaminated with TCE and its reductive daughter products beneath a mixed-use area. The ROD-selected remedy for this site features ISCO for TCE concentrations >50,000 mg/L, in situ bioremediation (ISB) for TCE >500 mg/L but < 500 mg/L.

Recent characterization featured the MiHPT and Waterloo APS tools, vertically discrete soil/groundwater sampling, onsite laboratory analysis, and 3-D visualization. Results showed that lower permeability silts are directly impacting contaminant transport in some areas of the site. This helped explain why TCE was not being detected at significant concentrations in areas of the site where the plume was thought to be migrating. Importantly, the characterization program showed that the 50,000 mg/L hotspot is no longer present. This implies that the entire ISCO remedy component is no longer needed, and that the entire site can be treated with ISB and MNA. Elimination of ISCO could represent up to a $3 million savings over the life-cycle of the remedy.

In addition, a field pilot program is underway to evaluate the best amendment injection strategy for the site and to assess overall ISB performance under field conditions. The ISB pilot program incorporates the use of shear thinning fluid (STF) into the ISB amendments. STFs are a low-cost material that is added to commercially available ISB amendments. They cause the viscosity of the injected amendment to decrease when it encounters lower permeability zones in the subsurface, thus enabling the amendment to more easily penetrate these layers, resulting in more uniform distribution.

ISB pilot injections and initial monitoring events indicate injections using STFs were completed with relatively high flow rates and low pressures, similar to that of the non-STF ISB area. Preliminary monitoring suggests good electron donor.

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Session 11: New Challenges in Evaluating and Communicating Health Risks

Overview of California's Emerging Risk Communication Issues
Bridgette DeShields, Integral Consulting Inc., Santa Rosa, CA

Communicating Environmental Risk to Judges and Juries
Don Sobelman, Downey Brand LLP, San Francisco, CA

Risk Communication Strategies for Emerging Contaminants
Jenny Phillips, TRC, Fort Collins, CO

New Monitoring Strategies to Assess Risks of CECs in Aquatic Environments
Alvine Mehinto, Southern California Coastal Water Research Project Authority, Costa Mesa, CA

Glyphosate Risk Assessment to Assess Proposition 65 Requirements for Pesticide Applicators and Construction Workers
Ann Verwiel, ToxStrategies, San Rafael, CA; Deborah Proctor and Mina Suh, ToxStrategies, Inc., Mission Viejo, CA

Overview of California's Emerging Risk Communication Issues

Bridgette DeShields

A number of challenging issues, with respect to both risk assessment and risk communication, have emerged in California over the last few years. These stem from news headlines, agency initiatives and regulatory changes, and increased focus on certain pathways and constituents. For example, increased regulatory scrutiny on indoor air and vapor intrusion, as well as the intersection of Proposition 65 warning requirements, increasingly requires delicate communications to the public and potentially affected parties. When sampling has to occur on residential or commercial properties, occupants have to be informed and the communications need to be simple, clear, and accurate. In other cases, news headlines and agency advisories create fear about the safety of drinking water supplies and ingestion of fish caught in local water bodies. PFAS compounds, 1,2,3,-trichloropropane (1,2,3 - TCP), and other emerging contaminants as well as legacy contaminants such as PAHs and PCBs are amongst the chemicals that are increasingly in the public eye and the subject of toxic tort and product liability lawsuits. This talk will present the emerging issues and provide guidance on how to craft effective messages and communicate risk to the public and stakeholders.

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Communicating Environmental Risk to Judges and Juries

Don Sobelman

Effectively communicating scientific/technical opinions concerning environmental risk is difficult in any circumstance. In the context of a civil jury trial, it is particularly hard, given that the expert needs to have a clear understanding of two very different audiences: the judge, who functions as the "gatekeeper" regarding whether the opinions are admitted to evidence, and the jury, which is the "factfinder" that will decide how much weight to give the opinions when reaching a verdict. This presentation will discuss strategies for addressing these two, very different audiences when testifying as an expert witness. Topics will include: the role of the expert in addressing environmental risk issues; deposition versus trial testimony; surviving admissibility challenges; presentation of credible, effective opinions during direct examination; and defense of those opinions during cross-examination.

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Risk Communication Strategies for Emerging Contaminants

Jenny Phillips

Risk communication is an art and a science. Communications regarding emerging contaminants add several challenges to an already challenging practice. The goal of risk communication is to simply and clearly present information to interested parties regarding the potential for adverse risk and potential exposures, and also to listen. Recognition that all concerns and questions are valid assists in communications regardless if the concern is a potential risk or not. Adding to the complexity of risk communication is the very real issue of emotional or perception of risk vs. scientific evidence and the tendency for the public not to know who to trust in impacted environmental situations. Uncertainties associated with the risk and toxicity of emerging contaminants make preparation and thoughtful delivery of clear messages and responses even more critical. In this presentation, the basic tools of risk communication will be presented, with the focus on adjustments necessary when discussing emerging contaminants. A summary approach will then be presented as a tool for future risk communications with regulatory agencies, stakeholders, and community members.

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New Monitoring Strategies to Assess Risks of CECs in Aquatic Environments

Alvine Mehinto

Current monitoring programs target individual chemicals for which robust analytical methods exist but do little to address the presence of unexpected contaminants (e.g. drug metabolites, transformation products). Moreover, this approach doesn't take into account the risk that complex mixtures may pose to human and environmental health. High throughput, cell-based assays have shown promise as bioscreening tools to assess environmental mixtures and prioritize sites requiring further chemical and/or toxicity testing. These assays are designed to respond to groups of chemicals acting via a common mode of action by initiating a molecular event (e.g. cell receptor activation) associated with specific biological pathways. As such, bioscreening tools offer an integrative approach to complement conventional chemical and toxicity testing. In recent years, we have conducted a series of laboratory and field studies to evaluate their robustness and potential utility to environmental management agencies. Our initial work focused on the evaluation and optimization of endocrine related cell assays such as estrogen receptor assay. Standardized protocols were then applied to screen water and sediment samples from various environments across California. In parallel, sub-samples were analyzed using both targeted and non-targeted chemical analyses. Bioscreening responses were generally minimal and in agreement with available chemical monitoring data. Additional research was conducted to characterize the relationship between *cell-based* and animal/community responses induced by environmental chemicals. Our findings demonstrate that cell assays can be used as a protective screen for toxicity before severe damage occurs, and serve as promising tools to modernize water quality monitoring.

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Glyphosate Risk Assessment to Assess Proposition 65 Requirements for Pesticide Applicators and Construction Workers

Deborah Proctor, Ann Verwiel and Mina Suh

Glyphosate, the active ingredient in several herbicides including Roundup™, has had wide-spread use for many decades, but its listing under California's Proposition 65 law has raised the need for risk assessment to assess the need to warn. We conducted a risk assessment to assess the potential hazards to herbicide applicators applying glyphosate at the maximum recommended application rate for turf. We also evaluated a unique construction scenario involving removal of turf and top soil and burying the treated media as fill.

We calculated exposure, non-cancer hazard, and potential cancer risks for applicators using the USEPA's Occupational Pesticide Handler Exposure Calculator. With chemical-specific toxicological inputs and product-based application rates, two application scenarios which involved mixing, loading, and applying herbicides using a hand sprayer, and using a tractor ground boom were evaluated. To evaluate construction worker exposures, the USEPA Regional Screening Level Calculator for construction worker activities was used to assess exposure for construction workers who remove turf and top soil over an 85-acre area, bury the turf, and generate dust by driving on treated soil. Relevant exposure pathways include soil ingestion, dermal contact, and inhalation of resuspended dust. To evaluate the construction scenario, grass/soil samples were collected three days following application, and the levels of glyphosate in treated turf were approximately 200 mg/kg.

Construction worker exposures were 2,000-times lower than the proposed No Significant Risk Level (NSRL) (1,100 µg/day), and the hazard index for construction workers was 0.009, well below the target level of 1. The non-cancer hazard index for applicators was 0.02, and exposures to applicators were 50,000-lower than the proposed NSRL. These results indicate that this use, as well as most uses of glyphosate to treat turf and remove dead grass and associated soil, is not likely to require a warning under Proposition 65.

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Session 12: Vapor Intrusion II

VI Attenuation Factors and Seasonal Variability at Large Industrial Buildings
Bart Eklund, Jessica Milose, Lisa DeGrazia, Carly Ricondo, and Helen Artz Patton, AECOM, Austin, TX

The Invisible VI Pathway: Evaluating TCE Diffusion Through Concrete
Matthew Mraw, Geosyntec Consultants, Blue Bell, PA; Jared Brisman, Geosyntec Consultants, Ewing, NJ; Eric Lovenduski, Geosyntec Consultants, Saratoga Springs, NY; Todd Creamer, Geosyntec Consultants, Portsmouth, NH; William Wertz, Geosyntec Consultants, Castleton, NY

Benzene in Natural Gas – Occurrence, Health Risk, and Regulation
Chuck Lambert, Intrinsik, Venice, CA

VI Preferential Pathways: Rule or Exception
Jay Clausen, USACE ERDC-CRREL, Hanover, NH; Darrell Moore and Lawrence Cain, USACE, Concord, MA

A New Vapour Flux Chamber Method to Quantify Surface Mass Flux for Vapour Intrusion Risks
Adrian Heggie, WSP Australia, Sydney, Australia; Bill Stavropoulos, SGS Australia, Brisbane, Queensland, Australia

Determining Cause and Effect of Indoor Air VOC Variations
Blayne Hartman, Hartman Environmental Geoscience, Solana Beach, CA; Mark Kram, Groundswell Technologies, Santa Barbara, CA; Cliff Frescura, Groundswell Technologies, Goleta, CA

VI Attenuation Factors and Seasonal Variability at Large Industrial Buildings

Bart Eklund, Jessica Milose, Lisa DeGrazia, Carly Ricondo and Helen Artz Patton

Two questions of frequent interest for vapor intrusion (VI) studies are 1) what attenuation factor is reasonable to assume for large industrial buildings, and 2) how many rounds of testing are needed to adequately characterize sub-slab soil gas. An on-going investigation at a major industrial facility in the Midwestern US provides insights to these questions. The findings should be generally applicable to other industrial buildings.

The buildings at the facility were ranked in terms of VI potential and 46 buildings were tested in the October 2016 to May 2018 timeframe. During the first round of testing, approximately 375 paired sub-slab and indoor air samples were collected. The number of sampling locations per building varied with the size of the slab. As many as 49 sample pairs were collected within a single building and nine or more sample pairs have been collected at 22 of the 46 buildings. To date, re-testing has been performed at 16 of the buildings where sub-slab and/or indoor air concentrations exceeded project-specific screening levels. Up to three rounds of follow-up testing have been performed to evaluate seasonal variability and an additional 200 sample pairs have been collected.

Various volatile chlorinated compounds were detected in the sub-slab samples (e.g., PCE, TCE, CFC-12), with concentrations exceeding 1,000 µg/m3 in a number of cases. Building-specific attenuation factors (?) were calculated based on compounds that were present at relatively high levels in the subsurface but with minimal indoor or outdoor sources. The vast majority of these ? values have been well below 1E-03. Seasonal variability in sub-slab concentrations was found to be lower than expected. The range of values for ? and coefficient of variation (%CV) for repeat sampling will be presented along with a statistical analysis of the data set.

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The Invisible VI Pathway: Evaluating TCE Diffusion Through Concrete

Matthew Mraw, Jared Brisman, Eric Lovenduski, Todd Creamer, Helen Dawson and William Wertz

Conventional approaches to vapor intrusion evaluation and mitigation typically deal with identifying and intercepting advective flow of soil gas into buildings through foundation cracks, joints, utility penetrations and atypical preferential flow pathways. However, volatile organic compounds (VOCs) in soil gas also diffuse through concrete slabs into indoor air. But there is limited information available regarding the significance of this mass transport mechanism to the vapor intrusion pathway. Contributions of VOCs to indoor air via diffusion through concrete can be significant, and traditional vapor mitigation approaches may not satisfactorily address this vapor intrusion mechanism.

The authors evaluated trichloroethene (TCE) diffusion through concrete at three sites, where sub-slab TCE concentrations were reported in excess of 1,000,000 µg/m^3. This presentation will describe the variables that influence diffusion through concrete, effective sampling methods for evaluating diffusion conditions, and successful mitigation techniques to address this vapor intrusion mechanism. This presentation will also have a focused discussion on the types of considerations that should be made during the investigative phase to avoid costly overdesign of engineered mitigation systems which may not have an attributable impact on diffusion across the concrete footprint. Mitigation approaches implemented by the authors include: increased indoor air exchange rates, sub-slab ventilation, concrete seal coating, and institutional controls. The presentation will describe site specific results of each mitigation option. In addition, the presentation will discuss an analytical model developed by the authors that uses an explicit finite difference solution to solve a partial differential equation for transient diffusion in one dimension through a layer of defined thickness; and field data from sites to compare against modeling results.

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Benzene in Natural Gas – Occurrence, Health Risk, and Regulation

Chuck Lambert

Benzene occurs naturally in natural gas (?90% methane). Benzene concentrations in natural gas can be significant from an analytical perspective and a potential human health concern. A comprehensive literature search revealed that benzene concentrations in natural gas are variable and that natural gas delivered to US residential and commercial customers may contain up to 100 ppm benzene (approximately 0.01% v/v). Benzene levels in European natural gases were also searched and generally range from 20-50 ppm but have been measured up to 800 ppm. A recently completed European human health risk assessment of benzene in natural gas will be reviewed, particularly with concern to US-specific exposure scenarios. Using what is known about benzene in natural gas in the US and the exposure scenarios developed in the European assessment, we will discuss the risk presented by natural gas containing as much as 100 ppm (0.01% v/v) benzene, as well as how natural gas may influence indoor air background concentrations of benzene. The state of regulations limiting benzene in natural gas will also be presented.

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Presenting Author: Chuck Lambert

VI Preferential Pathways: Rule or Exception

Jay Clausen, Darrell Moore and Lawrence Cain

Trichloroethylene (TCE) was released into the environment from various leaks and spills next to a large government building. The releases occurred over a period spanning several decades with the most recent event occurring over 20 years ago. In response to a perceived conventional vapor intrusion (VI) issue a sub-slab depressurization system (SSDS) was installed below the foot print of the building 5 years ago. SSDS operation resulted in the reduction of building TCE vapor concentrations. Operational data suggests the SSDS is operating as designed. However, subsequent periodic spikes of TCE in vapor have been observed based on daily HAPSITE™ measurements throughout the building. Two rounds of smoke tests (2017, 2018) were conducted where smoke from a smoke candle was introduced into a sanitary sewer and storm drain manholes located on effluent lines coming from the building. Smoke was blown into the piping using a fan until smoke was observed exiting system vents on the building roof. Smoke testing resulted in discovery of many leaks in both the storm sewer and sanitary sewer systems within the building through the emanation of visible white smoke. In some cases, smoke odors were detected but no leak or suspect pipe was identified suggesting the odor may have originated from an unidentified pipe located behind or enclosed in a wall. In some cases, the smoke test results correspond to locations where elevated airborne TCE levels have been measured with the HAPSITE™.

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A New Vapour Flux Chamber Method to Quantify Surface Mass Flux for Vapour Intrusion Risks

Adrian Heggie and Bill Stavropoulos

The measurement of surface fluxes of volatile organic compounds (VOCs) from natural ground surfaces and building floors has in former years been a commonly used measurement method for assessment of vapor intrusion risks at contaminated sites. To date the US EPA developed dynamic flux chamber has been the mainstay of the technology for surface molecular flux measurement. The method has declined in popularity due to its complexity of operation and bulkiness of equipment. Recently, a new instrumental method, utilizing the passive absorptive measurement principle, has been developed and the method has been recently published. The new method provides a technically simpler and lower cost means of surface vapor flux measurement. This presentation describes the theory of the new passive flux chamber, presents the data validating the theory, and presents comparison trials of the new passive flux chamber against the traditional dynamic flux chamber.

The passive flux chamber was developed to provide a technically simpler and more cost effective means of quantifying vapor intrusion rates into buildings where the dominant pathway for VOC intrusion through floors is molecular diffusion rather than pressure driven advective flows through floor gaps. Substantial diffusive mass fluxes of chlorinated VOCs through building floor slabs at industrial sites have been measured by the new flux chamber method.

The flux capture efficiency of the passive chamber was tested by measuring comparative concentrations in adjacent identical chambers, one fitted with and the other without an absorptive sampling tube. Field results showed an average capture rate of 85%, indicating the method provides an effective means of capturing total diffusive mass flux.

Eighteen field comparisons of surface fluxes measured by the passive and dynamic flux chamber methods showed that on average the passive chambers produced flux rates a factor of two greater than the dynamic flux chambers.

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Determining Cause and Effect of Indoor Air VOC Variations

Blayne Hartman, Mark Kram and Cliff Frescura

Indoor air sampling for volatile organic compounds (VOCs) is generally done with passivated canisters or passive samplers. Typically, only a few contaminant concentration measurements are made in a structure, often on two occasions six months a part. This paucity of data does not enable temporal variations in contaminant concentrations to be recognized.

Continuous monitoring enables the collection of a large volume of contaminant concentration data over time (~150 analyses per day) which enables recognition of indoor air concentration variations. Using this system, we have found temporal variations in every structure we have sampled, commercial and residential, over time periods as short as a few hours. Once the concentration pattern is recognized, simultaneous monitoring of additional parameters such as sub-foundation pressure, wind speed and barometric pressure enables the opportunity to determine the cause of the pattern. Once the cause is determined, then remedies can be attempted, and the effect of the remedy on the VOC concentrations is monitored by the system. Data from the system is uploaded in real-time to a server with an interactive dashboard allowing the practitioner to monitor the data within minutes of analysis from their desk.

Data collected from a number of new sites, not shown previously at AEHS, will be presented. The data demonstrate the ubiquitous variability of VOC concentrations in structures, both commercial and residential. This has ramifications on the future of indoor air sampling. In addition, examples from real sites determining the cause of the concentration variations and the effect of remedies will be presented.

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Session 13: The Many Dimensions of Sustainable Remediation

Sustainable In Situ Bioelectrochemical Remediation of Petroleum Hydrocarbon-Contaminated Soil
Song Jin and Paul Fallgren, Advanced Environmental Technologies, Fort Collins, CO; Jason Ren, Princeton University, Princeton, NJ; Yi Zuo, Chevron Energy Technology Company, San Ramon, CA

Sustainable Solar Powered SVE Remediation of Former Oil and Gas Production Pits
Rob Rebel, LT Environmental, Inc., Bend, OR; Kyle Waldron, Andeavor, Auburn, WA

Sustainable Remediation Case Study at "The Broadway" Development in Oakland California
Hayley Farr and Christopher Glenn, Langan Engineering, Oakland, CA; Christina Rain, Langan Engineering, San Francisco, CA

Methodology to Calculate Environmental Sustainability Index: Contaminated Site Remediation Case Study
Krishna Reddy, University of Illinois at Chicago, Chicago, IL; Adan Trentin and Antonio Thome, University of Passo Fundo, Passo Fundo, Brazil

Two Innovative Approaches to Implementing Green and Sustainable Remediation (GSR) Best Management Practices (BMPs) in Accordance with ASTM E2893-16
Betsy Collins, Jacobs, Raleigh, NC; Monica Fulkerson, Jacobs, Charlotte, NC; Jeff Gamlin, Jacobs, Englewood, CO; Paul Favara, Jacobs, Gainesville, FL; Matt Louth, Jacobs, Virginia Beach, VA; David Cleland, NAVFAC, Norfolk, VA; Charity Delaney, MCB Camp Lejeune, Jacksonville, NC

Development of a Sustainability Program for a Small-Business Environmental Consulting Company
Jason McNew, EA Engineering, Science, and Technology, Abingdon, MD; Frank Barranco, EA Engineering, Science, and Technology, Inc., Hunt Valley, MD

Sustainable In Situ Bioelectrochemical Remediation of Petroleum Hydrocarbon-Contaminated Soil

Song Jin, Paul Fallgren, Jason Ren and Yi Zuo

Bioelectrochemical (BEC) systems have been applied to environmental remediation to enhance contaminant biodegradation. BEC systems stimulate bio-oxidation reactions of various contaminants by establishing a highly efficient electron transfer conduit and expediting the rate of electron transport within the impacted matrix, as well as providing a perpetual and favorable terminal electron acceptor. This technology consumes no energy during its operation, even generating electricity when electrons flow through the circuit. Such generated electricity, though of low power density, can serve as a convenient indicator and remote monitoring parameter of in situ biodegradation.

BEC systems have been typically applied in situ in water-saturated matrices; however, unsaturated soil makes up a significant portion of matrices impacted by petroleum hydrocarbon spills. The primary challenge of applying BEC systems for remediation of unsaturated matrices is the limited medium for microbial electron transfer. A tubular BEC system design was implemented at a petroleum hydrocarbon-contaminated site, where the majority of the BEC system was within the unsaturated zone. Voltage generation was observed indicating electron transfer from contaminant biodegradation was occurring. It was also observed that diesel range compounds tended to be degraded before lighter gasoline range compounds. Overall, the field implementation of the BEC system for petroleum hydrocarbon biodegradation enhancement has demonstrated that the BEC system is an effective and sustainable in situ remediation technology for contaminated soils

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Sustainable Solar Powered SVE Remediation of Former Oil and Gas Production Pits

Rob Rebel and Kyle Waldron

Remote oil and gas (O&G) locations present unique challenges for the remediation practitioner. Traditionally dig and haul is employed where infrastructure for in-situ remediation is not available which is costly, has an increased greenhouse gas footprint, produces landfill waste, and disrupts site operations. To remediate a series of O&G production pits a solar powered soil vapor extraction (SVE) skid has been deployed. The skid is currently finalizing remediation at the first pit and will be deployed at two others following remediation completion. The skid includes a 4.9 horsepower regenerative blower providing vacuum through a series of subsurface wells which enhances volatilization of hydrocarbons. The blower is powered directly from a 6 kilowatt solar array via a variable frequency drive (VFD) eliminating the need for batteries while operating 10 to 14 hours per day. To date the system has removed 4 tons of volatile organic compounds (VOCs) in less than a year and compliance soil sampling will be conducted in September 2018. By employing a solar powered SVE skid the remediation project is more sustainable, creates less disruption to site operations, and has reduced project costs. The presentation will provide the production pit case study detailing site challenges, sampling results, innovative solutions, and lessons learned.

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Sustainable Remediation Case Study at "The Broadway" Development in Oakland California

Christopher Glenn, Christina Rain and Hayley Farr

Langan provided environmental and geotechnical engineering services for the design and construction of a 7-story, mixed-use development in Oakland's historic Auto Row. The project is a critical piece for the city's future, providing 423 residential apartments and 20,000 SF of retail space to alleviate housing shortages and revitalize the underutilized neighborhood into a vibrant, mixed-use district. The site was formerly the landmark Connell GMC Pontiac Cadillac dealership, but became an underutilized brownfield site following departure of the dealership.

Redevelopment was complicated by subsurface impacts by petroleum compounds, including BTEX compounds leaking from underground storage tanks. Langan designed an innovative approach that limited soil excavation to those soils that needed to be removed for the development site grading. In situ bioremediation was implemented to address the remaining contaminants, through installation of gypsum-backfilled borings that provided sulfate for biodegradation of petroleum compounds. This took advantage of natural biological processes while reducing carbon emissions, waste generation, and material, energy, and water use compared to traditional remediation approaches. Without the innovative remedial approach, neither the remediation nor the overall development project would have been financially feasible. Sustainable remediation was therefore critical to the cleanup of the brownfield impacts and the social contributions of the project to the neighborhood.

Aspects of social sustainability for this project included providing much needed housing supply to alleviate Oakland's housing crisis, contributing to revitalization of a neighborhood in transition from industrial to mix-use, serving as a keystone project that prompted revitalization projects at neighboring properties, and incorporation of the former auto dealership showroom façade into the new development to preserve this historical landmark and link Oakland's past into the project.

Overall, this project serves as an example of the benefits of sustainable remediation, which contributed to the environmental, social, and financials successes of the project.

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Methodology to Calculate Environmental Sustainability Index: Contaminated Site Remediation Case Study

Krishna Reddy, Adan Trentin and Antonio Thome

Many countries have problems with contaminated soils and groundwater. In the United States alone, the U.S. Environmental Protection Agency (USEPA) has identified several tens of thousands of contaminated sites that need remediation. Globally increased attention is being paid to this problem of soil and groundwater contamination. Several soil and groundwater remediation technologies have been developed, and there has been an increase in the number of decision support tools, especially for environmental impact assessment. The objective of this study is to present a quantitative methodology to determine environmental sustainability index for contaminated site remediation projects based on the Integrated Value Model for Sustainable Assessment (MIVES). MIVES methodology converts different quantified environmental impacts into a dimensionless quantity scaling between 0 and 1 using a value function. In this study, the MIVES methodology is applied to evaluate the sustainability of three potential remediation options to a site with soils contaminated by BTEX, PAHs, PCBs, and metals. The potential remediation options considered include: electrokinetic remediation, excavation and disposal, and phytoremediation. After the remediation options are selected, the environmental sustainability of each option is evaluated by considering four environmental criteria (air, water usage & impacts, energy, and land & ecosystem) consisting a total of ten environmental indicators. The environmental criteria and indicators are defined based on the scoring data obtained from the life cycle assessment endpoint scores using SimaPro software. The weightings of criteria and indicators are defined and the results are used to calculate environmental sustainability index for each potential remediation option. The best option from environmental considerations is identified to be phytoremediation, with an environmental sustainability index of 0.33 and the least preferred option is excavation and disposal, with an environmental sustainability index of 0.01.

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Two Innovative Approaches to Implementing Green and Sustainable Remediation (GSR) Best Management Practices (BMPs) in Accordance with ASTM E2893-16

Betsy Collins, Monica Fulkerson, Jeff Gamlin, Paul Favara, Matt Louth, David Cleland and Charity Delaney

When properly implemented, green and sustainable remediation (GSR) goes hand-in-hand with accelerating cleanup timeframes and reducing costs. ASTM E2893-16 “A Standard Guide for Greener Cleanups” provides a process for identifying, prioritizing, selecting, implementing, and reporting activities to reduce the environmental footprint of a cleanup. This presentation outlines the distinctive paths that two military facilities took while implementing GSR best management practices (BMPs) in accordance with ASTM E2893-16.

The first military facility developed and implemented innovative, site-specific GSR BMPs, including transitioning an existing pump and treat system to 100% solar power, installing multiple sub-grade biogeochemical reactors to reduce source area concentrations, and using phytoremediation to treat a large trichloroethene plume. These actions significantly reduced electricity usage (approximately 790,000 kilowatt hours [kWh] annually, resulting in an over $50,000 per year reduction in electricity costs) and reduced greenhouse gas (GHG) production (approximately 930 tons of carbon dioxide annually) were realized.

The second military facility leveraged the power of scale to achieve meaningful GSR goals. At this facility, 20 GSR BMPs were implemented at 42 active Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) sites during all stages of investigations including site assessment, remedy selection, remedy design and implementation, operations and maintenance, monitoring, and optimization. Implementation of these BMPs included using no-purge sampling technologies, coordinating with state regulators to remove a minimum purge volume requirement, and continual optimization of monitoring well network and frequency. These practices minimized waste generation and management (avoiding 1,500 gallons of aqueous waste per year and eliminating use of 15,000 feet of sample tubing per year), reduced greenhouse gas emissions related to transportation, and reduced electricity usage.

This presentation will detail the different approaches these two facilities took to develop and implement BMPs, provide examples of BMPs implemented, and share lessons learned from the process.

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Development of a Sustainability Program for a Small-Business Environmental Consulting Company

Jason McNew and Frank Barranco

The increased use of natural resources and recognition of the negative impacts associated with their use has resulted in a push to consider sustainable practices as part of a company's operations. The implementation of sustainable practices is especially important as remedial efforts should not result in excess resource use and creation of detrimental effects that outweigh the benefits. To incorporate sustainability into a company's operations, a sustainability program should offer a comprehensive framework for evaluating opportunities to apply sustainability components, developing implementation methodology, and finally measuring results. But how does a company take on this challenge, especially a small business with limited available resources?

EA Engineering, Science, and Technology, Inc., PBC (EA) established a corporate sustainability program in 2008. EA is incorporated as a Public Benefits Company, which serves as the foundation of the sustainability program. From that foundation, three pillars were established (Professional Development, Community Support, and Charitable Giving) which help guide company sustainability decision making. Components of the sustainability program include carbon footprint reporting, establishment of an employee sustainability committee and working groups, development of a waste generation/recycling program, and establishment of an environmentally preferred purchasing program. The successes and areas to improve are captured in sustainability highlights, as well as through Ecovadis scoring. Additional efforts include employee training, sustainability evaluations on projects to satisfy client's sustainability initiatives, and recognition of sustainability efforts through annual awards.

Sustainability is fluid, and as such, sustainability programs must be flexible to adapt as new information is learned and areas to improve are identified. Continual evaluation ensures that the program remains relevant and appropriate to accomplish the company's sustainability goals. This presentation will highlight several components of a sustainability program and provide some insight into the challenges and the successes of the development and continued operation of the program.

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Session 14: Chlorinated Compounds

Perchlorate System Assessment, Augmentation, & Analysis at a Former Army Ammunition Plant
Heather Knotek-Smith and Catherine Thomas, US Army Corps of Engineers, Vicksburg, MS

Fate and Transport Modeling of Perchlorate Stringfellow Superfund Site, Riverside County, CA
Jim Finegan, Kleinfelder, Riverside, CA

Adaptive Biostimulation Remedy to Quickly and Safely Treat Chlorinated VOC Plume in a Residential Community
Lisa Campe, Woodard & Curran, Inc., Dedham, MA

Bioremediation of Chlorinated Solvents, 25 Years of Progress
Michael Sieczkowski, JRW Bioremediation LLC, Lenexa, KS

Looking Back at Sites Treated with Thermal Remediation
John Sankey, True Blue Technologies, Inc., Vancouver, BC, Canada

Perchlorate System Assessment, Augmentation, & Analysis at a Former Army Ammunition Plant

Heather Knotek-Smith and Catherine Thomas

Long Horn Army Ammunition Plant (LHAAP) is a former government-owned facility located in Karnack, Texas, about 40 miles west of Shreveport, Louisiana. The Army Base Realignment and Closure Division (BRAC) is overseeing the environmental cleanup of contamination at the site that resulted from the production of various defense items (such as explosives, pyrotechnics, illuminants and rocket motors) beginning near the start of WWII, through the early 1990s. This includes remediation of perchlorate contaminated groundwater by pump and treat. A fluidized bed groundwater treatment system is used to degrade perchlorate prior to discharge. The purpose of this effort is to support the LHAAP Groundwater Treatment Plant (GWTP) in optimizing and augmenting their current perchlorate treatment system. The objectives of this work were to 1) develop a secondary system for treatment of perchlorate during times of plant upset as the primary perchlorate treatment as well as to be used as a final step after the FBR during normal operation, 2) assist LHAAP with characterizing and optimizing their existing FBR treatment process, and 3) identify an onsite perchlorate analysis method and evaluate that method for use.

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Fate and Transport Modeling of Perchlorate Stringfellow Superfund Site, Riverside County, CA

Jim Finegan

The Stringfellow Superfund Site in Riverside, California, overlies an aquifer system comprising alluvium, weathered bedrock, and unweathered bedrock. Perchlorate impacts to groundwater extend approximately 5 miles downgradient from a box canyon containing the source area through an alluvial paleovalley towards the Santa Ana River. A three-dimensional numerical model of groundwater flow and perchlorate transport in this system downgradient of the source area was developed in 2003, was subsequently updated and refined in 2010/2012 to provide predictions of solute transport and evaluation of remedial alternatives, and reconstructed using new modeling capabilities in 2018 to incorporate substantial additional information. The current model reconstruction uses a quadtree grid structure implemented in MODFLOW-USG to improve refinement in areas of high data density and of significant hydraulic features. Existing remedial systems installed to control the migration of volatile organic compounds comprise pump-and-treat extraction wells along the plume path. Following detection of perchlorate in 2001, remedial investigations have focused on control of this compound, although additional perchlorate sources (e.g., Chilean fertilizer and quarry blasting chemicals) besides the Stringfellow Site have also been identified as impacting local and regional groundwater.

The numerical model has been used to test several remedial alternatives in support of the site feasibility study, including no action, continuing current pump-and-treat remediation, modifying existing pump-and-treat systems, and *in-situ* bioremediation. However, because there are additional sources of perchlorate, stable and chlorine/oxygen isotope analyses are being used to assist in separation of the comingled plumes. These data along with a large number of hydraulic-test (slug and pumping) results will be incorporated into the calibration and use of the numerical model to evaluate cleanup times to prescribed goals. The numerical model is also expected to serve as a tool for annual capture analyses and future site investigations.

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Adaptive Biostimulation Remedy to Quickly and Safely Treat Chlorinated VOC Plume in a Residential Community

Lisa Campe

Highly concentrated chlorinated VOC (CVOC) plumes are difficult and costly to remediate in a timely fashion but are of significant concern when sensitive receptors are exposed, or ongoing sources persist. In this case study, vapor intrusion issues in a new residential development required immediate mitigation and a concentrated CVOC groundwater plume required remediation. Sub slab depressurization systems were used to rapidly and effectively address vapor intrusion. An approach was also required to address a separate groundwater source area with TCE concentrations up to 150,000 ppb and lower levels of cis 1,2- dichloroethylene and vinyl chloride. An adaptive, in-situ biostimulation approach was used that successfully reduced plume concentrations by up to four orders of magnitude (10,000 times lower) over a three-year time period.

The groundwater plume contained concentrations above regulatory “upper concentration limits” (UCLs) and was considered an ongoing source of contamination migrating off-property. The objectives for this source area were to reduce groundwater concentrations to below UCLs for TCE (50,000 ug/l) and breakdown products, and accomplish sufficient mass flux reduction to achieve a stable or contracting plume and allow for long term MNA as a final remedy. In situ bioremediation was selected based on indications of natural biodegradation, cost-effectiveness, and safety. An adaptive approach was employed by using the results of each injection event to modify and optimize subsequent injections. An organic carbon blended with zero valent iron was used to simultaneously promote anaerobic biodegradation and reductive dechlorination via biotic and abiotic pathways. The solution composition was adapted in each of three events to prevent degradation “stalling” and promote continuing augmentation, as well as modifying injection point locations. Monitoring post injections showed sustained concentration reductions and transformation to harmless ethenes/ethanes.

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Bioremediation of Chlorinated Solvents, 25 Years of Progress

Michael Sieczkowski

The concept of introducing organic substrates to the subsurface to promote the biological reductive dechlorination of ethenes was first introduced as a viable remedial option in the late 1980's. Today after more than twenty five years of research, development, and practical applications on thousands of sites, the process has changed to incorporate not only biological processes but also chemical processes associated with geochemical manipulation of subsurface systems.

Early applications of the technology included the introduction of highly soluble substrates like sodium lactate and molasses. As it became apparent that controlling the system for longer periods of time was preferred to attain optimal results in some situations, the choice of substrates quickly expanded to include materials like vegetable oil and lactate esters. The basic principle remained the same; provide an electron donor that would stimulate reductive dechlorination for a period of time sufficient to meet the goals of your project. Little attention was paid to optimizing the biological processes or to the ancillary chemical processes "fortuitously" at work as the geochemistry of the systems were being manipulated.

As the state of the practice matured, research began to better identify some of the specific biotic and abiotic processes responsible for contaminant transformation. Many of the abiotic processes were also those seen in chemical oxidation or chemical reduction. Today this knowledge is being utilized to improve remedial performance through a number of approaches such as combining readily soluble and slowly soluble organic substrates to promote both short and long term biological activity to the co-injection of organics with inorganics to promote both biotic and abiotic transformation.

This presentation looks at the state of the practice in its early years and compares that to some of the cutting edge applications found today related to combined enhanced reductive dechlorination and chemical transformation.

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Looking Back at Sites Treated with Thermal Remediation

John Sankey

Background/Objectives: Site owners and consultants often ask what happened years later at sites that were treated with Thermal Remediation. This presentation brings together data and status updates from several sites in California that were treated using Thermal Remediation. Often, bioremediation and other remedies were used to treat the less contaminated downgradient plume. The lessons learned should help site owners and consultants plan future in situ thermal applications.

Approach/Activities: Thermal Remediation technology was used to treat soil and groundwater, reducing the time to clean up volatile and semi-volatile organic compounds (VOCs and SVOCs) from years to months. The technology rapidly remediated the soil and groundwater impacted by chlorinated solvents and petroleum hydrocarbons, regardless of lithology.

On several sites using Thermal Remediation, there was *in situ* contaminant destruction through both biotic and/or abiotic mechanisms. The contaminant concentrations continued to decline for years after Thermal Remediation treatment due to these enhanced mechanisms. In addition, Thermal Remediation was combined at some sites with other treatment technologies (bioremediation and chemical oxidation) to optimize and enhance their performance for remediation of recalcitrant compounds in groundwater, including pentachlorophenol (PCP).

Results/Lessons Learned: After looking at several sites in California that were treated with Thermal Remediation, the contamination was reduced by several orders of magnitude and continued to be reduced for years after with naturally enhanced bioremediation. Many sites received a No Further Action letter while others have not completed cleaning the entire site. The lessons learned will help site owners and consultants plan future in situ thermal applications.

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Session 15a: NAPL

Electrical Hydrogeology of NAPL Sites: Advancements and the Future
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Estimates of Hydrocarbon NAPL Depletion from Compositional Change over Time
George DeVaull, Shell Global Solutions, Houston, TX

The Sheen Stops Here: How to Select a Remedial Technology that Won't Pass the Buck
Shannon Dunn, Arcadis, Minneapolis, MN; Rick Ahlers, Arcadis, Irvine, CA; Todd Cridge, Arcadis, Syracuse, NY

Electrical Hydrogeology of NAPL Sites: Advancements and the Future

Todd Halihan, Stuart McDoonald and Cullen Pickens

Hydrogeologists have relied on physical and chemical sampling from monitoring wells to characterize NAPL sites with mixed success. Direct push tools have allowed approximately one order of magnitude increase in data density. Surface deployed electrical imaging methods have allowed multiple orders of magnitude increases in data density in characterizing these sites.

After electrically imaging/scanning and sampling hundreds of sites, significant lessons in characterization and remediation have been learned. The heterogeneity in NAPL ecology and remediation effectiveness indicate that sampling at monitoring wells or direct push data density are limited in their effectiveness and should be limited to targeted confirmation data at locations based on subsurface electrical imagery. The future is also bright in characterizing and potentially farming microbes in the subsurface to facilitate cheaper and more effective remediation, as imaging data allows an improved view of their ecology. Recent developments, lessons learned, and future expectations of this approach will be discussed.

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Estimates of Hydrocarbon NAPL Depletion from Compositional Change over Time

George DeVaull

There are significant challenges in assessing depletion rates for hydrocarbon releases to the environment, particularly for subsurface zones of non-aqueous phase liquids (NAPL). Applied methods have included indirect measurement of constituent volatilization or dissolution rates from the NAPL or measurement of biodegradation reactants or products entering or leaving the NAPL zone. Direct evaluation may include measuring changes in total in situ NAPL mass (or volume) over time.
This presentation alternatively shows a method for directly estimating depletion of both the total bulk hydrocarbon mass and individual chemical constituents based on measured compositional changes in the NAPL over time. The method is consistent with available forensic methods but does not rely on a priori selection of conservative biomarkers.

Applied examples are shown using constituent-specific NAPL analysis results, collected over several decades, from multiple sites. Mean estimates and confidence limits on NAPL depletion rate are included.

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The Sheen Stops Here: How to Select a Remedial Technology that Won't Pass the Buck

Shannon Dunn, Rick Ahlers and Todd Cridge

When non aqueous phase liquid (NAPL) migrates from soil and sediment to the surface of a water body and visible sheens occur, the Clean Water Act of 1972 (the "Sheen Rule") requires that anthropogenic sheens be mitigated. The ability to predict the potential for NAPL seepage and resulting sheens, as well as their potential magnitude, requires a characterization of NAPL quantity, mobility, natural depletion, hydrogeology, and groundwater-surface water hydrology. The scale and aggressiveness of mitigation measures should be connected to the existing and future potential for NAPL seepage to generate sheens (i.e., mobile NAPL), rather than assuming that all NAPL, both near the groundwater-surface water interface (GSI) and in the upland, will contribute to the generation of sheens.

The NAPL seepage conceptual site models (CSM) includes delineation of mobile NAPL and identification of NAPL transport mechanisms. A robust NAPL seepage CSM will allow selection of the appropriate remedial technology. The selection and design of a remedial technology is based on the amount of mobile NAPL, the seep mechanism, and the mass flux of NAPL. Remedial technologies to control NAPL seepage can be categorized based on how they prevent NAPL seepage and the resulting sheen. By using the NAPL seepage CSM and the remedial technology categories, the remedial technology is selected that will best control the NAPL seepage.

This presentation discusses the development of NAPL seepage CSM and the state of the art in NAPL seepage mitigation. It will also discuss ASTM's development of NAPL mobility in sediment standards.

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Session 15b: Heavy Metals

Strategic Injections of Calcium Polysulfide (CPS) for Successful In-Situ Remediation of Hexavalent Chromium (CrVI) Contamination
Thomas Barzyk, BB&E, Inc., Northville, MI

Enhancing Management of Heavy Metals Contaminated Lands Using Stable Isotopes
Jun Lu, Hefei University of Technology, Hefei, China; Lucas Hellerich, AECOM, Rocky Hill, CT; Lihai Hu, University of Utah, Salt Lake City, UT

The Exide Residential Soil Database: An Extraordinary Database of Urban Soil Quality from 8,900 Homes
James Wells and Jorge Matos, L. Everett & Associates, Santa Barbara, CA

Strategic Injections of Calcium Polysulfide (CPS) for Successful In-Situ Remediation of Hexavalent Chromium (CrVI) Contamination

Thomas Barzyk

Straits Steel and Wire Company conducted manufacturing operations involving the plating of refrigerator racks and other fabricated wire products for the home appliance market from the 1940s to the early 1990s at their former site in Ludington, Michigan. Plating operations ceased in the early 1990s; however environmental impacts from the historical plating operations resulted in contamination to soil and groundwater creating an approximate 2,000 foot long hexavalent chromium (CrVI) groundwater plume within the local Lake Michigan dune, lacustrine, and glacial sand environment. Remedial response activities conducted to date include soil removal, groundwater plume interception via hydraulic control, and the strategic injection of calcium polysulfide (CPS) reducing agent for the in-situ treatment of CrVI soil and groundwater contamination. CPS is a reducing agent utilized for the conversion of CrVI (more toxic) to trivalent chromium (less toxic). Pre-injection design focused on the refinement of planned injection areas along with bench scale testing to optimize the CPS injection doses and chemistry. Injections focused on the placement of the CPS treatment chemistry into historical source areas. Post injection performance monitoring has indicated favorable groundwater contaminant trends within and downgradient of the former hotspot source areas. Long-term monitoring (LTM) is on-going and continues to document favorable groundwater contaminant trends. A No Further Action (NFA) status with LTM and an Environmental Restrictive Covenant (ERC) has been approved by the Michigan Department of Environmental Quality (MDEQ). Key aspects of the overall remediation success include the development of positive regulatory relationships, commitment of ownership to resolve historic environmental issues, and collection of key site data for the enhancement of the Conceptual Site Model (CSM) to enable an optimized and cost effective remedial solution. In addition, recent State of Michigan emerging contaminant concerns with per- and polyfluoroalkyl substances (PFAS) at historical metal plating facilities were quickly evaluated and addressed.

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Enhancing Management of Heavy Metals Contaminated Lands Using Stable Isotopes

Jun Lu, Lucas Hellerich and Lihai Hu

Heavy metals in contaminated lands can be derived from a variety of activities such as mining, manufacturing, and the use of synthetic products. Understanding sources and environmental characteristics of the heavy metals is crucial in many aspects of management of contaminated lands including liability resolution, contamination prevention, and remedial site investigation. This paper presents two case studies that are related to source identification and remedial site investigation.

First case study involves use of lead isotopes to identify sources of lead in sediment. The sediment core was taken from a lake which several large lead mining areas and lead smelters drained into from late 1800s to early 1900s. The concentrations of trace metals and lead isotopic compositions of the sediments sampled from the core with known age were measured. The result shows that the lead concentration in sediment increased dramatically at the same time of the rapid growth of lead production in the USA. The same trend of increasing contribution of mining activity is also observed in lead isotopic compositions. The findings provide a scientific basis to promote prevention of sediments from further contamination of heavy metals and other contaminants in the region.

The second case study is to assess isotopic characteristics of chromium in groundwater at two sites where groundwater has been contaminated with Cr (VI): one with electroplating operations between 1930 and 1995, and another by soluble chromium-processing wastes between 1911 and 1963. The results show significant enrichment of ^{53}Cr over ^{52}Cr by reduction of Cr (VI) to Cr (III) and influencing factors including concentration of Cr (VI) and dissolved organic carbon and age of the releases. The findings from this study provide an additional aspect to consider within the overall framework for evaluation of chromium fate and transport processes, including natural attenuation, at chromium impacted sites.

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The Exide Residential Soil Database: An Extraordinary Database of Urban Soil Quality from 8,900 Homes

James Wells and Jorge Matos

The shallow soil of up to 10,000 homes is believed to be contaminated with lead from the Exide secondary lead smelter in Vernon, California. Battery recycling had been conducted at this site from 1922 until 2014. Starting in about 2014, off-site sampling indicated that residential areas surrounding Exide may have been impacted by lead fallout from the facility's air emissions. Eventually, the California Department of Toxic Substances Control (DTSC) identified a Preliminary Investigation Area (PIA) that extends approximately 1.7 miles radially from the former Exide facility, thought to contain elevated levels of lead in shallow soil due to Exide's releases. It is well known that exposure to even low levels of lead in the environment can pose public health problems, especially for children. Elevated blood lead levels in children are associated with neurological problems, learning problems, hyperactivity and anemia. In 2016, Governor Brown signed legislation that directed $176.6 million in state funds to expedite and expand testing and cleanup of residential properties, schools, daycare centers and parks around the former Exide facility. DTSC embarked on a characterization program which eventually resulted in an extraordinary database of more than 325,000 samples from 8,500 homes and all of the schools and daycare centers within the PIA. The Exide PIA database provides an unprecedented resource for assessment of urban soil quality. Interpretation of this data is complex: in addition to naturally-occurring lead, urban environments may also be affected by other sources of lead including legacy lead-based paint, legacy fallout from leaded gasoline and, possibly, other regional industrial sources. In this paper, we explore the spatial variability of the residential data to better understand fate and transport of airborne lead in an urban environment. The database is also an important resource for inquiries into natural and urban background and source attribution.

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Session 16: Vapor Intrusion III

Investigation of Vapor Migration and Vapor Intrusion Using Continuous Vapor Monitoring and Web-Based Real-Time Data Reporting
Richard Baldino and Raghu Nagam, SRS, Chicago, IL; Nova Clite, OTIE, Ventura, CA; Mark Kram, Groundswell Technologies, Santa Barbara, CA; Blayne Hartman, Hartman Environmental Geoscience, Solana Beach, CA; Jim Mitchell, USEPA Region 5, Chicago, IL

Risk Factors and Investigation Protocol for Sewer Preferential Pathway Vapor Intrusion
Lila Beckley, GSI Environmental, Austin, TX; Thomas McHugh, GSI Environmental, Inc., Houston, TX

New Methods Using Measurable Evidence for Quantifiable Confidence in VI Decisions
Henry Schuver, US EPA, Washington, DC

Using HAPSITE to Define and Monitor Trichloroethene Impacts on Indoor Air
Jack Besse and Wolfgang Calicchio, Wood Environment & Infrastructure Services, Portland, ME; Avery Whitmarsh, Wood Environment & Infrastructure Services, Oakland, CA

Using Mass Flux to Inform VI Mitigation System Termination Decisions
Theresa Gabris and Helen Dawson, Geosyntec Consultants, Washington, DC; William Wertz, Geosyntec Consultants, Castleton, NY; Todd McAlary, Geosyntec Consultants, Toronto, ON, Canada; Daniel Carr, Sanborn, Head and Associates, Inc., Dayton, ME

Vapor Intrusion Risk Closure Achieved with Cost-Effective Vapor Mitigation Solution
Tom Szocinski and Zach Gilmer, Land Science, San Clemente, CA

Investigation of Vapor Migration and Vapor Intrusion Using Continuous Vapor Monitoring and Web-Based Real-Time Data Reporting

Nova Clite, Richard Baldino, Mark Kram, Blayne Hartman, Raghu Nagam and Jim Mitchell

Vapor intrusion (VI) of chlorinated volatile organic compound (CVOCs) into residences was suspected from identified industrial sources via combined storm/sanitary sewers at a site in Kokomo, Indiana (USA). A multi-phased assessment of vapor migration and VI is being conducted by USEPA using an automated continuous vapor monitoring system to quantify and report in near-real time Trichloroethylene (TCE) and Tetrachloroethylene (PCE) using a TO-14 modified method with less than 1 microgram per cubic meter ($\mu g/m^3$) detection limits. The objectives are to 1) identify if the sewer lines were impacted with CVOCs and serving as VI preferential pathways, and 2) evaluate if VI is occurring in selected households requiring mitigation. The investigation is ongoing and anticipated to be completed during the summer of 2018. Vapor samples are being collected and analyzed from at least 50 monitoring locations distributed among sewer lines, soil vapor probes, and occupied residences. The investigation includes sewer line sampling, subsurface soil vapor sampling, and indoor air sampling in residences. The system is being used to identify TCE/PCE from indoor sources in “grab sample” mode. Continuous monitoring of both TCE/PCE and pressure differential readings are collected to assess the sensitivity of CVOC concentrations to changes in atmospheric pressure and identify VI patterns. By conducting eight-hour continuous monitoring at several locations, the pattern of variability of CVOC concentrations over short time intervals can be assessed. Additional monitoring may be conducted based on initial results.

The analytical system is integrated with remote telemetry and GIS to automatically report results through a Cloud-based visualization and response platform available 24-7 to the project team. Data are also automatically uploaded to EPA’s VIPER database. Technical challenges being addressed include maintaining sewer vapor sampling lines above water levels, preventing matrix interference from sewer gas components, and selecting representative soil vapor sampling locations.

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Risk Factors and Investigation Protocol for Sewer Preferential Pathway Vapor Intrusion

Lila Beckley and Thomas McHugh

The topic of preferential pathways for vapor intrusion (VI) has gained increasing attention in recent years. Nevertheless, there remains little specific technical or regulatory guidance on how to assess this pathway. Therefore, through the Department of Defense ESTCP program, we have conducted systematic testing to characterize volatile organic compounds (VOCs) in sewers in order to better understand their relationships with underlying impacted groundwater. This was done by measuring VOC concentrations in sewer lines at more than 35 sites. Multiple rounds of sampling were conducted at a subset of these sites to evaluate temporal variability in VOC concentrations. In addition to studying relationships between VOCs in groundwater and sewers, we utilized perfluorinated tracer (PFT) compounds to measure vapor migration between sewers and individual buildings. The tracer testing was conducted at a total of 7 residences and 8 commercial buildings. Attenuation factors were developed for the groundwater to sewer vapor pathway, and the sewer vapor to building pathway.

Data collected for this project were used to update the conceptual model for the sewer/utility tunnel preferential pathway for VI. Sites with higher risk for preferential pathway issues are characterized by direct interaction between the subsurface source and the preferential pathway (e.g., sewer line below the water table). Lower-risk sites are characterized by indirect interaction between the subsurface source and the preferential pathway (e.g., sewer line located in the vadose zone above the groundwater plume). Based on the relative risk, groundwater-to-sewer and sewer-to-building attenuation factors, and spatial and temporal variability observed in the sewer vapor dataset, recommendations for a sewer/utility tunnel investigation protocol have been developed.

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New Methods using Measurable Evidence for Quantifiable Confidence in VI Decisions

Henry Schuver

The primary goal for vapor intrusion (VI) assessments is risk management decisions that are, and will remain, appropriately protective for all receptors for as long as necessary. The acceptable level of confidence in environmental exposure decisions is well established (e.g., 95th%) and has been reasonably achievable for most other exposure pathways and scenarios. The VI exposure pathway presents a challenge for practitioners as it is difficult to assess and/or predict indoor air concentrations and meet the typical goal of 95% confidence because of variability over time and space, building-specific conditions and confounding background sources. Practical and empirical approaches under development have shown promise in providing quantifiable confidence levels, which significantly improves our understanding of VI processes and reduce this confidence gap. The approaches applied in practice have included: 1) contaminant mass-flux/loading analyses involving known ventilation rates and building pressures, and 2) using frequent measurements of Indicators, Tracers and Surrogates (ITS) to focus target-chemical sampling to the locations and times most likely to represent reasonable maximum exposures. These approaches have been developed and tested rigorously and provide promise for use in cost-effectively tracking of remediation performance and long-term risk reduction, a substantial gap in the present practice. This presentation will provide an overview of data and scenarios subjected to testing so far, as well as data and cases to be further explored by EPA-ORD and others in 2019. By the Fall it is anticipated that the datasets and case examples where these methods have been tested will be sufficiently robust to present a general understanding of the range of capabilities and limitations of these measurement-based methods. We believe the Fall 2019 time-period will be appropriate for a full-day Workshop that will: 1) present the details of the latest technical evidence for such approaches and 2) elicit input from the workshop participants to compare their observations, experiences and datasets. Most importantly, this workshop will seek input from Regulators and other practitioners on what types of additional data, testing and/or modifications in approaches, minimum numbers of samples, etc. are recommended to improve the confidence in regulatory VI decision-making. This (Spring 2019) presentation will be an opportunity to help structure and design the Fall workshop so that it may provide the maximum improvement in our understanding and better management of VI risk. We look forward to your input.

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Using HAPSITE to Define and Monitor Trichloroethene Impacts on Indoor Air

Wolfgang Calicchio, Jack Besse and Avery Whitmarsh

Regulatory approaches for investigation of vapor intrusion (VI) typically focus on collecting 8- to 24-hour time-weighted average (TWA) samples utilizing Summa canisters, with results usually received weeks later. Alternatively, non-selective screening can be accomplished with a handheld photoionization detector (PID) that can only be relied upon as a gross screening tool. These methods of investigation have limitations, yield spurious results, and provide a limited understanding of the true potential for VI at a site.

Historic releases of trichloroethene (TCE) to soils at a federal site in New Hampshire caused VI to indoor air. Following initial evaluation using TWA samples collected into canisters, the site transitioned to real-time analysis using HAPSITE a portable gas chromatograph with a mass spectral detector (GC/MS). The HAPSITE initially was used to evaluate potential preferential pathways and evaluate interior sources of TCE. For example, by collecting samples using the HAPSITE before, during, and after adjusting a basement exhaust fan, the team was able to evaluate the means of TCE migration through the building.

Five years later, there are now two HAPSITES in operation at CRREL, with over 28,000 air samples analyzed and regulatory acceptance of the results in place of canister samples. Continued, daily indoor and outdoor air monitoring and VI investigation using the HAPSITE has provided a broader understanding of the dynamic nature of VI and an awareness of the impacts of significant VI drivers at this site, including barometric pressure changes, air flow movements outside of and within the building envelope, identification and impacts of interior sources. This has allowed for an evaluation, monitoring, and modification of the mitigation strategies in place to reduce or remedy the TCE impacts as well as fast tracking of the project and cost savings for the client.

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Using Mass Flux to Inform VI Mitigation System Termination Decisions

Theresa Gabris, Helen Dawson, William Wertz, Todd McAlary and Daniel Carr

National vapor intrusion (VI) guidance currently lacks standard criteria for the shutdown of VI mitigation systems. Decisions to shutdown subslab venting (SSV) systems typically require several lines of evidence and data collected over a long period. ESTCP research project ER-201503 is evaluating using SSV mass flux monitoring of SSV systems in residences downgradient of the former Redfield Rifle Scope manufacturing facility in Denver, Colorado (Site) to inform system shutdown decisions. A long history of groundwater monitoring and indoor air sampling has demonstrated that elevated VOC concentrations in the residences arise from the underlying VOC-contaminated groundwater. SSV systems have been operating at these residences for over 10 years.

The research project is monitoring SSV mass flux at eight residences at the Redfield Site. Spatial variability is being evaluated by comparing mass flux among the eight residences and temporal variability is being evaluated by comparing mass flux at each residence over four seasons. The SSV mass flux results are being compared to estimates of diffusive mass flux from the underlying contaminated groundwater using routine groundwater monitoring data from nearby wells to determine whether they can be used to support termination of the system.

This presentation will discuss the findings of four rounds of SSV mass flux monitoring. Stack monitoring as a tool for determining whether SSV operation can be terminated has already been approved by the Colorado Department of Public Health and the Environment and may prove particularly useful for homes where other lines of evidence are not readily available.

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Vapor Intrusion Risk Closure Achieved with Cost-Effective Vapor Mitigation Solution

Tom Szocinski and Zach Gilmer

Background: Located in Renton, Washington, a suburb of Seattle, a former jazz club, located adjacent to a former dry-cleaning operation had identified subsurface contamination caused by chlorinated VOC's beneath the former club. Through indoor air sampling it was determined that the subsurface concentrations of VOC's were found to pose a direct risk to the indoor air quality for the building above the Washington State DOE risk screening level of indoor air quality.

Approach: Both indoor air and sub-slab soil vapor assessment was conducted at the property in 2016, to assess the VOC vapor intrusion from the adjacent dry-cleaning facility onto the property. The results indicated the presence of PCE and TCE at a concentration above Washington State DOE Vapor Intrusion Indoor Air cleanup levels.

In January 2017, further evaluation of the indoor air quality and assessment of the VI risk to the property was conducted. The data was compared to DOE's VI screening levels. Again, the presence of PCE and TCE were found to be above Washington State DOE's screening levels, resulting in the need for a mitigation measure at the property. To eliminate the VI risk pathway the consultant proposed the use of Retro-Coat^{TM} vapor barrier. Retro-Coat was installed across the entire floor and basement walls. To confirm and conduct a VI closure evaluation, post VI barrier installation, indoor air samples were collected.

Results: The objective of mitigating vapor intrusion of VOCs was met by the installation of the Retro-Coat Vapor Intrusion Coating System. The post indoor air sampling results indicated no VOCs have been detected above DOE's indoor air screening levels since the vapor barrier implementation. This safe and effective installation was completed in three days, VI closure was achieved in less than six months, and it provided a significant cost savings to alternative remedial approaches.

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Session 17: TPH Risk Assessment

What is in a TPH Result?
Catalina Espino Devine, Lauren Kristofco, Renae Magaw, and Tim Patterson, Chevron, San Ramon, CA; Rachel Mohler, Chevron, Richmond, CA; Kirk O'Reilly and Sungwoo Ahn, Exponent, Inc., Bellevue, WA; Natasha Sihota, Chevron, Houston, TX; Dawn Zemo, Zemo & Associates, Inc., Incline Village, NV

Overview of ITRC's New TPH Risk Evaluation at Petroleum Contaminated Sites Guidance
Roy Thun, GHD, Santa Clarita, CA; Thomas Booze, CalEPA, Sacramento, CA; Mike Kwiecinski, Department of Labor and Employment, Oil and Public Safety, Denver, CO

Human Health Risk Assessment – Total Petroleum Hydrocarbons – ITRC Guidance
Amy Goldberg Day, Arcadis, San Rafael, CA

Ecological Risk Assessment of Total Petroleum Hydrocarbon (TPH) Mixtures – ITRC Guidance
Usha Vedagiri, Wood, Oakland, CA; Shanna Alexander, Georgia Department of Natural Resources, Atlanta, GA; Amanda Bess, Chevron, Houston, TX; Bjorn Bjorkman, GEI Consultants, Fort Collins, CO; Thomas Booze, CalEPA, Sacramento, CA; Mike Kwiecinski, Department of Labor and Employment, Oil and Public Safety, Denver, CO; Jonathon Naile, Shell, Houston, TX; Mala Pattanayek, Integral Consulting Inc., San Francisco, CA; David Rigg, Arcadis, New York, NY; Ross Steenson, San Francisco Bay Regional Water Quality Control Board, Oakland, CA; Lyle Trumbull, OBG, Houston, TX

What is in a TPH Result?

Catalina Espino Devine, Rachel Mohler, Kirk O'Reilly, Natasha Sihota, Lauren Kristofco, Sungwoo Ahn, Renae Magaw, Dawn Zemo and Tim Patterson

Petroleum releases are complex mixtures that contain hundreds to thousands of organic compounds, the majority of which are petroleum hydrocarbons. Site assessment at petroleum release sites includes the analysis of soil, groundwater and soil vapor samples for individual constituents within the petroleum mixture that are risk-drivers (e.g., benzene, toluene, ethylbenzene, and xylenes [BTEX]). In many cases, it also includes an effort to assess the overall petroleum mixture by using a Total Petroleum Hydrocarbons (TPH) analysis. Evaluating the petroleum mixture has been problematic because it has been technically infeasible to quantify the thousands of individual hydrocarbons that make up the petroleum mixture due to lack of analyte-specific method for each compound found in the petroleum mixture. Furthermore, it is known that the petroleum mixture changes over time and oxygen containing organic compounds (i.e. polar compounds) are being produced as part of natural attenuation. Individual states have taken different approaches to assess the petroleum mixture, ranging from a few states that do not use TPH analyses at all, and instead rely only on the relatively few indicator risk-driver chemicals, to most other states that require some type of TPH analysis to assess the petroleum mixture. In principle, the option of measuring the “the petroleum mixture” by a TPH method sounds appealing as this is a low-cost analytical method widely offered by commercial labs that provides a TPH concentration result supposed to represent the “total petroleum hydrocarbons”. However, the different TPH methods that are used are not a direct measurement of the total petroleum hydrocarbons in the petroleum mixture. Rather, TPH analysis is a non-specific measurement of total extractable organics which can include non-hydrocarbons in the mixture such as background organics (biogenic and anthropogenic), oxygen-containing organics produced by biodegradation, and even lab artifacts. Furthermore, two different TPH methods are not equal and two different labs using “the same TPH method” are not equal. There is high variability in the TPH methods even if they refer to the same SW-846 Standard Operating Procedure due to changes in the labs operating parameters. If the TPH methods employed reference different SW-846 SOPs (e.g. EPA 8015c vs. EPA 8260) then the methods measure the organic mixture differently due to method variability (e.g. type of detector, lab standards and operating parameters of the analytical instrument) and will provide different results.

Even with all the limitations of the TPH methods, the TPH result can still be a useful tool for site assessment and decision-making if a science-based tiered approach is used to employ the different TPH methods to information and update the Site Conceptual Model. Useful TPH interpretation is possible by understanding what each TPH method result means and its limitations. This presentation will discuss an approach to understanding TPH method results and the use of more specialized TPH methods for interpretation of site assessment data when warranted.

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Overview of ITRC's New TPH Risk Evaluation at Petroleum Contaminated Sites Guidance

Roy Thun, Thomas Booze and Mike Kwiecinski

Risk evaluations for petroleum release sites present complex and unique challenges to site managers, risk assessors, regulators and other stakeholders. Mischaracterizing risks associated with petroleum contamination can lead to unnecessary cleanups, inappropriate property use limitations and unrealized site hazards. Once released to the environment, petroleum contamination changes over time and space due to natural and anthropogenic weathering processes. Traditional surrogate compounds (BTEXN) may be absent from samples and therefore not properly identify petroleum contamination or degradation products (metabolite compounds) which can pose a risk to human health and ecological receptors. The Interstate Technology and Regulatory Council (ITRC) has produced a new technical guidance on TPH Risk Evaluation at Petroleum Contaminated Sites. A diverse team of over 140 experts from state and federal regulatory agencies, local governments, academia, industry, consulting and public stakeholders developed this guidance. The ITRC TPH Risk guidance draws from the 1990's foundational work of the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG) and many recent publications. The ITRC TPH Risk guidance also incorporates a survey of state regulatory agencies from across the United States. ITRC's TPH Risk guidance will improve regulators and project managers understanding of the unique properties of TPH and provides the tools, techniques and lessons learned to make better-informed risk management decisions at petroleum-contaminated sites.

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Human Health Risk Assessment – Total Petroleum Hydrocarbons – ITRC Guidance

Amy Goldberg Day

Background: Total petroleum hydrocarbons (TPH) mixtures are not always evaluated in human health or ecological risk assessments. Instead a somewhat arbitrary 100 parts per million is often applied as a cleanup goal. To address the lack of TPH criteria, TPH is often evaluated using surrogate chemicals such as benzene, naphthalene, and ethylbenzene. To address the lack of TPH risk assessment guidance, the Interstate Technology Regulatory Council (ITRC) will be publishing a TPH Risk Assessment guidance document, due to be released in November 2018.

ITRC Guidance Document: The objective of this guidance is to build on previously published research to assist users in evaluating potential risks and risk-based corrective action assessments at petroleum hydrocarbon spill and release sites. In general, this guidance will present the current science and understanding of TPH risk characterization. The document will present why TPH risk characterization is important and provide a resource to guide users in making technically defensible assessments at TPH impacted sites to protect human and environmental health. The document will also describe the unique issues that should be addressed when characterizing TPH risks. Applicability and limitations of this will also be presented.

Presentation: This presentation will discuss the methods for performing both human health and ecological risk assessment. This includes providing information on the various analytical methods available. Sampling strategies for both human health and ecological evaluations will be included. The ITRC TPH document will also identify the tool gaps for evaluating human health and ecological risk for TPH. Guidance will be provided on how to address data gaps so that risk-based conclusions can be as complete and be effective in terms of supporting risk management decisions. A demonstration of the on-line tool will also be included.

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Ecological Risk Assessment of Total Petroleum Hydrocarbon (TPH) Mixtures – ITRC Guidance

Usha Vedagiri, Shanna Alexander, Amanda Bess, Bjorn Bjorkman, Thomas Booze, Mike Kwiecinski, Jonathon Naile, Mala Pattanayek, David Rigg, Ross Steenson and Lyle Trumbull

This presentation will provide an overview and decision-making process for addressing ecological risk from complex TPH mixtures that often function as both physical and chemical stressors to ecological receptors. The Interstate Technology and Regulatory Commission (ITRC) has developed a guidance document for risk evaluation of total petroleum hydrocarbons (TPH). While TPH is widely distributed in the environment, there is currently no comprehensive or systematic guidance at the national or state level to evaluate ecological risks associated with TPH. A systematic and comprehensive approach to identifying the TPH chemicals of potential ecological concern (COPECs) is presented in the guidance, by considering COPECs on the basis of origin, composition and environmental behavior. Sources and methods for development of screening values and toxicity reference values and several options for risk characterization are presented. A discussion of strengths, limitations and uncertainties for both mechanistic models and empirical data-based approaches will be presented with examples and case studies. This document will be the first comprehensive presentation of ecological risk assessment methods for TPH chemicals and will be released to the public in late 2018.

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Session 18: Per- and Polyfluoroalkyl Substances (PFAS)

PFAS Analysis: What to Expect and How to Evaluate the Data
Elizabeth Denly, TRC Environmental Corporation, Lowell, MA

Which Method Should/Did You Use for PFAS?
David Gratson, Environmental Standards, Santa Fe, NM; Rock Vitale, David Blye, and Meg Michell, Environmental Standards, Valley Forge, PA

Per-and Poly-fluoroalkyl Substances (PFAS): ITRC's Team Progress and the Latest Information
Rula Deeb, Geosyntec Consultants, Oakland, CA; Bob Mueller, NJ DEP, Trenton, NJ; Virginia Yingling, State of MN, St. Paul, MN; Lesley Hay Wilson, Sage Risk Solutions, LLC, Austin, TX

Closing the PFAS Mass Balance in Sediments and Tissues: The TOP Assay
Karla Buechler, TestAmerica, West Sacramento, CA

PFAS Fate and Transport Modeling Challenges: Limitations, Options, and Uncertainties
Ted Lillys, RTI International, Duxbury, MA; Robert Truesdale, RTI International, Research Triangle Park, NC

PFAS Analysis: What to Expect and How to Evaluate the Data

Elizabeth Denly

It is well understood that the analysis of PFAS is being performed using liquid chromatography/dual mass spectrometry (LC/MS/MS). Currently, the majority of laboratories are utilizing a modified version of USEPA method 537, which was designed for drinking water samples. The EPA is in the process of developing methods for non-drinking water matrices but these methods are not yet available. In addition, there is no consistency in the laboratory community with regards to what modifications are implemented, how the samples are prepared, quality control procedures, and whether or not sample cleanups are performed. We need to be sure we understand the modifications our laboratories are implementing or not implementing. This presentation will summarize what the analytical laboratories are doing, how methods/modifications such as isotope dilution, selection of solid phase extraction (SPE) cartridge, use of secondary transition ions, etc. can vary between laboratories, and what these variations can mean to the final PFAS result. The typical measures of quality control utilized in the PFAS analysis and their effect on the sample results will be discussed. The presentation will also provide instruction on how to read a PFAS analytical report, what you should expect to see in a basic report, what you want to look out for, and what the quality control results mean. Finally, after looking at method modifications and quality control, the evaluation of the ultimate usability of the PFAS data will be discussed.

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Which Method Should/Did You Use for PFAS?

David Gratson, Rock Vitale, David Blye and Meg Michell

Poly and perfluorinated alkylated substances (PFAS) continue to make headline news as numerous sites across the US are under active investigation. In the US there are currently three published methods as well as quality control requirements specified by the DoD/DOE within QSM 5.1, Appendix B (2017). EPA has only issued an approved method for drinking water, Method 537, Rev. 1.1. EPA has indicated they are working on additional methods across multiple matrices. There are significant differences both in the published methods, and how they are employed across the commercial environmental community. Several of the published methods have only undergone single laboratory validation, yet are widely used. This presentation will describe both variations in the procedures across the methods, and variation that we have observed within a specific method across the laboratory community. The potential impact that these technical variables can have on final reported values and data quality will be described. The lack of data comparability is of great concern given the absence of uniform PFAS analytical methods.

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Per-and Poly-fluoroalkyl Substances (PFAS): ITRC's Team Progress and the Latest Information

Rula Deeb, Bob Mueller, Virginia Yingling and Lesley Hay Wilson

Per- and polyfluoroalkyl substances (PFAS) are a large and complex class of anthropogenic compounds whose prevalence in the environment have become an emerging, worldwide priority in environmental and human health. Some PFAS are environmentally persistent, bioaccumulative, and pose human health risks. Recent high-profile cases involving human exposure in the United States have further focused both public and regulatory scrutiny on PFAS.

The scientific community's understanding of PFAS sources, site characterization, environmental fate and transport, analytical methods, toxicology, and remediation methods is growing rapidly. However, there is no central clearinghouse available that presents this information in a manner that is readily accessible to those other than subject-matter experts. As a result, there is a gap in the broad technical understanding necessary for informed and expedited decisions by regulators and policy makers.

The Interstate Technology & Regulatory Council (ITRC) established a technical team to produce concise technical resources that will help regulators, consultants and stakeholders to improve their understanding of the current science regarding PFAS.

This poster will provide an overview of the ITRC PFAS Team's goals and the status of specific efforts that are complete or underway. These include seven core-subject fact sheets, available at https://pfas-1.itrcweb.org, the web-based Technical and Regulatory Guidance Document, a Risk Communication toolkit, and training resources.

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Closing the PFAS Mass Balance in Sediments and Tissues: The TOP Assay

Karla Buechler

Current methodologies for the analysis of PFAS are designed to measure a discrete list of ~30 compounds. There are many additional PFAS compounds that are not determined as discrete compounds by existing analytical methods, including Method 537. Therefore, we may be underestimating the PFAS risk potential present in the environment. There is significant pressure from the public, environmental agencies, and others to apply methodologies that more closely measure the full extent of PFAS contamination. A new procedure, the Total Oxidizable Precursor (TOP) assay, can help measure the concentration of non-discrete and difficult to measure PFAS compounds that are not determined by conventional analytical methods. To date, the TOP assay has typically been applied to aqueous matrices. Additional challenges exist for more complex sediment and tissue matrices. Assessment of TOP assay data may improve our understanding of potential PFAS risk in sediment and tissue matrices. TestAmerica Sacramento implemented the TOP assay on solid matrices as a solution to this complex problem. The TOP assay rapidly converts polyfluorinated PFAA precursors into PFAAs including PFOA, using a hydroxyl radical-based chemical oxidation method. The TOP assay replicates what micro-organisms in the environment would achieve after many years. The end result is to provide a range of PFAAs which are detectable by LCMSMS. The TOP assay quantifies the sum of PFAS that could be converted to PFAAs in the environment.

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PFAS Fate and Transport Modeling Challenges: Limitations, Options and Uncertainties

Ted Lillys and Robert Truesdale

The difficulty of obtaining and using appropriate fate and transport parameters for the community of PFAS constituents makes it difficult to reproduce or predict their movement in the environment. General behaviors of PFAS in various media have been observed and documented, but reliable methods for modeling these behaviors are still needed. In the case of groundwater, colloidal and anionic behaviors, affinity for media interfaces and organic content of perfluoroalkyl acids (PFAAs) like PFOA and PFOS combine to make for challenging modeling. Unrealistic tweaking of modeling parameters to obtain agreement with observed behavior may generate a “good” fit for one set of subsurface conditions, but might not be applicable at another site or a different compound. In this paper, we intend to look at the various limitations of single-phase approaches and linear sorption models to account for these behaviors. We will consider other options for both approaches (e.g., colloidal models; geochemical models), how realistic are these approaches in practice as well as hybrid approaches, and where that leaves us in terms of getting a better handle on predictive modelling.

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POSTER PRESENTATIONS

(in alphabetical order by presenting author)

Qualitative Evaluation of Field Uncertainties on Groundwater Pollution Management Model Predictions

Mohammad Al-Suwaiyan

Many communities throughout the world consider groundwater to be the main and sometimes the only source of relatively fresh water. Such a source is indeed representing the lifeline for both domestic as well as agricultural needs. Protection of groundwater against quality deterioration is a very important task that must be handled by concerned authorities. Due to the hidden nature of groundwater flow and the transport of contaminants, mathematical modelling becomes essentially the only tool that can be used to help decision makers develop national policies and solve arising problems related to groundwater pollution. During the last few decades numerous modelling software packages dealing with the various aspects of groundwater pollution have become available. Currently, modelling packages capable of handling movement of dissolved components in both the saturated zone as well as the vadose zone, while incorporating many mechanisms that influence the transport process, are available. In addition, the more complex problem of immiscible flow and the interaction between the nonaqueous phase and groundwater including mass transfer between the two phases is possible to model. In this paper, previous deterministic modelling results from two previous studies are placed under scrutiny and criticism, and possible factors that have significant influence on the flow and transport processes will be presented along with qualitative examination of their influence. These factors include adopted initial and boundary conditions, utilized subsurface properties, as well as calibration processes. The main conclusion from the discussion is the need to limit the use of deterministic models to screening stages and move away from such models as much as possible and turn into stochastic models that allow the inherited variation in subsurface, boundary and initial conditions to influence the results and give decision makers a better tool on which they can make general policies affecting groundwater quality.

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Benthic Epilithic Diatom Community Structures and their Relationship to Water Chemistry of Swartspruit River, South Africa

Emmanuella Nnabuo-Eguzozie, Harrison Atagana and Rasheed Adeleke

An assessment of epilithic benthic diatom communities and their relationship to physicochemical water quality of Swartspruit River was undertaken. Water samples for water chemistry and diatom material analysis were collected from six preselected sampling sites during August, September and November 2014. The physicochemical water chemistry parameters measured include; water temperature, pH, dissolved oxygen, electrical conductivity, phosphate and nitrate. Diatom communities were characterized using microscopic approach. A minimum of 400 valves per sample were counted and identified at 1000x magnification with a light microscope. One way analysis of variance (One-way ANOVA) was carried out to determine if there were significant differences amongst the study sites and the different sampling periods. Significance was taken at a probability level of $p < 0.05$. Principal component analysis was performed to determine the correlation between the overall measured water quality parameters and the study sites and also to determine the similarities and dissimilarities amongst the identified diatoms from the different sampling periods and water quality of the river. Results from water chemistry data showed that the river was slightly eutrophic in August 2014 and hyper-eutrophic in September and November 2014. Microscopic characterization of the epilithic diatom communities revealed a total of 52 diatom species belonging to 27 genera. Diatom species that were more tolerant to hyper-eutrophic conditions were *Cocconeis placentula var. euglipta*, *Gomphonema pavulum*, *Navicula symmetrica*, *Nitzchia palea* and *Planothidium frequentisimum*. This was an indication that the prevalence of tolerant diatom species was enhanced with increase in the trophic status of the river while the occurrence of hyper-eutrophic intolerant species depleted. The results also revealed that of all the physical and chemical variables measured, the main gradient along the PCA first axis was hyper-eutrophic. This was indicated by its significant correlation with phosphates and study sites during the September and November 2014 sampling periods.

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Hazard Analysis: Remedial System Design, Installation, & Operation Down Range from a Gun Club

Kevin Lienau and Byron Baden

Due to a historical environmental liability, a soil vapor extraction (SVE) system designed and planned for construction at a location downrange from an operating shooting range. The shooting range is used by public and private concerns employing shotgun, pistol, and rifle armaments. A previous remedial system at another segment of the remedial area used an earthen berm to protect a SVE system from the potential impact of stray projectiles. Due to logistical considerations, the earthen berm option was not a viable option at this location. What could be done to minimize potential hazards to personnel and equipment?

The original proposed design used an earthen berm similar to the former remedial system as a means to protect the equipment from stray projectiles during operation. However, due to a necessary change in location during the design process, the berm option was then viewed unfavorably by the design team. To assess options for equipment protection, a hazard review analysis was conducted to assess potential risks, risk probabilities, risk outcomes, and potential mitigation measures to the system equipment in response to a potential strike by stray projectiles. Personnel protection during installation and operation was also assessed and hazard mitigation approaches were determined.

Identification of risk and risk probability along with evaluation of risk outcome is a viable means to determine methods to “harden” equipment installations in the event of impact by a stray projectile. Identified risk to personnel, however, was determined to be of a higher hazard level and alternative measures were implemented.

The presentation will provide a discussion of how the various risks to the equipment and personnel were evaluated as well as identify the approach to risk tolerance and risk mitigation. Although used at a shooting range, these same processes are applicable to the evaluation of many external risks proximal to remedial sites.

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The Air National Guard (ANG) Programmatic Approach to PFAS Impacts from AFFF

Thomas Barzyk and Dennis Pinigis

The ANG has historically utilized aqueous film-forming foam (AFFF) as part of routine fire-fighting and crash rescue capabilities at ANG installations nationwide. ANG fire fighting forces also routinely supplement local community fire-fighting efforts through mutual aid agreements and commonly serve as the primary on-call crash and fire-fighting service at many municipal airports with an ANG presence. The use of AFFF through incident response (both on- and off- active installations), or through associated preparatory training exercises, has resulted in the release of AFFF and associated PFAS constituents to the environment. The ANG proactively implemented Mission wide Preliminary Assessments (PAs) of all active air facilities commencing in 2015 in response to identified off-site potable well impacts from PFAS near select ANG installations. PAs were completed at 68 separate installations in 2015-2016 with a focus on determining Preliminary Release Locations (PRLs) associated with AFFF releases either through storage, training, or usage within active ANG installation boundaries. The ANG, through the PA/SI process, is determining if other off-site impacts have occurred at other installations nationwide through AFFF usage and whether time critical response actions are required. Through the PA process, more than 600 PRLs were initially identified and prioritized for follow-on Site Inspections per CERCLA and Air Force requirements. PRLs typically consisted of fire training areas (FTAs), aircraft maintenance hangars, fire stations, and fire equipment testing areas. As of August 2018, 68 Site Inspections have been completed or are underway at numerous ANG installations nationwide with additional Supplemental SIs and Remedial Investigations (RIs) pending per CERCLA requirements. Key findings regarding PFAS detections will be presented including soil, groundwater, sediment, and surface water sampling results and trends. The ANG response to off-site impacts from AFFF releases from installations in New York, Iowa, Pennsylvania, and West Virginia will also be discussed.

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Remote Vapor Intrusion Air Sampling Using SGS Galson-Smart Sense Technology

Harry Behzadi

When chemicals or petroleum products, such as gasoline or diesel fuel, dry cleaning solvents, and industrial degreasers, are spilled or leak from underground storage tanks, they potentially emit gases or vapors that can seep into buildings through cracks in basements, foundations, sewer lines and other openings. These vapors pose an unseen, and sometimes odorless, health risk for residents or workers in those buildings. For monitoring situations that would benefit from the ability to capture intermittent vapor emissions, SGS Galson-*Smart Sense*, allows you to get the job done *remotely* from wherever you are in the world. SGS Galson -*Smart Sense,* the only sampling initiation system available in the industry, tracks key parameters including VOCs, particle concentrations, O3, NO2, temperature, pressure and humidity, and other contaminants, with available sensors. It can remotely or automatically, based on pre-set triggering concentrations, actuate switches that control sampling pumps and whole air solenoid valves. This allows for a sample to be collected in a Summa canister as a vapor is being emitted rather than collecting a diluted composite sample that may or may not accurately reflect the presence and/or concentration of a pollutant. This innovative technology can also be utilized for other air monitoring situations such as Fenceline Monitoring.

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The Next Frontier on PFAS Contamination, Sediment, Surface Water and Fish Tissue

Harry Behzadi

PFAS are a class of synthetic fluorinated chemicals used in many industrial and consumer products, including defense-related applications. They are persistent, found at low levels in the environment, and bioaccumulate.

The sources which can release significant quantities of PFAS to the environment vary, from industrial and municipal wastewater treatment plants (e.g. textile industry, chrome-plating industry, among others), landfill leachate treatment plants, firefighting incidents and firefighting training areas (e.g., airports, fuel production and storage facilities) and landfills. Human exposure to PFAS is mainly by ingestion of contaminated food and water. These compounds are not metabolized, bind to proteins (not to fats) and are mainly detected in the blood, liver and kidneys. Elimination of PFOS, PFHxS and PFOA from the human body takes some years, whereas elimination of shorter chain PFAS is in the range of days, which is why EPA is primarily concerned with long-chain PFAS compounds.

Studies show these compounds being detected more often in surface water, sediments and/or bioaccumulated into fish tissue. Because longer chain PFAS compounds have a greater affinity for fish than other environmental matrices, certain compounds are often found in fish tissue, but not in the water or sediment.

More generally, PFAS is the compound that has generated the most concern in fish due to its frequent occurrence in the environment, its bioaccumulation in fish tissue, its potential human health risk, and the availability of health effects information needed to develop fish consumption advisories.
In summary, PFAS compounds are widely distributed in many bodies of waters all over US due to historic and current industrial activities, as well as the presence of military facilities. These compounds are of concern because they do not break down in the environment, they bioaccumulate in humans and biota, and may pose risks to human health

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The Impacts of Oil Pollution in the Niger Delta – A Focus Group Case Study

Ime Ben, Colin Hunter and Jim Baird

Petroleum hydrocarbon pollution of the Niger Delta ecosystem frequently occurs via contaminated surface and groundwater and this oil pollution can occur through equipment failure, sabotage or oil mismanagement. The exponential increase in oil production has consequently led to a higher accumulation of carcinogens and other pollutants. This contamination has resulted in poor health conditions within the surrounding communities. Despite the increase in the country's GDP, the Niger Delta, in particular the oil producing communities, are marginalized through oil politics. Therefore, communities are often underdeveloped, with poor or no infrastructure and their way of life is endangered by the toxic effects of these persistent environmental pollutants. The purpose of the current research is to explore oil spill incidents and develop focus group environmental matrix to evaluate oil spill impacts within the host communities. It also focuses on developing an environmental framework on oil spill management as a novel technique in the Niger Delta. This approach utilized qualitative analysis through focus group discussion, which serve as a framework for environmental policy. A comparative review of both qualitative data and the site characterization helps in the environmental policy structure as well as the sustainability of the Niger Delta. Activities involved responses from key stakeholders of oil and gas, focus group mapping, oil pollution incidents of the Niger Delta, Ogoniland and developing focus group environmental matrix. Sustainability of the host communities is determined by the extent of health, socio-ecology, socio-economic, socio-cultural, environmental, agricultural, communication, and oil politics regarding the oil producing communities. In addition, the sustainability framework of the region anchors on government regulators, and environmental checklist questions. Therefore, community engagement through focus group interaction maximised sustainability as a novel technique in oil spill management.

Key Words: Hydrocarbon, Remediation, Community-Engagement, Sustainability, Focus-Group Matrix, Environmental Policy.

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Using HAPSITE as an Investigation Tool for Characterizing Trichloroethene in Groundwater

Wolfgang Calicchio, Jack Besse and Avery Whitmarsh

Groundwater samples are typically analyzed at a fixed laboratory, resulting in significant expense if a short turnaround is needed. However, recent sample module updates to the HAPSITE® ER now allow for the analysis of aqueous samples by adding a Solid Phase Microextraction (SPME) module. This tool has allowed for the on-site analysis of groundwater samples for TCE in support of ongoing investigation, pilot testing, and remediation activities at a federal site in New Hampshire.

Split samples from the site have been collected and analyzed with both HAPSITE analysis and method 8260B to determine comparability. Scatter plots of the data were produced with coefficients of determination ranging from 0.97 to 0.99, indicating excellent comparability between the HAPSITE and 8260B results, with comparable reporting limits (0.5 µg/L using 8260B and 1 µg/L using HAPSITE).

Frequent analysis of groundwater has been performed on samples from monitoring wells at the site in proximity to ongoing soil vapor extraction (SVE) pilot studies, in order to monitor the impact on groundwater as soil gas concentrations decreased. Analysis has also been performed site-wide to monitor the impacts of a 30-day constant rate aquifer pilot test. On-site analysis of up to 20 samples per day using the HAPSITE allowed for accurate analysis of samples in the field in support of these pilot studies and investigations. With rapid turnaround time, the data was used to support real-time decision making in the field, which would not be possible using a fixed laboratory, and would have resulted in significant costs if samples were analyzed on a 24-hour turnaround at a fixed laboratory.

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Characterization of Concentrations at the Groundwater Interface to Evaluate Vapor Intrusion

Everett Bonniwell and Francis Ramacciotti

Contaminant volatilization from impacted groundwater is known to be a potential source of vapor intrusion (VI). Consequently, federal and many state regulatory jurisdictions call for VI investigations based upon the concentration and distribution of dissolved volatile organic compounds (VOCs) in groundwater. However, conventional groundwater sampling methodologies are designed to characterize the conditions relating to the groundwater ingestion exposure route and not at the groundwater interface ("surface") where volatilization actually occurs. As contaminated groundwater plumes migrate, groundwater recharge often occurs from ongoing infiltration of precipitation, resulting in mixing and dilution of dissolved impacts at the groundwater interface. As the potential for groundwater-sourced vapor intrusion is generally considered to be diffusion limited, the contaminant concentrations at the groundwater interface are widely acknowledged to be the source of vapor that could migrate into indoor air. The failure of conventional groundwater sampling methods to measure concentrations at the groundwater interface has the potential to overestimate the magnitude and extent of vapor intrusion risk associated with groundwater impacts. Such mischaracterization also likely contributes to the observed disparity between site-specific and generic groundwater attenuation factors. To resolve these issues, a unique sampling methodology has been developed to measure concentrations in groundwater at the interface. The method utilizes customized passive diffusion bags (PDB) that have been buoyed to maintain their position near the top of the groundwater even with fluctuations in groundwater elevation. Initial use of the devices along an approximately 3,000 ft long chlorinated VOC plume identified a five-fold reduction in VOC concentrations near the groundwater interface relative to conventional low-flow sampling methods. Additional evaluations utilizing the devices are ongoing, and are expected to further refine and support decision making in the evaluation of groundwater-sourced VI.

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PFacts versus PFear on PFAS – Separating Truth from Fiction

Lisa Campe

The topic of Per- and Poly-fluorinated compounds (PFAS) is inundating the media, politics and regulatory arenas and has taken center stage in the areas of water supply and water resource management. Although the information about PFAS is typically rooted in evidence-based facts or scientific research, these realities can become misconstrued by fear, misinformation and/or hyperbole. As environmental professionals, it is crucial that information concerning PFAS prevalence, assessment, toxicity, potential impacts, and remedial or risk management strategies be clearly and factually communicated to stakeholders and the public. There should be an informed lens through which we evaluate and set protective but reasonable, enforceable and achievable regulatory limits. But, why are regulatory limits or proposed standards so low in many states? What is the variability in standard setting in the US and internationally? What do we really know about the different toxicity end points and the June 2018 report released by the Agency for Toxic Substance and Disease Registry (ATSDR)? With respect to assessment, when do you really need to sample and how do you separate out the ubiquitous background? Regarding the potential for risk of harm to health, how to you assess the meaning of the data? What media and specific PFAS chemicals should and can be quantitatively evaluated? How do you communicate risk and results?

This presentation will focus on distilling and conveying key facets of information in a transparent manner including:

- Toxicological information and uncertainties;
- Exposure and Risk Assessment focus and methods;
- Recent history and cycles of regulation setting for environmental contaminants and concerns in US; and,
- Other countries' approaches to PFAS.

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Biological Side-Effects from Activated Carbon When Used in Contaminated Sediment Treatment: Trying to Put Things into Perspective

John Collins, Joseph Jersak, John Hull and Tore Hjartland

Background/Objectives: Abundant data published over the last 10+ years shows activated carbon (AC) as a highly effective sorbent of many organic sediment contaminants. As a result, AC's international use in in-situ isolation capping and treatment has grown dramatically. Earlier in-situ treatment projects involved mechanically mixing AC-bearing material into surface sediments (mechanical mode), while later projects involved placing thin AC-bearing layers overtop sediment and relying on natural bioturbation for mixing (thin-layer mode). While AC's international reputation as a highly effective sediment management tool has grown substantially, so has the number of studies reporting biological side-effects from AC when used in in-situ treatment (both modes). There also appears to be a common belief that powdered AC (PAC) causes greater harm to benthic organisms than granular AC (GAC). While credible evidence of AC's biological side-effects cannot be discounted, conclusions being drawn from available results need to be carefully scrutinized.

Approach/Activities: From 2005-17, 23 studies evaluating AC effects on benthic organisms were published in international journals. Typically, the studies were by American and/or Scandinavian researchers, were laboratory or field-based, involved either of the AC treatment modes, used PAC or GAC at different dosages, evaluated responses of selected benthic species or communities, and focused on specific ecological endpoints or community level responses. A critical review of this research was performed, and key findings will be presented.

Results/Lessons Learned: Given currently available published data, the goal was to determine what conclusions can defensibly be drawn - or not - on biological side-effects from AC when used in in-situ treatment of contaminated sediments. Several questions to consider will be addressed.

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Combining Enhanced Reductive Dechlorination (ERD) and Solar-Powered Soil Vapor Extraction to Sustainably Remediate VOCs in Groundwater and Soil

Betsy Collins, Daniel Brown, Mike Perlmutter, Natnael Ume, Matt Louth, David Cleland and Charity Delaney

Combined treatment technologies are being evaluated to reduce contaminant mass at a chlorinated solvent site in an industrial area in Eastern North Carolina. In the target treatment area tetrachloroethene is detected at concentrations of 930 micrograms per kilogram in soil and 560 micrograms per liter in groundwater. The depth to groundwater in the source area is approximately 25 feet below ground surface (bgs) and the vadose zone is comprised of fine silts and sands with intermittent clay stringers.

The objective of the study is to evaluate the effectiveness of enhanced reductive dechlorination (ERD) in reducing concentrations of volatile organic compounds (VOCs) in groundwater combined with a solar powered soil vapor extraction (SVE) system to treat VOCs in the vadose zone. A 3 percent by volume lactoil/water solution followed by bioaugmentation culture was injected at 17 locations from 22 to 30 feet bgs via direct push technology in March 2018. Two SVE wells, screened 5 to 10 and 12 to 17 feet bgs respectively, and a solar powered SVE system were installed and the system was put into operation in May 2018. Pulsing of the extraction system when there is limited solar availability allows mass to re-enter permeable pathways and will increase the efficiency of mass removal, since more mass is removed with less energy and cost. In addition to removing VOCs, the SVE system may also capture biogas generated from ERD injections and provide further protection against vapor intrusion (VI) into nearby structures. Performance monitoring is ongoing to assess reduction in VOC concentrations, identify achievable injection/extraction rates and pressures and corresponding radius of influence, and evaluate the potential for VI into nearby structures.

The presentation will include the design basis, a description of the combined system, nine months of monitoring, and the cost and sustainability impacts of using a solar powered SVE system.

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Improved Soil Screening Levels for Volatile Petroleum Chemicals: Including Volatilization in Surficial Soils Criteria

George DeVaull

Risk-based criteria for volatile chemicals in surface soil presented and applied by USEPA, ASTM, and in some state programs assume human exposure and uptake from summed evolved vapor inhalation, dust inhalation, dermal contact, and direct ingestion. In screening estimates the volatilization route presumes an infinite source of chemical; the other exposure routes presume constant soil concentrations over long-term chronic lifetime exposure durations.

Volatile chemicals will, however, deplete over time in surficial soils. Model equations for surficial soils criteria have been developed which incorporate depletion due to volatilization. Favorable comparison of the revised model estimates to multiple sets of measured data is shown for volatilization and soil concentrations. Comparison of screening level surface soil criteria for selected volatile organic chemicals with and without depletion is presented. A calculator which includes the improved model equations is discussed.

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Focus on Geology to Improve In-Situ Remediation Outcomes: Perspectives for Remediation Design

Paul Dombrowski and Tim Eilber

In-situ remediation technologies utilize chemical, biological, and physical treatment processes and have been demonstrated to be effective for treating a wide range of contaminant types. Implementing in-situ remediation is a commonly applied approach due to limited site disruption, reduced exposure to contamination, and ability to combine with other technologies.

In-situ treatment and injection of remediation chemicals can be performed with viewpoint of “let’s see what happens” or “it worked at another site so let’s do it again”. Alternatively, when treatment is tailored to be site-specific considering soil lithology, heterogeneities, and contaminant fate and distribution, in-situ injection remediation technologies have the potential for achieving rapid reduction in contaminant concentrations and yield more contaminant destruction per dollar spent. Enhanced site characterizations and high-density sampling are tools to support remediation planning. Although at many sites, schedule, cost, access or other reasons force remedial decisions and design with limited available data. Further, heterogeneities in the subsurface vertically and horizontally prevent a complete view of the subsurface for any treatment area. Therefore, remediation engineers must process the available data into design of systems. In-depth evaluation of geologic and hydrogeologic data is a critical step in remediation design, especially grain size, lithology, interfaces between soil types, and organic content.

Geology-focused remediation design can improve remediation success rate and/or reduce treatment volumes, in turn reducing overall cost and remediation time. This presentation will share lessons learned from actual sites where geology-focused approaches were utilized for highly successful remediation results, including projects with fast-track schedules, in very low permeability soils (e.g., clay, tills), isolated contaminated intervals, and/or very high contaminant concentrations. Collaborative interpretation of available data, including boring logs, soil concentrations, groundwater concentrations, photoionization detector readings, field screening, membrane interface probes, and hydraulic conductivity will be discussed and how they are used to optimize in-situ remediation.

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Reconsidering ISCO for Treating Low Contaminant Concentrations

Paul Dombrowski and Tim Eilber

In-Situ Chemical Oxidation (ISCO) is a demonstrated remediation technology for reducing contaminant source mass and groundwater concentrations but is not commonly considered for sites with low contaminant concentrations, or to attain stringent remedial goals such as drinking water criteria and/or to attain single digit micrograms per liter (mg/L). Numerous in-situ remediation technologies can significantly reduce contaminant groundwater concentrations. However, successfully achieving low remedial goals in a cost-effective manner can be a challenge for all remedial technologies. The 2016 ESTCP report titled "Development of an Expanded, High-Reliability Cost and Performance Database for In-Situ Remediation Technologies" presented that only 21% of 710 monitoring wells and 7% of 235 sites evaluated achieved typical Maximum Contaminant Level (MCL) criteria of 5 mg/L. Monitored natural attenuation (MNA), often required for a long and unpredictable period of time, is assumed to be a component for nearly all remediation sites. However, many sites have remediation schedules driven by regulatory requirements, property transfer, and/or development.

The presentation will share experiences of performing ISCO at 5 sites with low remedial goals for a wide range of contaminants including chlorinated solvents, petroleum hydrocarbons, and 1,4-dioxane. Pre-ISCO treatment contaminant concentrations at three of the sites were less than 20 mg/L. One site received ISCO as a polishing step following successful enhanced biodegradation. Oxidants applied at the four sites include permanganate, activated sodium persulfate, and hydrogen peroxide (Modified Fenton's Reagent). In general, ISCO injections resulted in lowering contaminant concentrations at all four sites facilitating attainment of stringent remedial goals, with reductions ranging from 50 to 80% in individual performance monitoring wells following injections in target treatment area(s). Oxidant selection and dosage, ISCO performance, oxidant residual, and lessons learned from applying ISCO for successful attainment of low concentration criteria will be discussed in the presentation.

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Subslab Depressurization Study

Denise Yaffe and Mark Drollinger

Citadel Environmental Services, Inc. (Citadel) conducted a preliminary subslab depressurization study at a historic building undergoing redevelopment and restoration. The building located in Los Angeles, California lies in a methane mitigation zone. The building was constructed with a basement that housed boiler equipment and was used for newspaper production operations. Citadel collected nine indoor air samples from the basement and first floor areas in contact with the ground. Significant concentrations of benzene and trichloroethene (TCE) were detected, indicating a possible vapor intrusion risk. To further define these conditions, Citadel completed a sub-slab sampling program and depressurization study in preparation for possible mitigation measures. Citadel installed 28 sub-slab soil gas sampling probes at ground level locations across the basement and first floor stories of the building. Seven of the 24 sub-slab soil gas samples had detectable levels of TCE with concentrations ranging up to 3.1 ?g/L. Given the size of the structure and lack of a definitive significant source of contamination, and considering the likely methane mitigation requirements for the site, a sub-slab depressurization system was proposed as the most likely remediation technique. Citadel installed two vapor extraction wells (VE1 and VE2) in the basement slab to access the building base gravel for vapor extraction. A vapor extraction pilot study was then performed at the site using vapor extraction wells VE1 and VE2. This presentation details the sub-slab soil gas sampling and preliminary depressurization testing completed to mitigate a possible vapor intrusion risk.

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Bioremediation Potential and Challenges for Two Emerging Contaminants: 1,4-Dioxane and 1,2,3-Trichloropropane

Sandra Dworatzek, Jennifer Webb, Jeff Roberts and Alicia Quintanilla

Bioremediation is a widely accepted technology used at chlorinated solvent and petroleum hydrocarbon sites around the world. Likewise, bioremediation is a promising approach for two emerging contaminants, 1,4-dioxane and 1,2,3-trichloroproane (TCP) that can be biodegraded either through natural attenuation or using biostimulation or bioaugmentation. Nevertheless, these compounds present some specific challenges for successful enhanced in-situ bioremediation (EISB) when compared to many chlorinated solvents including low groundwater concentrations, high mobility, inhibitory effects of co-contaminants and stringent drinking water MCLs.

To better understand the challenges and potential for bioremediation of 1,4-dioxane and TCP bench-scale testing has been completed to: i) develop consistent protocols to evaluate aerobic EISB approaches for 1,4-dioxane and anaerobic reductive dechlorination of TCP; ii) confirm the effectiveness of several different bioaugmentation cultures; and iii) identify the conditions and treatments associated with successful outcomes, as well those that were ineffective or negatively affected outcomes. Results from bench-scale studies for EISB of 1,4-dioxane and TCP will be presented.

Several promising bioaugmentation cultures have been developed for 1,4-dioxane, however successful bioaugmentation using metabolic 1,4-dioxane degrading organisms has not yet been conclusively demonstrated in the field. A significant challenge is the low 1,4-dioxane concentrations (starting at less than 100 micrograms per liter) encountered in the field and the delivery of sufficient oxygen for aerobic 1,4-dioxane degradation pathways. For TCP, successful field scale pilot testing of a TCP bioaugmentation culture has been completed at a site in California. Site field results have indicated that California MCLs were reached within 6 months after bioaugmentation.

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Selenium Source in Las Vegas Valley

Sahar Ehsani, Dave James, Vernon Hodge

Selenium bioaccumulation in the food chain causes dietary selenium exposure to aquatic organisms and their predators. Recently, there have been concerns over the elevated concentrations of selenium (above EPA safe levels) in the tributaries that feed the main stream Las Vegas Wash. Las Vegas Wash drains the 4,100 km^2 Las Vegas Valley watershed in the southeast portion of the Las Vegas Valley in Clark County, Nevada. The Las Vegas Wash drains into Lake Mead which provides drinking water to the city of Las Vegas. In 2006, The Nevada Division of Environmental Protection listed three Las Vegas Wash tributaries and the main stem of the Wash above the wastewater treatment plants, as impaired water bodies in terms of selenium concentration. According to literature review, 22% of selenium concentration in the Wash is from shallow groundwater. However, to date, there have not been any studies to determine the origins of selenium in Las Vegas Valley shallow groundwater. Identifying sources of selenium is an important step to assist water agencies and authorities to develop management strategies to potentially control the release of selenium into groundwater and eventually its accumulation affecting Las Vegas Wash and Lake Mead water quality.

In this study, collected field data, soil reports' data, land surface elevation map, geology and groundwater maps are combined to understand the source of elevated selenium in shallow groundwater in the Las Vegas Valley. We hypothesize that selenium concentrations in shallow groundwater in east and southeast of the Valley are elevated because rainfall, irrigation of seleniferous soils, and septic system effluent infiltrate the ground, interact with sediments derived from volcanic and evaporites on its flow path and leads to release of high concentrations of selenium from soil into groundwater.

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Accounting for Background Sources for Risk-Based Decision Making at Vapor Intrusion Sites

Lisa Goode, Neal Durant, Robert Ettinger, Vitthal Hosangadi and Michael Pound

At sites with volatile organic compound (VOC)-impacted soil or groundwater, VOCs detected in indoor air may be from subsurface sources through vapor intrusion (VI) but also from background indoor and ambient air sources that are unrelated to site contamination. Identification and removal of potential background sources prior to sample collection is challenging even when a thorough building survey is conducted. There is a wide variety of potential background sources to consider, including the use and storage of consumer products (e.g., cleaning solutions, air fresheners, insect repellent, glue, paint, solvents, and fuel), emissions from materials (e.g., furniture, carpet, finished wood, and dry-cleaned clothing), and activities (e.g., automotive repair, craft hobbies, cooking, building renovations, vehicle traffic, and industrial activities). Consequently, distinguishing compounds that are VI-related from those that are due to background sources is an important step in interpreting indoor air sample results. This presentation describes a clear, logical process for identifying compounds that are not VI- related and utilizing this information when calculating risks.

A VI risk evaluation was conducted at Naval Air Station North Island. This investigation included the collection of indoor air, outdoor air, and sub-slab soil gas samples at 22 buildings across three sites. A multiple-lines-of-evidence (MLE) approach was implemented for each building to identify compounds that are not VI- related. The MLE assessment included (i) comparison of indoor air concentrations to outdoor air and sub-slab soil gas results, (ii) comparison of indoor air concentrations to indoor air background levels reported in literature, and (iii) a concentration ratio analysis (i.e., comparison of relative concentrations in each media for the primary subsurface contaminant of concern [trichloroethene] and common background contaminants). This method provided an improved estimate of VI risks by accounting for the contribution of background sources which leads to better risk-based decision making for the site.

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Remedial Optimization: The Good, the Bad, and the Ugly

Kevin Lienau and Richard Finch

Optimization is a required and necessary process to drive remedial action site progress, efficiency, and efficacy. The concept of Remedial Process Optimization (RPO) has gained acceptance in the industry. RPO combines system optimization (e.g. application of the remedial solution for the problem) with process optimization (e.g. best processes for effecting treatment). Techniques for conducting optimization vary and are commonly implemented in a staged manner during the course of a remedial program. Results can be significant, from both a good and bad perspective.

Optimization efforts can result in great success in reducing overall project complexity, operating costs, and/or expediting attainment of site endpoints. However, optimization must be viewed in a holistic manner and recognize that one “tweak” to part of the system/process may have profound effects on subsequent remedial processes and/or anticipated results. Implementing a simple decision tree-based approach can identify possible outcomes without overcomplicating the RPO process.

Consideration of systemic effects of optimization must be examined in the vetting process of any potential optimization technique targeted for implementation. Use of a “what’s the worst/best thing that can happen” analysis is used to identify potential good and bad impacts to the remedial efforts at the site. Often, a potential optimization effort will present both good and bad aspects, but by examining and quantifying these effects (e.g. risk/reward), a rational decision can be made on if an optimization option is appropriate for implementation. Additionally, the evaluation process can determine potential leading-indicators that are used to verify that the optimization effort is effective and/or causing unanticipated good/bad issues.

The presentation will provide a discussion of how to look at optimization from a holistic point of view and how process analysis is used to vet a potential technique. In addition, we will examine examples of where optimization efforts produced good and/or bad results.

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Horizontal Directional Drilling and Well Installation for Substrate Injection

David Bardsley, Brian Younkin and Jacob Gallagher

Horizontal/directional drilling (HDD) methods have been utilized in the environmental drilling industry for the installation of monitor and remediation systems for over thirty years. New refinements in drilling equipment, steering/locating technology and an understanding of fluid dynamics have made the use of horizontal/directional injection wells another option in the toolbox of remediation expertise. The most frequent concern among injection experts is “won’t all the injectate come out in the beginning of the well?” By reviewing conservation of mass, friction loss, including losses across individual slots, the well open area (slot pattern) can be designed to insure equal flow rates. In other words, each horizontal directional well has a project specific screen design.

Proper drilling and installation techniques are very important to the injection well process. Drilling fluids and well development must be carefully monitored to insure the well screen has communication with the formation. Surface seals are important also; the injectate must remain in the injection interval, not travel along the riser casing to the ground surface. This paper will detail proper drilling and well installation techniques along with a screen design case study.

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Sustained Remediation of Chlorinated Solvents Using In-Situ Formation and Regeneration of Ferrous Sulfide

Lee Hovey, Robert Stanforth and Elizabeth Schwartz

Background/Objectives: Groundwater at a site in Southern California had been impacted with the chlorinated solvent tetrachloroethene (PCE). Site access limitations confined the selected remedial approach (injections) to the accessible portion of the plume containing the highest concentrations of PCE. The remedial approach was designed to treat PCE and its degradation products over an extended period of time and in a cost-effective manner since the PCE plume extended upgradient of the treatment zone.

Approach/Activities: Injections of dry cheese whey and water were delivered via wells to promote enhanced in-situ bioremediation (EISB). Groundwater at the site contained elevated concentrations of nitrate and sulfate, which are competing electron acceptors and can adversely affect amendment longevity in the remediation process. Following the EISB injections, concentrations of nitrate and sulfate decreased and concentrations of ferrous iron increased, as expected under reducing conditions, in nearby performance wells. Additionally, hydrogen sulfide (H_2S) odors were observed following the injection, a qualitative indicator that naturally occurring ferric iron and sulfate were reduced as a result of the EISB injections.

Results/Lessons Learned: Performance monitoring results suggest PCE degradation was sustained for an extended period of time after the dry cheese whey amendment had largely been utilized. This sustained degradation of PCE may be attributed to various reactions with iron sulfide minerals formed in-situ from the byproducts of biologically-mediated ferric iron and sulfate reductions (i.e., ferrous iron and sulfide, respectively). Additional lines of evidence supporting the in-situ formation of iron sulfide minerals involved the collection and laboratory testing of sediment samples from within the casing of treatment zone wells. The findings from these studies provide insight into using in-situ formation and regeneration of ferrous sulfide minerals as an engineered remedial approach.

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Innovative Approach of Evaluating and Remediating Vapor Intrusion Problems

Chris Jaros

Vapor Intrusion (VI) is an arena that always seems to be learning from new phases of data, research and practical application. Throughout the nation and predominantly in our cities, there are undesirable legacy plumes of volatile organic compounds left over from decades of industrial and commercial use that cause VI risks to patrons/residents and this effects current and future development. Knowing how exposures occur from these contaminants has long been a growing science and challenge beckoning appropriate engineering and risk management solutions.

Along with mitigating VI exposures attenuating from groundwater plumes downgradient of chlorinated solvent sources; the prediction, evaluation and appropriate control of exposure pathways if not altogether elimination of soil sources continues to be at the critical junction of cost benefit analyses and risk management. Additionally, long term monitoring and stewardship need to be factored in and can push costs and liabilities beyond those already difficult to shoulder. Performing full site characterization and predicting future potential exposure pathways are therefore critical in correctly understanding the dynamics and risks of VI so the appropriate remedy steps are taken.

This presentation will provide project examples and solutions to various soil sources of chlorinated solvents underneath structures and relating to various man-made and natural migratory pathways. Data and outcomes will be shared to demonstrate several cost-effective solutions, whether remediation, mitigation, risk management tools or combination thereof. Included in the presentation will also be an innovative and new approach using a patented technology of source removal utilizing ozone destruction for quick and efficient removal of what causes and sustains otherwise long-term site risks, and downgradient VI problems.

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Low-Intensity Electrochemical Destruction of Tetrachloroethene (PCE) in Groundwater at a Former Dry Cleaner Site

Song Jin, Paul Fallgren and Heather Otterstetter

The patented E-Redox® technology establishes low-intensity electric fields within the contaminated environmental matrix (e.g., groundwater and sediments), manipulating redox conditions to promote contaminant destruction and transformation. In practice, the application of a low-intensity electric field between electrodes of the E-Redox® system induces reductive reactions that include abiotic dechlorination of chlorinated solvents, without the common accumulation of daughter products such as dichloroethenes and vinyl chloride. A pilot-scale test was conducted at a former dry cleaner site in Wheat Ridge, CO, where tetrachloroethene (PCE) was the main constituent of concern in the groundwater. Data demonstrate a 33% decrease in PCE concentration and significant production of ethane from non-detectable levels to 125 mg/L. Based on mass balance calculations, the amount of ethane produced during the pilot study may have been 20 times greater than the sum of the chlorinated compounds detected in groundwater from laboratory analytical results. This may be attributed to the reduction of PCE desorbed from the subsurface soil matrix into the groundwater as a result of the E-Redox® technology. Lower voltage gradients were used at the site due to the high conductivity of the subsurface matrix. Full-scale implementation of the E-Redox® technology will be conducted where PCE is present in groundwater above regulatory cleanup goals. Although this abstract focuses on the pilot test and results, available data from the full-scale work will be included in the presentation by the time of the AEHS conference.

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A Novel Bioelectrochemical Tool for Real-time Monitoring of In Situ Biodegradation

Kylan Jin, Paul Fallgren and Jason Ren

The presence and patterns of microbial activities are important indicators for monitored natural attenuation (MNA), natural source zone depletion (NSZD), and in situ bioremediation for cleaning up contaminated sites. Biodegradation in groundwater is often assessed by groundwater sampling and laboratory analyses that include microbial counts, microbial speciation, multiple biodegradation-related groundwater geochemical parameters, and feasibility tests, which may take days to weeks to complete and interpret. The in situ production of electrochemical signatures such as electrical voltage and current during the oxidation of contaminants offers a unique venue to measure real-time biodegradation activities. Microbial degradation of organic (and some inorganic) compounds “releases” electrons that are transferred to electron acceptors (e.g., O2) to complete the pathway of energy (ATP) generation in microbes. Leveraging this mechanism, a bioelectrochemical (BEC) system (“BioRemeter”) is constructed to intercept electrons transferred within the contaminated matrix, essentially serving as a temporary and surrogate acceptor, where electrons are collected on a solid anode and eventually transferred through a circuit to a solid cathode to complete the electron transfer pathway. The electron transfer through the BioRemeter circuit produces electrical potential pattern that can be measured by a common multimeter. Studies conducted by teams at Advanced Environmental Technologies, University of Colorado Boulder, and Princeton University indicated that the electrical potential patterns correlate to biodegradation activities, and are semi-quantifiable based on different electrical potential ranges. These findings enable us to construct the BioRemeter that can be conveniently applied in groundwater monitoring wells in the field to directly measure biodegradation of petroleum compounds in groundwater. The obtained data are expected to enhance the effectiveness of remedial strategies and by simplifying monitoring for rapid decision-making, and performance assessment of in situ biodegradation of contaminants in different environmental matrices.

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Combined use of Microbial Consortia for the Enhanced Degradation of Type-II Pyrethroids

Parminder Kaur and Chandrajit Balomajumder

The unrestrained usage of pesticides to meet the burgeoning demand of enhanced crop productivity has led to the serious contamination of both terrestrial and aquatic ecosystem. The remediation of the mixture of pesticides is a challenging affair regarding inadvertent mixture of pesticides from agricultural lands treated with various compounds. Global concerns about the excessive use of pesticides have driven the need to develop more effective and safer alternatives for their remediation. We focused our work on the microbial degradation of a mixture of three Type II-pyrethroids, namely Cypermethrin, Cyhalothrin and Deltamethrin commonly applied for both agricultural and domestic purposes. The fungal strains (*Fusarium strain 8-11P* and *Fusarium sp. zzz1124*) had previously been isolated from agricultural soils and their ability to biotransform this amalgam was studied. In brief, the experiment was conducted in two growth systems (added carbon and carbon-free) enriched with variable concentrations of pyrethroids between 100 to 300 mgL^{-1}. Parameter optimization (pH, temperature, concentration and time) was done using a central composite design matrix of Response Surface Methodology (RSM). At concentrations below 200 mgL^{-1}, complete removal was observed; however, degradation of 95.6%/97.4 and 92.27%/95.65% (in carbon-free/added carbon) was observed for 250 and 300 mgL^{-1}respectively. The consortium has been shown to degrade the pyrethroid mixture (300 mg L-1) within 120 h. After 5 day incubation, the residual pyrethroids concentration in unsterilized soil were much lower than in sterilized soil, indicating that microbial degradation predominates in pyrethroids elimination with the half-life ($t_{1/2}$) of 1.6 d and R^2 ranging from 0.992-0.999. Overall, these results showed that microbial consortia might be more efficient than single degrader strains. The findings will complement our current understanding of the bioremediation of mixture of Type II pyrethroids with microbial consortia and potentially heighten the importance for considering bioremediation as an effective alternative for the remediation of such pollutants.

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Sustained ISCO of 1,4-Dioxane and Chlorinated VOC's Using Sustained Release Chemical Oxidant Cylinders

Tim Colgan, Patrick Evans and Dylan Kemmerer

Many groundwater plumes containing 1-4-dioxane and chlorinated solvents are not being treated to unrestrictive use and require ongoing management. Passive technologies that are capable of providing low-cost and sustained plume management are a pressing need. Slow-release chemical oxidant cylinders are a potential solution to this challenge. Wax cylinders containing sodium persulfate, potassium permanganate, or a mixture of these two oxidants, can be used to intercept a groundwater contaminant plume as a permeable reactive barrier or in a funnel and gate configuration. However, questions exist regarding the effectiveness of this technology. For example, it is not well documented whether the technology is capable of effectively reducing concentrations of 1,4-dioxane and chlorinated solvents in groundwater. Additionally, engineering design parameters such as minimum cylinder spacing are poorly understood.

The Department of Defense Environmental Security Program (ESTCP) funded CDM Smith to conduct a demonstration of this technology and document its cost and performance. The demonstration was conducted at Operable Unit 11 at Naval Air Station North Island, San Diego, California. At this location 1,4-dioxane and chlorinated solvents are present downgradient of the source area at concentrations approaching 10 mg/L each. The demonstration involved simulating a PRB, comparing technology performance to pre-established quantitative performance objectives, and comparing technology cost to various alternatives including pump and treat.

Results demonstrated that use of sodium persulfate oxidant cylinders promoted destruction of 1,4-dioxane and chlorinated solvents (1,2-dichloroethene, 1,1-dichloroethane, cis-1,2-dichloroethene, and trichloroethene) by more than 99% compared to a goal of 90%. Addition of activators was not required to promote chemical oxidation by sodium persulfate. The cylinders continued to release oxidant for at least 6 months and up to one year. Groundwater geochemistry downgradient of the reactive zone returned to natural upgradient conditions. Various cost-scenarios were evaluated and demonstrated the lifecycle cost of the technology was less than pump and

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PCB Analysis & Degradation in Soil Microcosms

Heather Knotek-Smith and Catherine Thomas

Polychlorinated Biphenyl (PCB) contamination has historically been remedied through scoop, haul and disposal as specified in 40 CFR 761.61. To support these activities analysis techniques have been limited to the parent Aroclor mixture concentrations. Current research has begun to look further into the dechlorination of the PCB molecule which creates a complex analysis of a possible 209 congener molecules. This research tested an HPLC method that could be run on soil extracts to evaluate the chlorination level of the PCB molecules in 35 minutes. Due to the complexity of the molecular mixtures the exact identities of the molecules will not be definitively known until samples are run by GC analysis; however this tool can be used by the researcher to know when progress has been made. This technique was used to evaluate PCB microbial degradation as a function of amendment (methanol & glucose) and incubation temperature (-20, 2, 12, 20° C). Indigenous microbial populations were identified from cleaned-up site with trace PCB contamination.

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Assessing Geothermal Energy Potentials in the Western Region of the US with GIS

Edmund Merem, Yaw Twumasi, Joan Wesley, Siddig Fageir, Marshand Crisler, Bennetta Robinson, Duro Olagbegi , Peter Isokpehi, Keishelle Jones and Mohammed Alsarari

In an era saddled by mounting energy dependency and insecurity, some are not only turning to renewable geothermal to ensure access, but it is growing in usage in the western region of the United States. The US role as a major producer of geothermal resources globally notwithstanding, the resource has over the years found ample use in various spheres of endeavors. The surging demand is much so that it now contributes to the generation of electricity for households and other activities from California to Nevada. With much of the production levels, installations and plant capacities of geothermal power entrenched in the western region, California stands out as the largest producer. For that, the demand for geothermal resource has been recurrent in counties over the years in California. In the face of widespread demands in the region, geothermal energy infrastructure in the form of new plants has penetrated different states under varying level of production and installed capacities to boost energy security. Even at that, very little has been done in the literature to undertake a regional assessment of the potentials of geothermal energy using a mix scale approach of spatial analysis anchored in GIS. This study will fill that void by utilizing mix scale tools of GIS and descriptive states in analyzing geothermal energy potentials. Emphasizing the issues, trends, impacts, production, factors and efforts, the results point to growing usage, changes in a set of energy indicators ranging from production and demands, installed capacity to others. The GIS mappings highlights dispersion of changing patterns in consumption and presence of infrastructural facilities clustered across the region. With all these attributed to socio-economic and physical factors, the paper proffered suggestions ranging from the design of regional geothermal energy information system, the education of the public and more infrastructural development in the sector.

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Developments in Data Handling for Improvement of Site Remediation Operations and Project Financial Controls

Laura Millan, Myles Hook and Mike Palmer

Historically, site derived data was forced into spreadsheets, left unchecked and uncontrolled. Analytical insights were gained at a glacial pace; sharing of information was confusing and encumbered. Subsequently data started being entered into databases that allowed for more robust data analysis. However, sharing of data was difficult and there was, oftentimes, a large lag between the timeframe in which the data was received and then entered into the database by hand. The advent of electronic data deliverables allowed for more seamless updating of the database, but still had the same data sharing issues.

Through technological innovation this presentation will highlight a host of new tools and techniques that have revolutionized the analysis, visualization and control of data derived from a Superfund Site in southern Los Angeles County. We show how new insights can be gained, costs can be controlled and regulatory institutions can be amazed by confident and innovative handling of data. This presentation will highlight how, through the use of automated HTML reports, data streams, dashboard visualizations, data alerts and cloud based project Enterprise Resource Planning (ERP) solutions (integrated management of core project processes), we have managed to regain control of our data, empower users to make insightful decisions and have gained greater control as to how our sites are run - not by the month or week but by the minute.

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Case Studies of Possible Chlordane Vapor Intrusion into School Buildings

Efrem Neuwirth, Debra Taylor and William Bosan

Chlordane, an organochlorine pesticide, was phased out in the United States from use on crops and landscaping in 1978 and as a termiticide for use in soil in 1988. Chlordane is persistent and highly toxic, having been measured in outdoor air, indoor air, and indoor dust decades after discontinuation of use. Vapor intrusion of chlordane is a likely source of higher indoor versus outdoor concentrations. Remedial investigations of school sites undergoing renovation in California were performed. Chlordane (as technical chlordane) was found adjacent to the foundation of some school buildings as part of standard site characterization in concentrations as high 0.14%. Step out sampling below the foundation of school buildings was performed where physically possible, usually associated with demolition or significant structural renovation to the buildings. Chlordane was, in individual cases found below a significant portion of some buildings and not just along the footings, suggesting application prior to construction. Concentrations in soil were highly variable but in individual samples were as high as 0.24%. Two buildings have been sampled thus far for chlordane in indoor air when removal of the impacted soils from below the foundation was not the first choice for remediation. Concentrations of chlordane (reported as technical chlordane) in indoor air have been measured as high as 0.14 ug/m^3 which is greater than the USEPA residential risk based screening levels (cancer endpoint) but similar to the commercial industrial screening levels (0.12 ug/m^3). The site characterization for chlordane and the investigation of vapor intrusion will be presented as well as recent updates on risk assessment for chlordane in California.

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Qualitative Titration Evaluation of Zero Valent Iron Products

Patrick Randall

Purpose: This paper presents the results of utilizing a newly developed chemical titration method to determine the reactivity, total treatment capacity and longevity of two of types zero valent iron.

Approach: Approximately 0.18 moles of coarse and fine ZVI (CZVI, FZVI) in separate 500 ml vessels were titrated with a 0.025 molar solution of permanganate. The permanganate solution was introduced into the ZVI solution in small batches of approximately 0.0004 moles, stirred, and the time required to eliminate the purple color recorded. The results were plotted and curve fitted equations developed to determine the reaction rate, longevity and total moles treated to exhaustion.

Results: The FZVI shown early reactivities about 15% greater than the CZVI, however, the greater reactivity quickly deteriorated with the CZVI maintaining a greater reactivity with about 91.5 percent of the FZVI life remaining. The derived average reaction rates were 0.048 moles/minute for the FZVI and 0.060 moles/minute for the FZVI. The longevity of the ZVI samples was estimated to be when the reactivity was reduced by 99 percent. The longevity of CZVI was 19% greater than FZVI. In the balanced redox equation 0.66 moles of MnO4 are reacted per mole of ZVI assuming the total mass of iron is available for reaction. This testing indicated 0.038 mole/mole for CZVI and 0.032 mole/ mole for FZVI.

Lessons Learned: The method was effective in deriving important factors (in hours rather than days) which can be used in selection of ZVI. Overall the method showed that the initial reactivity of FZVI was very short lived and CZVI displayed significant extended longevity and treatment capacity. Additional research is needed to correlate these results to reactivity and longevity rates for specific contaminates, however, provides a valuable tool in comparing potential ZVI products.

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Preparation of Cationized Dialdehyde Cellulose from Bamboo Pulp for Anionic Dye Adsorption

Akash Rathod

Anionic dyes are commonly used in the paper, dyeing, petroleum, and textile industries, contributing to global water pollution that harms important microbial populations and can be carcinogenic to mammals. However, current techniques of dye removal are largely inefficient and expensive, making them infeasible for large-scale use in developing countries, where the lack of access to clean water is most severe. The goal of this research was to develop an eco-friendly, affordable, and sustainable technique for wastewater purification. The methodology developed in this study utilizes the reaction between the aldehyde groups of dialdehyde cellulose (DAC) and cationic Girard's Reagent T to synthesize a positively charged cellulose derivative called cationized dialdehyde cellulose (cDAC). The use of cDAC as a cheap and sustainable adsorbent is considered for the removal of negatively charged dyes such as Congo Red (CR). The influences of a variety of parameters were tested, including pH, dye concentration, contact time, and cDAC concentration. The adsorption kinetics were modeled by pseudo-first-order kinetics and pseudo-second-order kinetics. Additionally, the adsorption equilibrium data conformed to the langmuir and freundlich isotherm models. Promising results were obtained for the use of cDAC as a new adsorption agent for CR, with a high adsorption capacity (Q_m) of 909.09 mg/g and the ability to remove 99.9% of dye from wastewater in just 15 minutes. This adsorbent opens numerous applications for sustainable and effective wastewater purification as cDAC can be used to design membranes with adsorption abilities to remove dyes, bacteria, and viruses. Furthermore, a cross-linked environment-friendly foam can be produced from cDAC that can be directly applied to the surface of contaminated water to remove contaminants. There are also applications of making the bamboo waste negatively charged so that it can be purposed to remove heavy metal ions such as arsenic (As) and lead (Pb).

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Environmental Footprint Analysis of HydraSleeve Sampling Technology at a Superfund Site

Brandon Reed and Amy Wilson

At a Superfund site, the use of passive sampling via HydraSleeve was recently approved as an alternative to low-flow purging or bailing, both of which had been conducted at the site for decades. The approval was granted on the basis that side-by-side laboratory results for low-flow purging and HydraSleeve were statistically similar. Though initially motivated by cost effectiveness, Hydrasleeve additionally proved to be a more environmentally sustainable approach.

After approval and full scale implementation of the Hydrasleeve, cost reductions were immediately clear. Environmental impact reductions, quantified using the EPA's remediation-specific Spreadsheets for Environmental Footprint Analysis (SEFA) calculation tool, were noted in the areas of water used, energy used, and greenhouse gases emitted.

Costs of the disposable Hydrasleeve were easily offset by the reduction of man hours required to perform a sampling event. The sources of the man hour reduction from implementation of Hydrasleeve are the removal of purging and decontamination processes which are required with the use of low-flow purging. Furthermore, because Hydrasleeve does not reuse equipment from well to well, sampling in order from the least to the most contaminated wells is not required. This allows for site personnel to sample with greater efficiency.

Quantification and analysis of environmental impact data through tools like SEFA can provide valuable metrics to assist in the decision-making process for investigation and remediation in cases where sustainability is a criterion. At this site, not only did passive sampling prove to be a technically viable and cost-effective approach, it simultaneously reduced the project's impacts locally in regards to air, water, and waste, and globally in regards to carbon footprint.

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Petroleum Forensics: When Standard Methodology Isn't Enough

Joshua Richards

Utilizing environmental forensics for source determination and times of release has been instrumental in tuning remediation activities for site closures and determining proper responsible parties. When applied to the investigation of petroleum products, forensic analysis is useful for proper hydrocarbon characterization, providing methodology for age constraints of release, and differentiating potential sources utilizing pattern recognition and/or compound specific isotope analysis (CSIA). This information coupled with other site information, can provide valuable tools for obtaining scientifically supported, court admissible, evidence in environmental legal disputes saving time and the increasing costs of remediation. Pace Analytical provides industry leading petroleum forensic testing and expert technical guidance to ensure successful project completion.

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Remediation of Deep Trichloroethene Plume Using Enhanced In-Situ Bioremediation Technology

Steven Ridenour and Mike Cassidy

Background/Objectives: Remediation of a deep groundwater plume heavily impacted by chlorinated volatile organic compounds (CVOCs), primarily trichloroethene (TCE), was conducted at an aerospace manufacturing facility located in Southern California. The depth to the impacted aquifer is approximately 90 feet below ground surface (bgs). The overall size of the TCE plume measures approximately ½ mile long (downgradient) by ¼ wide (cross-gradient), the majority of which extends offsite. Previous pilot testing activities conducted onsite demonstrated that Enhanced In-Situ Bioremediation (EISB) technology was cost-effective and feasible solution for remediation of CVOCs in groundwater. Following approval of the Groundwater Remedial Action Plan (GWRAP), remediation of the core of the TCE plume onsite was implemented.

Approach/Activities: EISB, or engineered bioremediation, is the acceleration of microbial activities using technology to enhance the degradation or detoxification of environmental pollutants in an anaerobic environment. The purpose of EISB is to increase the rate of microbial activity so the rate of reductive dechlorination is increased. As proposed in the GWRAP, Alta Environmental installed 75 dual-cased injection wells, screened at 88-98 and 103-113 feet bgs. The wells were located within the core of the onsite TCE plume area on an approximately 30-foot by 60-foot staggered grid pattern. The wells were then injected with a solution of bio-amendment products manufactured by Regenesis Remediation Services, consisting of 3-D MicroEmulsion® (3DMe, an injectable highly-distributable electron donor), Chemical Reducing Solution® (CRS, in-situ chemical reduction agent consisting of carbon and soluble iron), and Bio-Dechlor Inoculum® Plus (BDI, consisting of a natural microbial consortium containing species of dehalococcoides [DHC]). One application of 287,194 lbs of 3DMe, 114,418 lbs of CRS, and 1,964 liters of BDI (DHC) were injected into the 75 dual-nested injection wells. A total of 701,616 total gallons of the mixed 3DMe/CRS/DHC solution were injected. Post-injection groundwater sampling activties revealed reductions of TCE concentrations.

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Serving Potable Water from an Extremely Impaired Groundwater Superfund Source

Doug Roff, Danielle Cebra, Eric Lang, Holly Holbrook and Kamran Javandel

Groundwater at a Southern California Superfund site is contaminated with perchlorate, with concentrations up to 260 micrograms per liter (µg/L) at the capture well and higher upgradient. The California primary Maximum Contaminant Level for perchlorate is 6 µg/L. The remedy involves groundwater extraction, treatment, and discharge to local potable water supply. Ion exchange (IX) is often the best available treatment technology for groundwater contaminated by perchlorate. However, no potable systems have previously been permitted in California with pre-treated perchlorate concentrations greater than 50 µg/L. Therefore, the regulator required a pilot study to evaluate the safety, viability, and predictability of treating extracted groundwater.

An initial pilot test was performed using a single IX resin. The initial test did not perform as expected, with perchlorate breakthrough much earlier than predicted by resin vendor modeling. Based on the results of the initial test, a comprehensive forensic analysis was performed to determine the cause of this performance. To confirm this conclusion, a second pilot test was performed and configured to better simulate full-scale operations. In addition, three different gel resin IX media were tested in parallel. The pilot tests and the full-scale treatment plant have a triplex (lead, mid and lag column/vessel) design that allows safe treatment of high influent concentrations and more fully exhausts resin capacity in the lead column/vessel.

The samples collected to date demonstrate that the design of the second pilot test eliminated performance problems witnessed in the initial pilot test. The IX resin performance in the second pilot test has generally followed the expected detection and breakthrough curves as predicted by the vendors. The triplex design has proven safe and viable. As of this writing approximately 190,000 bed volumes have been treated. By the time of the conference, the pilot test is expected to have concluded and all data should be available for presentation.

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Lessons Learned from Surfactant Enhanced Aquifer Remediation of Light and Dense NAPLs

David Alden, Sangho Bang, Gary Birk and John Sankey

Background/Objectives: Surfactants, solvents and polymers have been used as aggressive NAPL removal methods. Published work on thoroughly monitored projects shows that over 90% of the NAPL contaminant mass can be removed. How have commercial remediation projects following these methods performed?

Approach/Activities: Technology developed at the University of Oklahoma, originally focused for enhanced oil recovery at petroleum reservoirs and subsequently adapted to the environmental arena, can lower the IFT sufficiently to allow physical mobilization of residual LNAPL with the limited production of thermodynamically stable emulsions. Part of this talk will focus on market acceptance and lessons learned from the use of artfully formulated surfactant blends that reduce solubilization and simply allow LNAPLs in saturated soils to become mobile. Lessons learned from other Department of Defense surfactant flood projects addressing DNAPL will be used to highlight similarities and differences to LNAPL recovery projects.

Results/Lessons learned: The presentation will review surfactant flood design methods and highlight results and lessons learned from various projects.

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Managing Complex Sites with High Resolution Characterization and Remediation

John Sankey

Background/Objectives: Recent groundwater characterization and instrumentation approaches have proven helpful in providing a sound and defensible Conceptual Site Model to help design a range of different remedies to reach the overall goal at a complex site.

High Resolution Characterization: An integrated approach has been developed to characterize baseline groundwater conditions, give a three dimensional picture of the problem with Ultra-high Resolution Scanning Technology and highlight the microbial community with Next Generation Sequencing.

High Resolution Remediation: To efficiently target remedies in a complex stratified regime will optimize the remedial design, we can use the following;

- Thermal, excavation and surfactant for the source zone,
- ISCR for the sub-source zone
- Bioremediation to polish the source/sub-source and remediate the downgradient plume.

The presentation will bring together 3 case studies of complex sites with high resolution characterization that resulted in high resolution remediation.

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Per- and Polyfluoroalkyl Substances (PFAS) – Remediation Approach Using Organoclays

Paul Scapan, Andrea Guhl and Martin Bertau

Perfluorooctanoic acid (PFOA) is the most commonly detected PFAS. Akin to its ~850 brethren in this group, it is ubiquitous in the environment. Decades of emissions from a multitude of industrial applications and a high persistence in water, soil, and biota led to growing concern and regulation. Produced since 1947 in the US, EU production was set to phase out between 2000 and 2004, with exemptions for companies in Germany and Italy. While a ban is set to be introduced in 2020, again, exemptions have already been announced. The majority of PFOS waste in the EU is currently disposed of in non-hazardous landfill (63 %), from where it often finds its unfortunate way into the environment. Elevated levels of PFAS have been detected in streams such as the Rhine, but also in tap water in some industrialized regions in Germany. Although levels are low, these substances are known for their persistence, bioaccumulation, and toxicity. The current approach to treat tap water with carbon filters is expensive and difficult to implement, and does not remediate the ecological problem posed by this threat. Organoclays are a class of materials attracting interest for their organophilic properties. These are natural clays modified with surfactants such as alkylammonium ions. Using hexadecyltrimethylammonium (HDTMA), compound materials with a multitude of applications are generated. The use of this material class in removing pharmaceutical residues from water currently generates elevated levels of interest. Unlike native clay, the material is now more suitable for water applications due to its improved permeability - and its ability to remove organic pollutants. The utilization of organoclays in remediating organic pollution still needs a lot of research. This is encouraged as global availability of clays offers a potentially low-cost, elegant solution for contamination management.

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Humboldt Community Services District Well Evaluation and Replacement

Stephen Sherman, David Livermore, David Hull, Eron Dodak and Ben Starr

Humboldt CSD's South Bay water supply well, which provided more than 1,000 gpm of water to the District's water supply system within the Elk River Valley Basin, began pumping saline water in 2013. After attempting well rehabilitation, the District hired Integral Consulting Inc. (Integral) to conduct a well evaluation. Integral's analysis determined that severe corrosion of the steel well casing was allowing shallow saline groundwater to enter the well, and that well abandonment and replacement would be required. Integral conducted a groundwater basin assessment to evaluate the groundwater basin resource for sustainable yield. Integral also conducted a water management alternatives analysis utilizing the District's existing WaterCAD model to evaluate utility water demand scenarios 20-years into the future. Integral's Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis provided the District with a decision document on which to base their decision to proceed with abandonment and replacement of the South Bay well. Integral completed a replacement well design utilizing PVC casing to increase corrosion resistance through the shallow saline water interval, and stainless-steel well screen in the production zone. Integral oversaw installation of the well and the well is successfully pumping water at yields required by the District. The methods utilized in this well evaluation are directly applicable to, and will support future sustainability planning within the Basin.

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Am I Looking at the Chicken or the Egg? Learning from Mathematical Approaches to Distinguish Soil from Groundwater Sources of Vapor Intrusion (VI)

Christopher Lutes, John Lowe, Mike Bedan, Elsy Escobar and Jennifer Simms

The effective management of VI sites requires an accurate understanding of where the primary contaminant mass is currently stored. Site specific data sets commonly include stratigraphic/soil type information as well as contaminant concentrations in multiple compartments: soil gas at various depths, bulk soil, and groundwater. Numerous models and spreadsheet approaches are available to solve equilibrium partitioning and diffusive transport equations. Frequently using soil gas concentration (modeled and observed) as a common basis of comparison is helpful. These approaches can allow practitioners to describe source architectures, verify conceptual site models, assess risk and select more effective remedial alternatives.

The authors intend to draw on and systematically compare prior work with tools such as:

- Analytical models such as Farmer's diffusion model
- Johnson & Ettinger Model
- API steady state model
- Jury's model and EMSOFT
- VLEACH model
- SESOIL Model
- PNNL's SVEET and VIETUS models
- Mass flux measurement
- Multi-stage contaminant mass discharge testing of soil vapor extraction systems
- Indoor concentration measurement during controlled pressure method testing of buildings

. This paper will discuss which approaches are most efficient to answer practical questions like:

- What is the most effective remediation or mitigation approach to protect current and future receptors?
- If I remediate the vadose zone only or groundwater only, will rebound occur?
- Is there a downgradient source?
- Will SVE allow me to turn off my VI mitigation system?
- Can I practically cleanup this site enough to not need mitigation?
- Is there a missing source or transport route that isn't accounted for?

The authors have applied these techniques at more than six sites, and intend to illustrate the mathematical approaches discussed with anonymous, generic case studies. The points were these techniques can be most fruitfully applied in site management under existing federal and state VI guidance documents will also be highlighted.

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Sustained Anaerobic Bio-Augmentation via In Situ Bioreactors

Eric Raes, Dora Taggart, Kerry Sublette, Anita Biernacki, Katherine Clark and Brett Baldwin

Background: The study updates the use and performance of an in situ bioreactor (ISBR) in promoting reductive dechlorination of trichloroethylene (TCE) in a bedrock monitoring well. The remediation has been ongoing for two years and has recently been expanded from one well to three, including an experimental ISBR design. The study also presents the testing of the longevity and potential for sustained biodegradation following ISBR removal and relocation to another well at the site.

Approach: The study site is a former chemical distribution facility where a deep, fractured aquifer had been impacted predominately by TCE (1,230 mg/L). An ISBR unit was initially installed in an existing monitoring well to promote reductive dechlorination. Groundwater samples were obtained to determine whether ISBR operation affected contaminant concentrations and geochemical conditions throughout the depth of the saturated zone. Bio-Trap® samplers were also deployed at multiple depths.

Results: Prior to the initial ISBR deployment, all data confirmed reductive dechlorination processes were limited under existing conditions. For example, cis-1,2-dichloroethylene was detected (133 mg/L) but vinyl chloride and ethene concentrations were below detection limits. Consistent with historical groundwater monitoring, *Dehalococcoides* concentrations were low (10^0 cells/mL) and vinyl chloride reductase genes were not detected. After approximately 6 months of operation, geochemical monitoring at 140 ft. BGS demonstrated sulfate consumption and methanogensis. After 9 months of operation, the *Dehalococcoides* concentration at 140 ft. BGS had increased by four orders of magnitude, surpassing 1 million cells/mL. After five quarters, all chlorinated solvents were non-detect. The inoculated ISBR was relocated to a new well and similar mass reductions and elevated microbial populations were observed. Most interesting, biodegradation processes remained elevated in the initial well, even after the removal of the ISBR. Overall, the results conclusively demonstrated that the ISBR successfully enhanced anaerobic bioremediation throughout the fractured bedrock well

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Evaluation of Potassium Persulfate as a Permeable Reactive Barrier

Brant Smith, Stacey Telesz and Brianna Desjardins

Background/Objectives: In situ chemical oxidation (ISCO) using activated persulfate has been widely applied to treat recalcitrant environmental contaminants of concern (COCs). Until recently, activated persulfate referred to highly soluble sodium persulfate activated by heat, alkalinity, hydrogen peroxide or chelated iron. These technologies have proven to be very effective, especially for source area treatment. Potassium persulfate is a lower solubility alternative that can be used to extend the period of active treatment, for application to low permeability soils and in permeable reactive barriers.

Approach/Activities: Two of the sites were contaminated with a mixture of 1, 4-dioxane, chlorinated ethenes, and chlorinated ethanes. The third site was contaminated with a mixture of petroleum hydrocarbons and pentachlorophenol. An evaluation of the contaminant mixtures at each site indicated that both oxidative and reductive pathways resulting from activated persulfate reactions would be necessary for complete treatment. Site soils and reagents were placed in a series of column reactors. Site groundwater was then run through the columns until the potassium persulfate had been consumed. Multiple time-point samples were collected, evaluating the COCs, pH, oxidation-reduction potential, and residual persulfate.

Results: This presentation will provide the results from each site and highlight key conclusions in terms of the effectiveness of the oxidative and reductive pathways and comparative benefits of two activation schemes for potassium persulfate. The data indicated:

- Sites 1 & 2: Hydrated lime induced alkaline-activated potassium persulfate reduced 1, 4-dioxane, chlorinated ethenes, and the chlorinated ethanes concentrations to below the detection limit.ZVI-activated persulfate resulted in treatment to non-detect of 1, 4-dioxane and chlorinated ethenes while reducing chlorinated ethanes by 20 to 60 percent.

- Site 3: Pentachlorophenol was reduced by three orders of magnitude at the third location tested.

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PFAS Risk Assessment Challenges and Opportunities

Laura Trozzolo

The objective of this presentation is to examine the value that risk assessment brings to the corrective action process and suggest methods for stakeholder engagement and trust, which is significant when dealing with poly- and perfluoroalkyl substances (PFAS). Through use of the following key tools, risk assessment and its acceptance by stakeholders can be greatly improved: 1) determination of key messages and objectives to share early and often, 2) conceptual site model and risk results in graphic form to aid in interpretation of site conditions, 3) frequent in-person meetings with stakeholders to build relationships and trust, 4) site-specific land use and exposure input to ensure the risk assessment reflects current and likely future conditions and 5) a clear tie to the regulatory process that will make risk-based decisions, so that the risk assessment has credibility. The following two components of PFAS exposure assessment will be utilized as an example of challenges in risk assessment: 1) fate and transport of PFAS; and 2) health effects of PFAS, which have led to a wide range of risk-based standards across the US and the globe.

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Removing PFOA and PFOS from Wastewaters Using Advanced Reductive Process Technologies

Liam Twight and Stephen P. Mezyk

Perfluorooctanoic acid (PFOA, $C_7F_{15}COOH$) is a synthetic carboxylic acid that has been extensively used in the manufacture of a wide range of consumer goods for over half a century. PFOA persists indefinitely in the environment, and epidemiology studies have shown that there is a significant link to PFOA exposure and human kidney/testicular cancer, thyroid disease, high cholesterol and pregnancy-induced hypertension.

For wastewaters being considered for reuse, the removal or complete degradation of PFOA or its sulfonated analogue PFOS (perfluorooctanesulfonic acid, $C_8F_{17}SO_3H$) is necessary. Direct potable reuse of wastewaters relies upon additional filtration (microfiltration and reverse-osmosis) after secondary treatment, plus the inclusion of an Advanced Oxidation Process (AOPs) as the final polishing step. Unfortunately, AOPs are oxidizing systems, creating highly energetic species such as the hydroxyl radical ($^{\bullet}OH$) or sulfate radicals ($SO_4^{-\bullet}$), but PFO(X) (X = A,S) is not readily oxidized. An alternative approach would be to use reducing radicals, such as the hydrated electron (e_{aq}^-) or formate radical (CO_2^-). These species are expected to react with PFO(X) to produce a fluoride ion, and a carbon-centered radical which can then add dissolved oxygen to form a peroxyl radical. At neutral pH we would have:

$$e_{aq}^- + PFO(X) \rightarrow F^-(aq) + [C_7F_{14}COO^-]^{\bullet} + O_2 \rightarrow [C_7F_{14}(O_2^{\bullet})COO^-] \quad (1)$$

$$CO_2^- + PFO(X) \rightarrow CO_2(g) + F^-(aq) + [C_7F_{14}COO^-]^{\bullet} + O_2 \rightarrow [C_7F_{14}(O_2^{\bullet})COO^-] \quad (2)$$

While a promising approach, these reactions would have to occur competitively against the reactions of these two radicals with dissolved oxygen. To establish the feasibility of this approach kinetics for Reactions (1) and (2) need to be quantitatively established. In this project we have determined absolute rate constants utilizing the electron pulse radiolysis facilities at the Radiation Research Laboratory, University of Notre Dame. Temperature-dependent measurements were also performed to elucidate the corresponding Arrhenius parameters for these reactions.

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Bioaugmentation of Contaminated, Low Functioning Soil with High Functioning Soil Communities

Bhagyashree Vaidya, Nina Goodey, Jennifer Krumins, Diane Hagmann and Jeniffer Balacco

Generation of waste from anthropogenic activities over the past century has resulted in dumping sites and landfills all over the world. The impact of accumulated waste on the soil in and around such sites poses serious repercussions to the environment and its inhabitants. However, some sites display robust plant growth and soil organism communities despite high contamination loads of organic and inorganic contaminants. Such a site was identified at Liberty State Park, Jersey City, New Jersey. Previous studies carried out at the location have indicated high contamination, high plant cover, and significant soil microbial activities at site 146. In contrast, adjacently located site 25R, a barren section of the park, exhibits negligible plant cover and soil microbial activity. The goal of our study was to investigate whether a high functioning soil from site 146 remediates the soil from site 25R. We mixed together the soils from both sites in various ratios, potted the soil, added seeds, watered, and monitored the phosphatase activity as well as plant growth in a growth chamber over a period of 65 days. An interesting trend was observed in the soil mixture containing an equal amount of soil from both sites: Phosphatase activity measured as an indicator of free soil enzymatic function showed a steady increase over time. Thus, our research implies bioaugmentation by microbial communities from high functioning contaminated soil and plants can improve the function of low functioning, highly contaminated soils.

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Responding to the World's Worst Lead Poisoning Outbreak in Zamfara, Nigeria

Casey Bartrem, Margrit von Braun and Ian von Lindern

Background: The 2010 lead poisoning outbreak in Northern Nigeria was called "unprecedented," resulting in over 400 deaths in children less than 5 years of age. Risk assessments identified severe soil lead contamination resulting from artisanal gold ore processing in residential areas. Gold prices increased dramatically in 2009-10 and resulted in a sharp increase in artisanal mining in the region, which is otherwise a subsistence agricultural area.

Methods: TerraGraphics International Foundation (TIFO) partnered with multiple international organizations, Nigerian government, and local traditional and religious leadership to provide an emergency medical, environmental, and public health response. The response aimed to i) provide exposure reduction for communities, especially children; ii) build local, state, and national capacity to respond to future environmental health crises; and iii) ensure environmental remedies would be sustained via safer mining practices. Medical treatment required children to live in a lead-free environment, necessitating emergency remediation. Using a coordinated environmental and health response model developed at the US Bunker Hill Superfund Site, project partners engaged multiple levels of stakeholders, both national and international. A "safer mining" campaign to keep lead out of residential areas involves mining leaders, imams, and tribal chiefs to sustain lead-free villages.

Results: During the ongoing 9-year interdisciplinary, multi-stakeholder response, children's blood lead levels have declined from >170 µg/dl to 90%, project management has transitioned from international partners to Nigerian authorities, and local leaders have championed safer mining at designated ore processing areas to prevent future outbreaks from occurring.

Conclusions: Local involvement in management, design, implementation, evaluation, and adaptation is crucial to long-term project sustainability. The Nigeria crisis exemplifies a growing pattern of health emergencies related to extractive industries in low and middle-income countries, where instability, climate change, and global demand for metals have fueled shifts from subsistence agriculture to subsistence mining.

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Human Health Risk Assessment in Soviet-Era Mercury and Antimony Industrial Complexes in Batken Province, Kyrgyzstan

Casey Bartrem, Ian von Lindern and Margrit von Braun

Background: Batken Province, Kyrgyzstan includes part of the Ferghana Valley, one of central Asia's most agriculturally productive regions and an area with longstanding ethnic conflict. Batken is also home to largely abandoned mercury and antimony mines/smelters that once supported the former Soviet Union weapons program. Both complexes contain vast quantities of heavy metal mine wastes directly adjacent to residential areas in the cities of Khaidarken and Kadamjay. In 2018, international investors began to revitalize both the mercury and antimony mining and ore processing facilities with plans to resume production in 2019.

Methods: TerraGraphics International Foundation (TIFO) is collaborating with Médecins Sans Frontières (MSF) to review historic environmental and health data and collect environmental samples at both sites. Initial human health risk assessment (HHRA) and mitigation efforts focused on MSF staff living in Batken. Mercury vapor concentrations were determined with a Lumex Vapor Mercury Analyzer. Soil heavy metal concentrations were determined with a Portable X-ray Fluorescence Unit and ICPMS. Water heavy metal concentrations were determined by ICPMS and CVAFS.

Results: Water and air sampling indicate minimal health risks at MSF clinics at current mine/smelter emissions; however, soil results suggest potential risks for children and for consumption of locally-grown produce. Reopening of the mercury and antimony mines/smelters would change risk profiles dramatically. Collaborative arrangements between TIFO, MSF, and Kyrgyz officials are underway to expand the project to include a community-wide HHRA to identify vulnerable local populations.

Conclusions: Batken is undergoing dynamic post-Soviet industrial, economic, ethnic, and cultural transitions. Risks associated with environmental hazards, including chronic exposures to heavy metals, are influenced by residential, occupational, and cultural factors. Risks to MSF staff are being mitigated with health and safety protocols. Future collaborative work will include investigating environmental hot spots, reviewing government data, identifying vulnerable groups, and developing culturally appropriate mitigation protocols.

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Trichloramine Reactions with Organic Species under Wastewater Treatment Conditions

Landon Watts and Stephen P. Mezyk

Orange County water district utilizes a water purification system ending in a final advanced oxidative process (AOP). Before entering the AOP, wastewater passes through a series of microfiltration (MF) and reverse osmosis (RO) membranes. These membranes serve to remove biological contaminants. Overtime however, biofouling will occur within the membranes, resulting in a lower overall efficiency of the treatment process.

To prevent biofouling, 12.5% basic hypochlorite solution is added to the waste stream prior to the MF and RO membranes. This hypochlorite reacts with ammonia in the wastewater producing a combination of chloramines, particularly trichloramine at the initial point of injection.

While chloramines function to prevent biofouling of the RO and MF membranes, their presence also has negative impacts upon reaching the AOP. In the AOP, chloramines competitively absorb UV radiation, preventing the production of hydroxyl radicals. This lowers the overall ability of the AOP to degrade persisting organic contamination.

It is established that chloramines react with organic matter prior to the AOP, however, there has been little insight into the reaction rates or products generated via these reactions. In this study, the decay reaction rates of trichloramine with organics will be studied through the use of stopped flow experiments and absorption spectroscopy. Due to the extensive amount of organic substances in wastewater, amino acids were employed as prototypical organic contaminants. Amino acid solutions were buffered at approximately pH 12 to emulate basic conditions of the hypochlorite point source region.

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Evaluation of the Effects of PFAS Soil Adsorption and Transformation in the Presence of Divalent Cations Under Ambient Conditions

Michael Eberle and Amy Wilson

A bench-scale study was conducted to evaluate the effect of variable concentrations of divalent cation (Mg^{+2}) on the adsorption of PFC to soil particles. The study entailed producing a synthetic soil consisting of a mix of sand, silt, clay and organic matter, introducing water collected from an impacted PFC water source and batch-testing the effectiveness of a range of Epsom Salt (soluble magnesium sulfate heptahydrate) concentrations, which consist of soluble magnesium sulfate heptahydrate. The results indicate that variable concentrations of magnesium (divalent cation) had a minor effect on the sorption of Perfluorooctanesulfonate (PFOS) with the highest sorption occurring in the strongest solution of Epsom Salt. An unanticipated result of the test involved apparent biomediated transformation of Polyfluorinated Alkylated sulfonates (Telomers or FTS) to Perfluoroctanoic Acid (PFOA), Perfluorohepantanoic Acid (PFHpA) and Perfluotonanoic Acid (PFNA). We believe this may be the first time the complete transformation of 6:2 FTS to PFHpA has been observed and reported under ambient surface water like conditions within six months.

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Maximizing Radius of Influence for More Efficient Big Building Mitigation

Rachel Saari, Mitch Wacksman and Rachel Wisman

Mitigating the vapor intrusion pathway in large commercial facilities presents unique challenges and can be costly. Maximizing the radius of influence possible can lead to more efficient building mitigation thereby decreasing capital expenditure, lowering the annual operating cost, and minimizing the footprint of the finished system.

This presentation will provide a summary of the pilot testing and design strategies successfully implemented for mitigation of large buildings with a focus on the importance of good pilot tests, the effect of expansion joint sealing, and the use of high vacuum blower systems on the achievable radius of influence. A case study will be presented that demonstrates the successful use of these techniques to mitigate the entire footprint of a 1,000,000 square foot building located in New York State. This multi-tenant facility includes health care, office, laboratory, and warehouse spaces that were occupied at the time of system installation. The final sub-slab depressurization system (SSDS) consisted of multiple vacuum blowers connected to a branched network of thousands of linear feet of piping and 60 suction points installed beneath the floor slab throughout the building interior. The SSDS was designed to maintain a minimum differential pressure of -0.004-inch water column between the sub-slab space and the indoor air space of the building under all building conditions. The SSDS was also designed to treat extracted soil vapor via vapor-phase carbon prior to its discharge to the atmosphere.

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An Evaluation of Electronic Field Data Collection Solutions: Lessons Learned

Thomas Wright and David Cleland

Background/Objectives: The advent of new electronic field data collection systems and backend data management software products has increased the availability of more robust technology solution for project implementation. The wide array of resources presents a challenge in the type and implementation of the field data collection system. This presentation draws upon experience from field applications to provide answers to the following questions.

- Which systems provide the best fit for an office or project?
- Do the solutions always need to be connected, and what kinds of limitations does that impose on the effort?
- Is there a singular solution?

Approach/Activities: Several different technology configurations exist in the marketplace for field data collection. These include: 1) tablets with specialized software, 2) ruggedized laptops, and 3) smartphones with various operating systems (OS), each of which can pair with different backend data management solutions. These different implementation approaches were evaluated quantitatively and qualitative across several projects types such as large and small groundwater monitoring projects, soil sampling, and field observation projects. Following the completion of the data collection, the field user was asked to provide a qualitative evaluation of the ease of use; likes/dislikes of the device or method of collection; and asked to provide improvement feedback. A quantitative assessment was made on the field data collection effort based on the reduction (or increase) in the number of billable hours it took to produce a report and the quality output from each data collection event. The output production included an assessment of the ease of moving the data from field collection unit to a backend data management system. An additional quantitative metric was added to the assessment in cost to equip each user with the specific field collection device.

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Characterization and Remediation of NAPL in Deep Groundwater System

Biniam Zerai

Non-aqueous phase liquid (NAPL) is one of the environmental contaminants that impacts the quality of groundwater. NAPLs are immiscible hydrocarbons in the subsurface that exhibit different behavior and properties than dissolved contaminant plumes. Apart from being notoriously difficult to remove, NAPL also serves as a continuous source of groundwater contamination that can cause environmental problems and health risks.

NAPLs were identified in a deep aquifer system, at depth below 100 feet, at a former tank farm site in Los Angeles, California USA. The composition and extent of NAPL at the site were assessed and evaluated using historical site information, analysis of ground water and soil boring data, cone penetrometer test and Ultraviolet Optical Screening Tool® (CPT/UVOST®), and analysis of free product recovered from monitoring wells.

The purpose of the presentation is to highlight and discuss the challenges of characterization and remediation of NAPL in a deep aquifer system. The discussion will include (1) data analysis to characterize hydrogeologic settings, water quality, and groundwater flow in the deep groundwater system, (2) tools and methods used to assess the vertical and horizontal distribution and extent of NAPL in the deep aquifer system at the site, and (3) proposed removal of NAPL identified at the site to the extent deemed technologically feasible and practicable.

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