行政院所屬各機關因公出國人員出國報告書

出國報告（出國類別：其他）

赴美國麻薩諸塞州阿默斯特參加「第33屆年度土壤、底泥、水質及能源」國際研討會

服務機關：	行政院環境保護署
姓名職稱：	倪炳雄副執行秘書
派赴國家：	美國
出國期間：	106年10月14日至10月22日
報告日期：	107年1月15日

摘要

環境健康與科學協會(AEHS, The Association for Environmental Health and Sciences)成立於 1990 年，經由舉辦研討會、刊物與論壇等方式促進國際間在各種環境議題上的資訊交流與經驗分享。AEHS 於 2009 年與美國環境鑑識協會(ISEF, The International Society of Environmental Forensics)合併，每年於美東與美西各舉辦一場大型研討會。

我國污染整治場址在整治工作執行期間，部分污染土壤採用離場再製產品的方式處理。為有效監控以再製產品方式作為污染土壤離場之運用情形，以避免產生污染擴散、強化資源循環利用的經營模式，因此深入了解特定產業之製程特性與其產品溶出特性之間的關係有其必要性，並可協助從產品品質標準角度研訂污染土壤再利用與處理許可之管理標準。順應我國資源循環再利用之原則，以污染土壤作為原料或材料使用為資源永續利用之具體方法。為建立污染土壤再利用之通路，同時避免污染土壤再利用產品於後端使用時有污染環境或危害人體健康之疑慮，因此，本次行程內容主要出席 AEHS 在美國麻州艾姆赫斯特舉辦之第 33 屆國際研討會，以了解國際間污染場址相關議題與技術的最新發展與應用現況，並與國外專家交流國內發展經驗。本次研討會行程主要活動包括(1)發表海報論文，分享我國在污染土壤離場處理再利用環境安全領域的技術進展。(2)參加研討會講座，了解國際環保技術的進展，包括底泥採樣與污染防治、整治與復育的永續思維、綜合性整治技術方案、現地含氯污染物整治技術之精進、現地化學還原整治工法與啟動物質結合技術、石灰岩地質整治四氯乙烯技術等議題。

經由本次研討會行程的學習與交流，對於國內未來的發展建議包括(1)本次研討會有幸獲得若干研究發表，提出新穎底泥採樣方式、污染物被動式採樣器等，可提供國內相關領域參考，強化底泥環境檢測能力。(2)綠色及永續型整治（GSR）近年在國內開始推廣。此種觀念強調整治工作必須考量工法的環境足跡，避免因整治作業產生負面影響。(3)石油類污染土壤在我國常見的場址為加油站，若可短期暫停營業，引用套裝式處理設備搭配小規模開挖，現場妥善處理石油類污染土壤，將可達到快速、影響規模小等優點，迅速回復土地利用等，可做為我國未來該類污染處理之思考方向。

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為與全球相關研究者交流土壤處理最新技術，規劃參與今年(106 年)33rd Annual East Coast Conference on Soils, Sediments, Water, & Energy 國際研討會，希望藉由國際交流發表我國在污染土壤離場再製產品環境安全管理經驗與最新研究成果，並吸取國際其他整治工作經驗，以利於建立污染土壤資源循環管理規範與制度。環境健康與科學協會(AEHS, The Association for Environmental Health and Sciences)成立於 1990 年，集結環境領域的產官學所共同成立之非營利協會，經由舉辦研討會、刊物與論壇等，提供平台促進國際間在各種環境議題上的資訊交流與經驗分享。AEHS 於 2009 年與美國環境鑑識協會(ISEF, The International Society of Environmental Forensics)合併，每年於美東與美西各舉辦一場大型研討會，每場均有 500-800 人來自世界各地共襄盛舉。

本次行程內容主要為出席 AEHS 在美國麻州艾姆赫斯特舉辦之第 33 屆國際研討會，研討會主題包括加勒比海之環境議題、環境法規與政策、整治技術、生物監測之風險評估、LNAPL、現地臭氧整治、風險評估、底泥、州及地區政府之氣候變遷政策、污染場址之管理分析工具、麻州潔淨能源經濟、PFAS、永續整治思維、綜合整治技術、氣候變遷之永續整治策略、整治之地質學理思考、場址調查、氣體入侵、現地整治技術等多個主題，主題範圍廣泛。

本次參與國際研討會，主要發表我國在污染土壤離場再製產品環境安全管理經驗與最新研究成果，針對水泥、紅磚、清洗土壤等 3 項污染土壤再製產品，利用 3 種溶出特性試驗找出永續利用的管理目標。3 種溶出特性試驗為 TCLP、SPLP、向上流動滲濾試驗(CEN/TS 14405:2004)等。試驗結果顯示，水泥重金屬鉻的 TCLP 溶出比率可達 30%，而 SPLP 僅 5%。向上流動滲濾試驗結果顯示，參照荷蘭 BMD 標準，水泥樣品中的重金屬鉻符合標準值 1,500 mg/m^2-100 yr；若對照我國第一類地下水質標準，在溶出的初期可能超過標準值 0.05 mg/L，表示若此類水泥建物在地下含水層中，有可能對下游地區民眾人體健康產生危害。利用污染土壤生產紅磚的樣品試驗結果與水泥樣品結果不同。紅磚中的重金屬鉻 3 個試驗之溶出比率均微，但是在 TCLP 試驗的重金屬砷溶出比率超過 10%。紅磚樣品之重金屬銅、鎘、砷亦完成相同的 3 種溶出試驗。期藉參與國際會議，與各國交換及吸取污染土壤離場再製產品管理工作經驗。

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參、行程及工作內容

本次出席 AEHS 在美國麻州艾姆赫斯特舉辦之第 33 屆國際研討會，研討會主題包括加勒比海之環境議題、環境法規與政策、整治技術、生物監測之風險評估、LNAPL、現地臭氧整治、風險評估、底泥、州及地區政府之氣候變遷政策、污染場址之管理分析工具、麻州潔淨能源經濟、PFAS、永續整治思維、綜合整治技術、氣候變遷之永續整治策略、整治之地質學理思考、場址調查、氣體入侵、現地整治技術等多個主題，主題範圍廣泛。總計 6 場短期課程、超過 200 場次口頭報告與 80 篇海報論文發表、及 48 家全球各大整治相關專業公司展示等。會議主題與研習交流內容說明如下：

一、發表我國研究成果及國外專家交流

發表海報論文分享我國在污染土壤離場處理再利用環境安全領域的技術進展（如附件一），主要內容摘錄如下：

(一)我國應用各種滲濾試驗技術研究各種環境情境下的再製產品重金屬滲濾(percolation)的成果（如圖 1）：

1. 水泥再製產品中，因水泥燒製後產生氧化態的六價鉻較易溶出，故成品酸鹼度呈現鹼性，使得重金屬鎘的氧化物較易溶出，故富含此 2 種重金屬污染的原料不建議用於水泥製造。

2. 磚再製產品中，遭受重金屬砷污染的原料不建議用於紅磚製造，另重金屬鎘污染的原料所製造之紅磚因較易溶出重金屬鎘，故不建議使用可能與人體或土壤有直接接觸，無隔離措施的設施中。

3. 受污染土石無法透過鹽酸清洗程序去除或是安定化重金屬鎘（清洗後土石中鎘的 TCLP 溶出達 40%），因此不可棄置於掩埋場中。

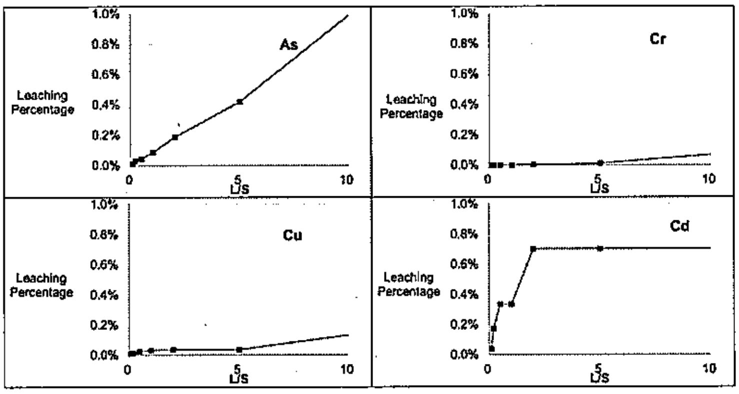


圖 1、清洗土石後之 4 種重金屬溶出特性

(二)利用重金屬滲濾(percolation)的成果進行未來相關處理許可法規律定標準之評估工作。水泥再製產品因氧化態的六價鉻易溶出而使產品酸鹼度呈現鹼性，導致重金屬鎘較易溶出，重金屬鎘將超過荷蘭 BMD 標準值；清洗後之土石在向上流動滲濾試驗結果中，各重金屬溶出數值計算荷蘭 BMD 數值並經比對，均未超過荷蘭標準，但是清洗後的土壤含有殘留重金屬鉻，不建議用於水泥製造。

其中，有多位美國從事污染土壤離場處理及資源循環再利用工作的專家對於我方在實際應用面的探討與結果極為稱頌；整治領域的專家則希望我們可將研究成果訂定法規標準的經驗向環境整治界介紹，藉以釐清多項再利用迷思，並有助於各國推動循環經濟必須注意之方向。海報發表情形如圖 2。

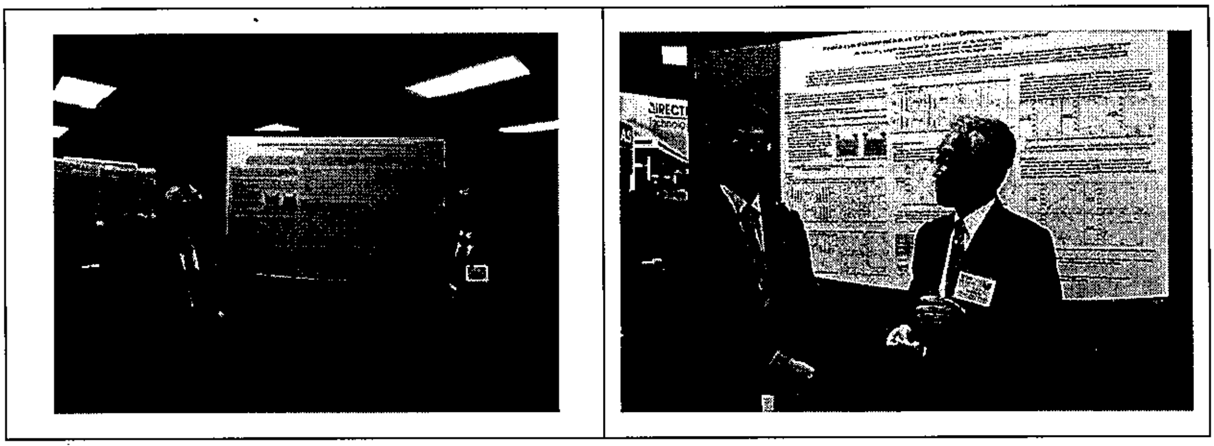


圖 2、海報陳列與發表狀況

二、研討會項目

國際研討會完整簡介如附件二，摘要介紹如下：

研討會及附屬短期技術課程於 2017 年 10 月 16-19 日在美國麻塞諸塞州波士頓近郊之艾姆赫斯特舉行，共有 6 場短期課程、超過 200 場次口頭報告與 80 篇海報論文發表、及 48 家全球各大整治相關專業公司展示等。研討會主題包括加勒比海之環境議題、環境法規與政策、整治技術、生物監測之風險評估、LNAPL、現地臭氧整治、風險評估、底泥、州及地區政府之氣候變遷政策、污染場址之管理分析工具、麻州潔淨能源經濟、PFAS、永續整治思維、綜合整治技術、氣候變遷之永續整治策略、整治之地質學理思考、場址調查、氣體入侵、現地整治技術等多個主題，範圍廣泛。

研討會各分區主標題、時間、場地名稱等資訊，各分區詳細口頭報告標題、摘要與主講人資料請詳見附件二。由於本次研討主題範圍廣大，主題演講同時於 6 個講堂舉行，參與廠商眾多，相關主題具有國際共通性、適合我國參採之議題含：

(一)底泥採樣與污染防治

(二)綠色及永續整治思維

(三)PFAS（多氟烷基碳化物）等持久性污染物檢測及管理政策

(四)褐地再生案例

(五)綜合性整治技術方案

(六)現地化學還原整治技術

(七)困難地質整治四氯乙烯技術

(八)石油類污染現場整治套裝技術等

本文主要針對底泥採樣與污染防治、綠色及永續整治思維、綜合、及困難地質整治技術等議題進行說明。

三、研討會內容報告

Session 6：底泥採樣與污染防治

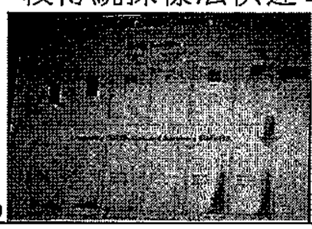
底泥採樣與污染防治主題含 3 場次專題報告，分別為 Development of a Passive Lignin Porewater Sampler for Metals、Factor Analysis and Variability of PCBs in Ambient Air from Contaminated Sediment, New Bedford Harbor、The Benefits of Sonic Drilling Techniques for Improved Recovery at Contaminated Sediment Sites。詳細內容如表 1 所列，歸納重點摘述如下：

1. 木質素採樣器是一種被動式利用木質素與重金屬的結合特性所設計出來的採樣器，主要是採取底泥顆粒間隙水的關切污染物。這種採樣器是利用紙漿與造紙工業廢水中所含的木質素做為基本材料，利用其快速結合重金屬的特性所研製而成。

2. 在環保抽泥的工作中，現場天氣條件影響抽泥效果比想像中的較大，因此設立現場氣象觀測站很重要。同時，慎選環保抽泥方式取決於污染物濃度與特性，因此對於許多環保抽泥技術的特性也很重要。

3. 超音波底泥採樣器具有高度岩心樣品回收率、無需使用鑽掘潤滑液及較傳統採樣法快速 2-3 倍等優點，並適用於超過 8 英尺深的底泥樣品，可先搜尋技術專利，找尋授權機會或代理商，將技術引進國內。

表 1、Session 6 底泥採樣與污染防治主題相關演講重點

論文標題	主要作者	重要內容	我國可參考之處
Development of a Passive Lignin Porewater Sampler for Metals	Stephen Clough	● 木質素取自紙漿與造紙工業 ● 吸附金屬快速 ● 可製成鈣化木質素 ● 有效吸附重金屬銅、鎘、鉛、鋅等 ● 可利用 0.1 篩網係數之孔徑來濾除來自土壤間隙水之微小顆粒	● 一種被動式利用木質素與重金屬的結合特性所設計出來的底泥顆粒間隙水採樣器進行推廣。 ● 這種採樣器是利用紙漿與造紙工業廢水中所含的木質素做為基本材料，利用其快速結合重金屬的特性所研製而成。
Factor Analysis and Variability of PCBs in Ambient Air from Contaminated Sediment, New Bedford Harbor	Michael Morris and Jonathan Blount	● PCB 濃度 > 100,000 mg/Kg ● 1998 年環保署選定面積 1,000 英畝的區域整治 ● 在 2004 和 2017 年間移除 550,000 立方碼的污染底泥 ● 現場設置氣象觀測站 ● 環保抽濬造成微小 PCB 氣體逸散 ● 潮汐與風速影響 PCB 氣體逸散最鉅 ● 最初使用水力抽泥，2015 年改用機械掘泥	● 慎選環保抽泥方式取決於污染物濃度與特性 ● 現場天氣條件影響抽泥效果比想像中的較大，因此設立現場氣象觀測站很重要
The Benefits of Sonic Drilling Techniques for Improved Recovery at Contaminated Sediment Sites	Peter Simon, Philip Simon, Mark DeLong, and Hugh Scott	● 適用於非結塊型有機性砂土 ● 高度岩心樣品回收率，90% ● 超音波採樣法適用於超過 8 英尺深的底泥樣品 ● 無需使用鑽掘潤滑液 ● 較傳統採樣法快速 2-3 倍 ● 	● 可先搜尋技術專利，找尋授權機會或代理商，將技術引進國內

Session 12：整治與復育的永續思維

整治與復育的永續思維主題含 4 場次專題報告，分別為 Life Cycle Inventory Data for Use in Assessing Environmental Footprints of Green Remediation Projects、Buses, Brownfields & Bedrooms - A Case Study of the Former Bartlett Yard Bus Garage Remediation、Programmatic Integration and Management of Green and Sustainable Remediation、Urban Background: The Development, Current Status, and Lessons Learned for the Southeast Regional Study。詳細內容如表 2 所列。歸納重點摘述如下：

1. 我國 2016 年開始推動 GSR 整治策略，整治專案均需考慮綠色永續工法。可加強涉略 Battelle 提供之工具集，以利未來推動強化整治工程計畫之執行。

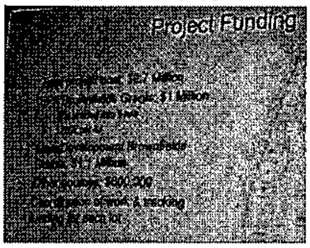
2. 廢料回收再利用需於拆除工作進行時仔細規劃與執行，工作品質要求較高。經費非全部仰賴政府支援，社區、廠商、社會團體、一般民眾之勞力、設備支援亦為重要因素。依據各國經驗，強化當地民眾參與可提供計畫成功率。我國近年推動褐地再利用整治型態，可借相關案例為鏡。

3. 整治計畫納入 GSR 概念之精神，由計畫提出者於執行之初即納入相關概念有利整體計畫運作，並確保 GSR 精神得以執行，但實務上因整治計畫重點之一為時間與經費之掌控，可能難以執行。

4. 長時間收集都市環境背景數據，將有助於分析都市成長與都市環境監控之關聯，並有利於了解非流行性疾病與都市環境品質之間的病理關係。

表 2、Session 12 整治與復育的永續思維主題相關演講重點

論文標題	主要作者	重要內容	我國可參考之處
Life Cycle Inventory Data for Use in Assessing Environmental Footprints of Green Remediation Projects	Paul Randall, David Meyer, Wesley Ingwersen, Scott Unger, Karen Scheuermann, and Michael Gonzalez	●USEPA 發展 SEFA，並於 2014 年更新文件 ●Battelle 提供 SiteWise 工具集 ●2 個商業 LCA 評估軟體 ●SEFA 計算工作必先設立係數假設值 ●SEFA 之估計結果在不同國家、單位操作、來源含	●我國近年開始推動 GSR 整治策略，整治專案均需考慮綠色永續工法。 ●可加強涉略 Battelle 提供之工具集，以利未來本所拓展整治工程計畫之範疇

論文標題	主要作者	重要內容	我國可參考之處
		有不同程度之誤差	
Buses, Brownfields & Bedrooms - A Case Study of the Former Bartlett Yard Bus Garage Remediation	Patrick Lyons and Paul Uzgiris	●位於波士頓之 Dudley Square 之褐地再利用計畫 ●拆除舊建築後，回收廢料並用於新建築工程。 ●強化當地民眾參與，共同重建該社區 ●總經費 270 萬美金  ●	●我國近年推動褐地再利用整治型態，美國相關案例可做為借鏡。 ●廢料回收再利用需於拆除工作進行時仔細規劃與執行，工作品質要求較高 ●強化當地民眾參與可提供計畫成功率 ●經費非全部仰賴政府支援，社區、廠商、社會團體、一般民眾之勞力、設備支援亦為重要因素
Programmatic Integration and Management of Green and Sustainable Remediation	Lindsay Burton and Frank Messina	●採用 SiteWise 工具集 ●GSR 之執行需要考慮：系統性的整合、經營管理、環境議題、整治效率、下包合約等 ●GSR 執行者必須為計畫主辦方，同時也必須為計畫統籌方。 ●計畫中之特殊工作，如整治工作、經費、公關、規劃等，應由下包商完成。	●整治計畫納入 GSR 概念之精神，由計畫提出者於執行之初即納入相關概念有利整體計畫運作，並確保 GSR 精神得以執行，但實務上因整治計畫重點之一為時間與經費之掌控，可能難以執行。
Urban Background: The Development, Current Status, and Lessons Learned for the Southeast Regional Study	Sheri Adkins and Christoph Uhlenbruch	●都市環境背景濃度資料收集，並存於資料庫中，以利於其他城市參考。 ●經費規畫部分用於數據收集，部分移做整治工作 ●使用手工具採取表土 ●經費永遠不足，如何將經費用於重要資料的蒐集是計畫成功關鍵 ●當計畫完成，並且相關州政府同意揭露這些資料時，數據將會公開。	●我國類似工作已執行多年，多是空氣品質相關數據、區域性地下水質數據等。 ●長時間收集都市環境背景數據，將有助於分析都市成長與都市環境監控之關聯，並有利於了解非流行性疾病與都市環境品質之間的病理關係。

Session 15：綜合性整治技術方案

整治與復育的永續思維主題含 2 場次專題報告，分別為 In Situ Chemical Reduction with ZVI and ZVI-Sulfide、Improving Remedial Actions Through Integrated Use of Direct-Push High-Resolution Site Characterization (HRSC) Technologies。詳細內容如表 3 所列。歸納重點摘述如下：

1.零價鐵之應用於環境整治已不是新議題，整治實務均採用各種衍生技術以克服零價鐵之缺點。惟因為零價鐵之特性難以克服，我國尚未有類似整治案例。此案例與其他現行國際經驗應可協助克服國內相關整治瓶頸。講者 Richard Raymond 提供該研究之效率比較，如圖 3，並現場示範藥劑混合，並展示混合後之穩定性，如圖 4。

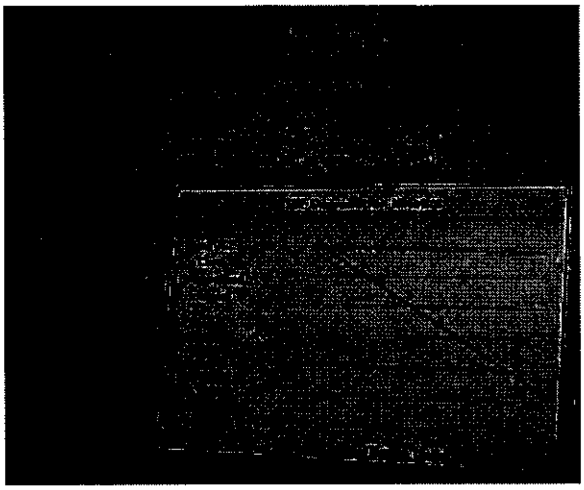


圖 3、講者 Richard Raymond 提供該研究之效率比較

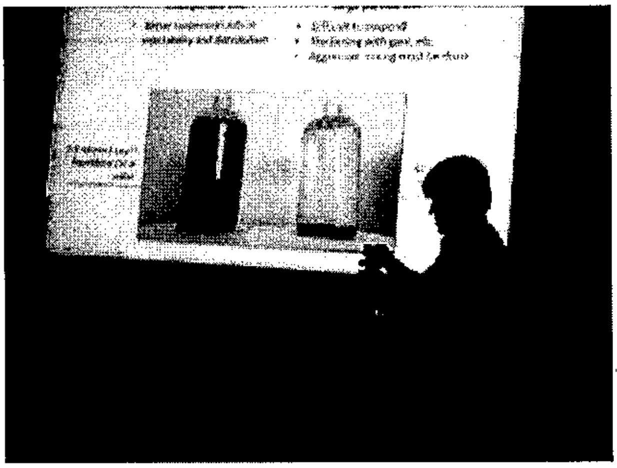


圖 4、講者 Richard Raymond 現場示範藥劑混合

2.整治工法設計前之場址調查很重要，但是往往礙於經費限制，只有少量數據可以取得。若能獲得寬鬆經費用於高密度數據支援，整治工法之設計與時程之掌握將可更精確，避免因有誤差之資訊造成錯誤整治，徒增資源浪費與經費增加。圖 5 顯示 HPT:hydraulic profiling tool、圖 6 顯示 MIP: membrane interface probe。

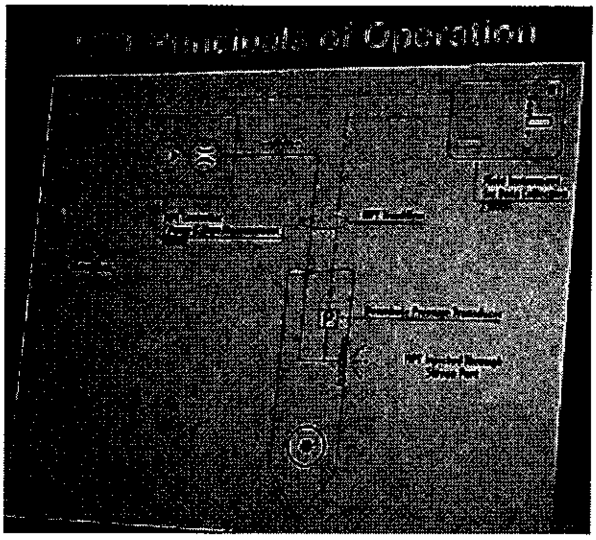


圖 5、HPT : hydraulic profiling tool

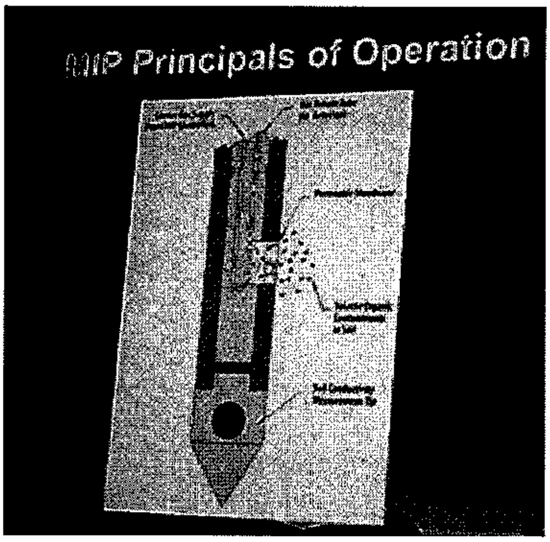


圖 6、MIP : Membrane interface probe

表 3、Session 15 綜合性整治技術方案主題相關演講重點

論文標題	主要作者	重要內容	我國可參考之處
In Situ Chemical Reduction with ZVI and ZVI-Sulfide	Richard Raymond and Michael Lee	●採用零價鐵與硫酸鹽製造硫化亞鐵。 ●使用製造生成之硫化亞鐵去處理含氯有機物。	●零價鐵之應用於環境整治已不是新議題，各整治經驗均已採用各種衍生技術以克服零價鐵之缺點。 ●我國尚未有類似整治案例提供相關經驗，可能是因為零價鐵之特性難以克服。此案例與其他現行國際經驗應可協助克服國內相關整治瓶頸。
Improving Remedial Actions Through Integrated Use of Direct-Push High-Resolution Site Characterization (HRSC) Technologies	Eric Garcia	●不同整治工法間之共同協作. ●高度數據精度與大量數據可使整治場址之細節得以呈現、不確定性降低、最佳經營策略明確化、實作性增加、數據密度提高等。	●整治工法設計前之場址調查很重要，但是往往礙於經費限制，只有少量數據可以取得。若能獲得寬鬆經費用於高密度數據支援，整治工法之設計與時程之掌握將可更精確，避免因有誤差之資訊造成錯誤整治，徒增資源浪費與經費增加。

Session 20：石灰岩地質整治四氯乙烯技術

整治與復育的永續思維主題含 3 場次專題報告，分別為 Evaluation of Extensive Groundwater Remedial Actions for Chlorinated Ethanes/Ethenes and Selection of In-Situ Chemical Oxidation for Chloroethane Polishing、Development of Klozur SP with a Built-in Activator: Overcoming the Challenges of Storage and Mixing While Maintaining Treatment Effectiveness。詳細內容如表 4 所列。歸納重點摘述如下：

1. 含氯有機物於土壤、地下水整治工作，因不均質及不可見等特性，難度很高，整治列車、綜合性聯合整治工法的概念在近年大行其道。本場講座說明過碳酸鈉使用在適合的地質條件場址，其好處在於使用後殘留之藥劑會自行衰減。另抽出處理工法因技術簡單，目前仍有許多場址在整治初期採用此工法，主要的因素即在於該法可在污染物濃度高時，快速降低污染物濃度，減少暴露風險。

2. 過硫酸鹽具水溶解度高、未使用前及溶解於水後皆穩定、對於污染標的物之反應性強，可與過錳酸鹽、酸鹼緩衝劑、鐵錯合物等物質共同使用之優點，但是缺點為自發反應需時過長，在整治區域易發生效應低落的結果。近年許多國外場址在應用過硫酸鹽的案例研究報告指出，過硫酸鹽需要其他短效期、更敏感的藥劑做為催化劑，可在設計位置誘發過硫酸鹽的氧化力。圖 7 展現結合過硫酸鹽與過錳酸鹽處理含氯有機物的效果。

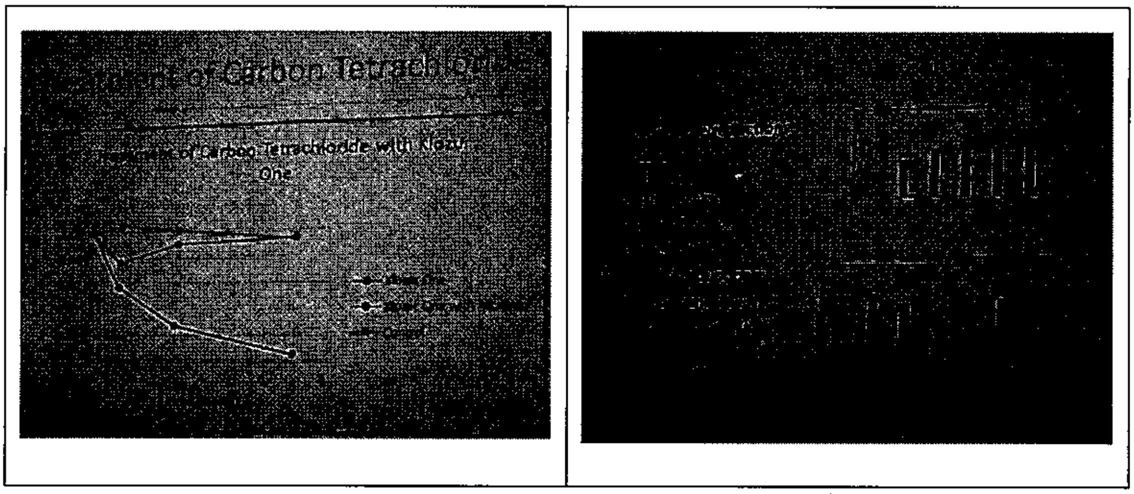


圖 7、結合過硫酸鹽與過錳酸鹽處理含氯有機物的效果

3. 會中亦有研究報告指出採用相同之過錳酸鹽做為催化劑，然過錳酸鹽之氧化力強且快，穩定性不高，另過錳酸鹽顏色深，使用過多易造成地下水顏色超過標準，需要較高的控制技術。

表 4、Session 20 石灰岩地質整治四氯乙烯技術主題相關演講重點

論文標題	主要作者	重要內容	我國可參考之處
Evaluation of Extensive Groundwater Remedial Actions for Chlorinated Ethanes/Ethenes and Selection of In-Situ Chemical Oxidation for Chloroethane Polishing	Yasemin Kunukcu and Nidal Rabah	●1994 年開始執行抽出處理工法 ●1995 年開挖深度地表以下 5-8 英呎；共挖除 9000 立方碼的污染土方 ●2002 年採用雙相萃取法（Dual Phase Extraction, DPE） ●2003-2011 年加強式現地生物整治（Enhanced in-situ Bioremediation, EISB）；加入 HRC-Advanced、HRC-X、3D-ME ●2013 年 5 月，轉用現地化學氧化法（in-situ Chemical Oxidation, ISCO）；加入 RegenOx、過碳酸鈉 ●2013 年 7 月，終止抽出處理工法	●含氯有機物再土壤、地下水整治一直以來的難度都很高，整治列車、綜合性聯合整治工法的概念在近年大行其道。 ●抽出處理工法雖然技術簡單，但是目前仍有許多場址在整治初期採用此工法，主要的因素即在於該法可在污染物濃度高時，快速降低當地的濃度，減少暴露風險。 ●過碳酸鈉的使用必須在適合的地質條件，若可使用，其好處在於用後可以不用抽除，殘留之藥劑會自行衰減。
Development of Klozur SP with a Built-in Activator: Overcoming the Challenges of Storage and Mixing While Maintaining Treatment Effectiveness	Brant Smith, Ravi Srirangam, Brianna Desjardins, and Ian Horner	●採用過硫酸鹽 ●混合粉狀藥劑後，以泥狀注入地下水整治區 ●過硫酸鹽的好處：水溶解度高、未使用前穩定、溶解於水後穩定、對於污染標的物之反應性強 ●與下列物質共同使用：過錳酸鹽、酸鹼緩衝劑、鐵錯合物	●過硫酸鹽之優點為穩定性高、反應強，無色無味。 ●過硫酸鹽之缺點為自發反應需時過長，在整治區域易發生效應低落的結果。 ●近年許多國外場址在應用過硫酸鹽的案例研究報告指出，過硫酸鹽需要其他短效期、更敏感的藥劑做為起動物質，可在設計位置誘發過硫酸鹽的氧化力。

肆、心得與建議

本次研討會在美國麻塞諸塞州波士頓近郊之艾姆赫斯特舉行，共有 6 場短期課程、超過 200 場次口頭報告與 80 篇海報論文發表、超過 48 家全球各大整治相關專業公司展示等。研討會主題包括加勒比海之環境議題、環境法規與政策、整治技術、生物監測之風險評估、LNAPL、現地臭氧整治、風險評估、底泥、州及地區政府之氣候變遷政策、污染場址之管理分析工具、麻州潔淨能源經濟、PFAS、永續整治思維、綜合整治技術、氣候變遷之永續整治策略、整治之地質學理思考、場址調查、氣體入侵、現地整治技術等多個主題，主題範圍廣泛。

本次研討會發表海報論文，與會海外專家均對於我國離場污染土壤搭配循環經濟之世界潮流深表贊同，同時對於我國能以模擬產品使用環境，研究再製產品中污染物之環境安全特性，並且以研究成果據以擬訂管理規範表示讚佩。甚有美國專家希望能保持聯繫，將最新之研究成果相互交流切磋，期望能對於環境保護與循環經濟貢獻最新研究成果，協助政府研擬妥適標準。

另國際間土壤、地下水整治的技術研發方向已逐漸結合政府區域規劃，各領域多著重在各種技術串聯執行後的經驗累積與效益評估，各種技術的商業產品逐漸增多，可藉由此類研討會交換經驗、引進有效技術產品。針對本次參與國際會議，摘述心得與建議重點如下：

一、發表海報論文，分享我國在污染土壤離場處理再利用環境安全領域的技術進展，主要分享內容包括：

（一）我國應用各種滲濾試驗技術研究各種環境情境下的再製產品重金屬滲濾(percolation)的成果。

（二）利用重金屬滲濾(percolation)的成果進行未來相關處理許可法規律定標準之評估工作。

（三）多位美國從事污染土壤離場處理及資源循環再利用工作的專家對於我方在實際應用面的探討與結果極為稱頌；整治領域的專家則希望我們可

將研究成果訂定法規標準的經驗向環境整治界介紹，藉以釐清多項再利用迷思，並有助於各國推動循環經濟必須注意之方向。

二、參加研討會講座，了解國際環保技術的進展，包括底泥採樣與污染防治、整治與復育的永續思維、綜合性整治技術方案、現地含氯污染物整治技術之精進、現地化學還原整治工法與啟動物質結合技術、石灰岩地質整治四氯乙烯技術、PFAS 管理等議題，內容摘錄如下：

（一）底泥污染與整治技術方面，介紹一種被動式利用木質素與重金屬的結合特性所設計出來的底泥顆粒間隙水採樣器。這種採樣器是利用紙漿與造紙工業廢水中所含的木質素做為基本材料，利用其快速結合重金屬的特性所研製而成。該採樣器對於重金屬銅、鎘、鉛、鋅具有良好的效果。

（二）利用音波震動的原理提升底泥採樣的樣品回收率的新穎底泥採樣器，有利於鬆散的有機性砂土的採樣，對於採取之岩心樣品可減少樣品擾動、提高樣品之回收率。此方法最佳採樣深度大於 8 英呎，大約是 2.44 公尺以上的深度。

（三）褐地再生案例，提及美國波士頓地區 Dudley Square 之前巴士停車修護廠。該地區由於工業使用及汽車機械保養造成髒亂、低度開發、污染、貧窮等問題。一系列再生工作包括拆除建物後之建材經處理後再度用於該區域建設、有害物質移除、社區共同討論拆除區域及再生規劃等。該計畫共需經費 270 萬美元，其中環保署提供 100 萬美元、麻州提供 110 萬美元、其他小額捐助共約 60 萬美元。2016 年時已完成整體規劃，預計 2021 年完成全區建設。

（四）綠色及永續整治(GSR)在美國近年來常在各大研討會開設專區廣為宣傳。SURF 與美國環保署設置 SiteWise 工具集提供各整治利害關係人運用，以利在整治規劃初期即開始導入綠色及永續整治觀念。GSR 之執行

需要思考整體規劃，包括建構之整體性、經營管理策略、環境關切面、整治效率分析、合約執行等。任何一個整治計畫的 GSR 必須與計畫的經費來源密切合作，達到協調的目的。下包商必須確實達成規劃的整治、財務、社會等目標。

（五）現地化學還原整治技術運用零價鐵及硫化零價鐵，做為處理含氯有機物的藥劑。這種組合性藥劑的好處包括維持一定的反應性、長期有效、容易使用、地下環境容易分散等優點。施用濃度介於 4-25 g/L，將藥劑配製成類似水的樣態便於在地下水的環境中分散。零價鐵應用於含氯有機物的整治技術已日趨成熟，亦發現許多實務上的缺點，因此各種轉質、改質配方因運而生。我國運用零價鐵整治的案例不多，可參考最新技術發展現況，適度引進技術，解決現地整治遇到之瓶頸。

（六）含氯烯類與烷類選擇現地化學氧化之思考重點，包括在整治初期使用傳統抽出處理法、中期使用雙相抽出處理法(DPE)、後期使用多種商業藥劑（如 HRC-Advanced、HRC-X、3D-ME、RegenOX、過硫酸鈉等），發現以 25%氫氧化鈉活化過的過硫酸鈉效果最好。

（七）石灰岩地形的四氯乙烯整治，在美國肯德基州常見。由於石灰岩與地下水接觸後產生鹼性環境，化學整治藥劑之用量常因此改變，並且石灰岩地質常呈現裂縫，造成污染物偵測不易、藥劑不易與污染物接觸等困難。本次研討會講座採用類似石油鑽探工業常用的水力壓裂法(fracking)，將藥劑在高壓氣化的條件下，水平打入污染地層中，利用高壓將藥劑帶入污染區域。同時可配合地質記錄儀，記錄高壓機內壓力驟降的深度與壓降程度，藉以探測地層裂縫的位置與大小。

（八）現場整治套裝技術已大量應用於石油類污染土壤之整治案例。本次研討會參展廠商提供建於貨櫃中之土壤熱處理設備資料，顯示該技術主要能

以小量批次以高溫處理遭石油類產品污染之土壤，並可在處理後，立即回填開挖區域，達成污染土壤現場處理不離場之目的。

（九）PFAS（多氟烷基碳化物）會議邀請多位學者，針對美國麻薩諸塞州、新罕布夏州、佛蒙特州、羅德島等地區分享水中全氟與多氟烷基碳化物的調查案例與管理政策，以麻薩諸塞州而言，目前該州環保署已制定 PFAS 基本資料表草案，內容包括物質特性、主要來源、建議限值、採樣與分析方法等，並預計於 2017 年秋季公告各項資訊，由於 PFAS 已符合危害物質的定義，且以健康風險而言，屬關切污染項目之一，因此擬訂整治標準極具必要性，已利該州污染調查與應變計畫的執行參考。

三、建議事項

參加本次國際研討會了解國際上在土壤、地下水整治的技術發展最新趨勢，從中檢討出部分我國值得作為借鏡及相關技術研發議題的參考，如：

（一）本次研討會發表海報論文，與會海外專家均對於我國離場污染土壤搭配循環經濟之世界潮流深表贊同，同時對於我國能以模擬產品使用環境，研究再製產品中污染物之環境安全特性，並且以研究成果據以擬訂管理規範表示讚佩。甚有美國專家希望能保持聯繫，將最新之研究成果相互交流切磋，期望能對於環境保護與循環經濟貢獻最新研究成果，並作為未來業者離場土壤參數標準重要參據。

（二）底泥整治為我國近年探討之環境議題之一。由於底泥不似土壤與地下水之規律性，受降雨與人為活動影響甚鉅，有效獲得具代表性樣品實為一大挑戰。本次研討會有幸獲得若干研究發表，提出新穎底泥採樣方式、污染物被動式採樣器等，可提供國內相關領域參考，強化底泥環境檢測能力。

（三）綠色及永續型整治(GSR)近年在國內開始推廣。此種觀念強調整治工作必須考量工法的環境足跡，避免因整治作業產生負面影響。美國已推廣多年，提供評估工具，便於整治規劃者及整治經費提供者使用。我國已

於今(106)年於環保署網站提供 GSR 評估工具，希冀推廣永續整治觀念，為整治技術提供不同的思考方向。

（四）零價鐵應用於含氯有機物的整治技術已日趨成熟。純粹使用零價鐵的技術已發現許多實務上的缺點，因此各種轉質、改質配方因運而生。我國運用零價鐵整治的案例不多，可參考最新技術發展現況，適度引進技術，解決現地整治遇到之瓶頸。

（五）石油類污染土壤在我國常見的場址為加油站，通常污染場址小、週邊交通繁忙、人口密集，因此不利大規模開挖。又，因我國都市地區土地珍貴，商業產值高，因此長期低密度之整治工法不受整治業者青睞。因此若可短期暫停營業，引用套裝式處理設備搭配小規模開挖，現場妥善處理石油類污染土壤，將可達到快速、影響規模小等優點，迅速回覆土地利用，可做為我國未來該類污染處理之思考方向之一。

（六）本署自 99 年起已逐年辦理新興污染物調查，並滾動式檢討地下水污染管制標準，由於 PFAS 涵蓋之全氟辛酸(PFOA)與全氟辛磺酸(PFOS)屬國內產業使用的物質，因此亦曾辦理潛勢區域調查，並列為我國地下水新增列管物質清單的關切項目，未來將加強此類物質於環境中流佈與可能來源的調查工作，並持續蒐整國內外調查結果，以做為管制標準檢討的依據。

附件一、海報論文及摘要

Sustainable Use of Contaminated Soils with Chromium, Copper, Cadmium, and Arsenic based on Leaching Characteristics

Pei-Yao Wu[1], Ping-Hsiung Ni[2], Shyh-Wei Chen[2], Jen Wang[2], Jen-Shen Chou[2], Mei Shiou Hung[1], Yu-Jen Liang[1], Chien Jung Lai[1]
1: Industrial Technology Research Institute, Taiwan, Republic of China
2: Environmental Protection Administration, Taiwan, Republic of China

In this study, cement, brick, and washed soils with contaminated soils are tested with 3 main leaching characteristic procedures : TCLP, SPLP, and CEN/TS 14405:2004. The results show that 30% of total chromium in the cement sample is leached in the TCLP test while less than 5% is leached in the SPLP test. However, the results of CEN/TS 14405:2004 show that the chromium in the tested cement samples complies with the Netherland Building Materials Decree (BMD) standard of 1,500 mg/m²-100 yr . The results of the CEN/TS 14405:2004 also show that the chromium leaching may cause the violation of the groundwater standard for drinking purposes (0.05 mg/L) in the early L/S ratios, which indicates possible health threats if the downstream groundwater is used for drinking or food processing. The results of the heavy metal leaching in the brick samples are different from those in the cement samples; for example, the chromium leaching concentrations in all 3 leaching tests are insignificant but more than 10% of the total arsenic in the brick samples is leached in the TCLP test. Copper, cadmium, and arsenic are also studied in the 3 leaching tests, and the discussions of the 4 metal leaching characteristics are presented.

Introduction

Slightly contaminated soils can be processed to become cement, red bricks, and clean sands in Taiwan. These methods employ acid wash, thermal pyrolysis, and vitrification processes. This study intents to evaluate the environmental suitability of these products and the results will provide a good chance to review the regulations of utilizing the soils from remediation sites.

Methods of Leaching Characteristic Tests and Data Normalization

- Aqua regia (nitrohydrochloric acid) digestion: ISO 11466, representing total digestible heavy metal concentration
- Toxicity characteristic leaching procedure (TCLP), representing the environment of the bottom of a household waste landfill with leachate
- Synthetic precipitation leaching procedure (SPLP), representing ground-surface living environment with acidic precipitation
- P CEN/TS 14405 Characterization of waste - leaching behavior tests - Up-flow percolation test with the Dutch Building Materials Decree (BMD) standard comparisons. Results also simulate 2 environments showing in Figure 1.
- Data normalization was performed with Equation 1 in order to compare the heavy metal leaching behavior among different total concentrations in soils.

Figure 1 Simulated conditions for CEN/TS 14405

$$\frac{\text{Leached conc.}\left(\frac{mg}{L}\right) \times \text{extraction volume (L)/sample weight (kg)}}{\text{Total conc. in the sample (mg/kg)}} = \text{Leaching percentage (\%)} \quad \ldots\ldots\ldots (1)$$

Results

Cement

Along the manufacturing process, contaminated soil, raw mixture, clinker, and cement product were collected. Leaching test results with data normalization are shown in Figure 2 and 3.

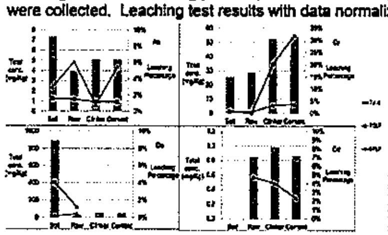


Figure 2 Comparison of cement leaching test results

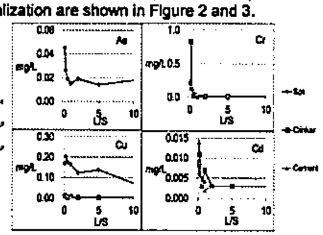


Figure 3 CEN/TS 14405 results of cement

Red Brick

Contaminated soil, heat-dried adobe bricks, and red bricks were collected. Leaching test results with data normalization are shown in Figure 4 and 5.

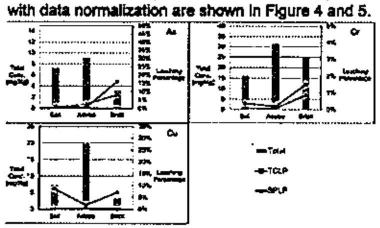


Figure 4 Comparison of brick leaching test results

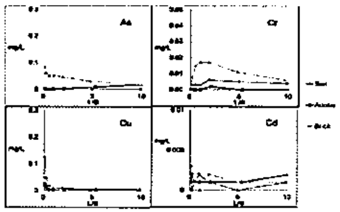


Figure 5 CEN/TS 14405 results of brick

Washed Soil

0.01 N hydrochloric acid was used to wash the soil. Leaching test results with data normalization are shown in Figure 6 and 7.

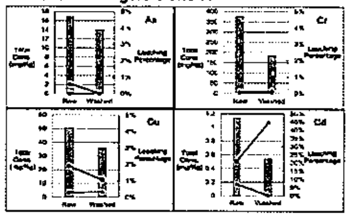


Figure 6 Comparison of washed soil leaching test results

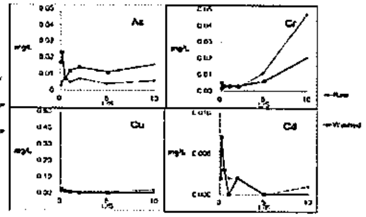


Figure 7 CEN/TS 14405 results of washed soil

Discussion & Conclusion

Cement

In Figure 3, chromium and cadmium groundwater concentration monitoring is needed in the early stage after cement structure is placed underground. The accumulated release is shown in Figure 9. Chromium and cadmium show continuous release throughout the leaching process. Copper shows insignificant release in the later part of L/S ratio.

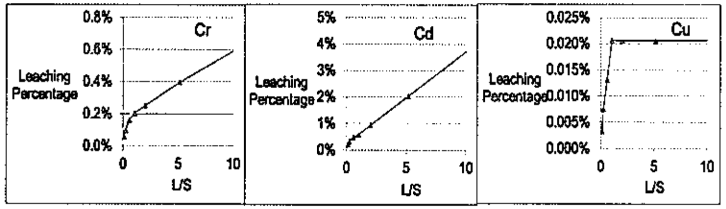


Figure 9 Metals showing accumulated release percentage in cement CEN/TS 14405 test

BMD concentrations were calculated based on the following assumptions: unmolded product, density 1,550 kg/m³ ; thickness 1 and 2 meters, 300 mm/yr infiltration without barriers and 6 mm/yr with barriers. The results are shown in Table 7. Chromium in cement shows the concentrations lower than the standard, but cadmium shows the concentrations greater than the standard when no barrier is used.

Table 7 Comparisons of the Tested Samples with the BMD Standards

Tested Sample	Concerned Item	Leached E mg/kg	Release I_b (calculated) mg/m²-100 year: Thickness 1 m, Case 1 No barrier	Thickness 1 m, Case 2 With barrier	Thickness 2 m, Case 3 No barrier	Thickness 2 m, Case 4 With barrier	BMD Standard I (mg/m²-100 year)
Cement	Cd	0.033	18.7	3.3	37.2	3.5	12
	Cr	0.328	428.4	29.7	729.1	30.3	1500
Red brick	Cd	0.029	12.5	2.2	24.8	2.3	12
Washed soil	Cr	0.129	69.6	4.8	118.5	4.9	1500

Red Brick

Chromium in red brick shows insignificant leaching in TCLP tests. Arsenic and copper show obvious increase in TCLP tests, indicating that the brick manufacturing might enhance the metal releases. In the SPLP test results, chromium and copper do not show increased release after manufacturing; however, arsenic shows increased release, indicating that the manufacturing process might make arsenic unstable. Figure 10 shows the results of CEN/TS 14405, showing that arsenic releases continuously with no sign of ending at the end of the test. Chromium and copper show that the release stops in the later part of the test.

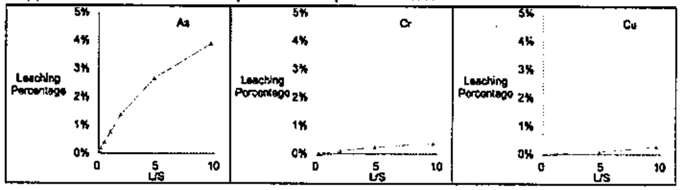


Figure 10 Metals showing accumulated release percentage in red brick CEN/TS 14405 test

Calculation results for BMD comparison shown in Table 7 indicate that cadmium-contained red brick might release its concentration more than the BMD standard under no barrier conditions.

Washed Soil

After the soil is acid washed, cadmium, arsenic, chromium, and copper show increased release in the CEN/TS 14405 test, indicating these 4 heavy metals become unstable after acid wash. However, the accumulated release percentage of the 4 metals is below 1% of the total metal concentration in the brick (Figure 11), indicating this treatment can remove these metals but the leftovers become, unfortunately, unstable.

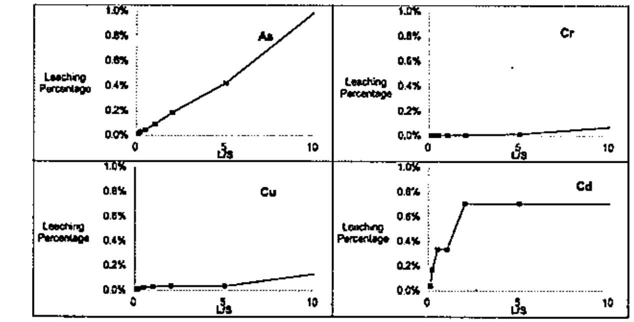


Figure 11 Metals showing accumulated release percentage in washed soil CEN/TS 14405 test

Calculation results for BMD comparison shown in Table 7 indicate that chromium-contained washed soil might release chromium but comply with the BMD standards.

Acknowledgements

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Abstract:

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Paul Kostecki, *AEHS Foundation, Inc.*

Mario Maspero, *eni*

Chris Mitchell, *AECOM*

Ellen Moyer, *Greenvironment, LLC*

Marc Nascarella, *Massachusetts Department of Public Health*

Lee Newman, *SUNY - College of Environmental Science and Forestry*

Sheree Pagsuyoin, *University of Massachusetts Lowell*

Frank Peduto, *JMT*

Karen Petho, *U.S. Department of Transportation*

Ioana Petrisor, *ToxStrategies*

Robert Pirkle, *Pace Analytical*

Thomas Potter, *MassDEP*

David Rabbe, *JMT*

Paul Rakowski, *AGVIQ, LLC*

Richard Raymond, *Terra Systems*

Alex Sherrin, *US EPA Boston*

Frank Sweet, *AECOM*

Christopher Teaf, *Florida State University*

Dallas Wait, *Gradient*

Richard Wenning, *Ramboll Environ*

Jessica Yeager, *Geosyntec Consultants*

WORKSHOPS

All workshops are FREE to municipal, state, and federal personnel registered for the conference. Use discount code REG-MSF. Pre-registration is required. If you are registering as "workshop only" and are not registering for the conference, the workshop fee applies.

All workshops are approved for all types of credit offered at this conference, unless indicated in the description. Credit is technical, unless otherwise indicated. Please see individual description for specifications/qualifications. Contact us with any questions: 413-549-5170 or brenna@aehsfoundation.org

Workshop 1 1:00pm – 4:00pm, *Room 168*

Environmental Forensics – The Integration of Various Fingerprinting Techniques to Evaluate Who Was Responsible for a Spill or Release of Organic Contaminants

Paul Philp, University of Oklahoma, Norman, OK

The concept of environmental forensics has evolved significantly over the years. Basically, it is concerned with establishing the relationship between a contaminant in the environment and its suspected source(s), or point(s) of release. Such contaminants can cover a wide range of compounds or mixtures of compounds. They may be volatile compounds such as benzene or chlorinated solvents or complex crude oil mixtures, refined products, or complex mixtures of aromatic compounds. They may be present as free product, dissolved in water, adsorbed on soil particles, or present in the vapor phase. A wide variety of techniques exist to characterize and establish their potential relationship with possible sources. The standard EPA methods that many are familiar with are of little use in forensic studies since those methods are directed towards obtaining concentration data for specific contaminants.

Forensic investigations typically use a tiered approach in terms of fingerprinting tools. Preliminary characterization is undertaken by gas chromatography (GC), followed by more detailed gas chromatography-mass spectrometry (GCMS) analyses. The fingerprints, or chromatograms, obtained in this manner often provide sufficient information to determine possible relationships between contaminant and possible release points. However, there are also many cases where the resulting GC and GCMS data are ambiguous and possibly misleading. In such cases, it is possible to go to a more specialized tier of analyses and utilize the stable isotope composition of individual compounds in the contaminant. This is particularly valuable for single component contaminants, such as MTBE, BTEX, or PCE, where GC and GCMS are of virtually no use for correlation or source differentiation. There are many examples that have been published where GCIRMS has been used to both differentiate sources of PCE/TCE as well as study natural attenuation at the contaminated sites.

Early applications of stable isotopes to environmental problems were limited to carbon and hydrogen isotopes. Chlorine isotopes can now be routinely measured for most of the common chlorinated groundwater contaminants, and in the not-too-distant future bromine isotopes will also be routinely available. This introduces the possibility of a 3D isotope approach for both source correlations and attenuation studies. Stable isotopes, including Cl, are well suited for use in the rapidly emerging area of vapor intrusion studies to differentiate indoor sources of contaminants vs. subsurface contaminants.

Finally, the use of the various fingerprinting techniques for monitoring attenuation at sites undergoing remediation will be discussed. The combined use of the stable isotopes, GC, and GCMS can be extremely valuable tools monitoring remediation as well as determining the onset of natural attenuation. Methods being developed for the incorporation of the isotope data into reactive transport models will also be discussed.

Workshop 2 1:00pm – 5:00pm, *Room 169*

Sustainable Remediation: Frameworks, Tools, and Case Studies

Anne Fitzpatrick, LHG, Geosyntec, Seattle, WA
Sabine E. Apitz, SEA Environmental Decisions, Hertfordshire, United Kingdom
David Harrison, NERA Economic Consulting, Boston, MA
Amanda McNally, Geosyntec Consultants, Pittsburgh, PA
Thomas Potter, Massachusetts Department of Environmental Protection, Boston, MA

Although guidance for sustainability considerations has been progressing from recommending best management practices (BMPs) to optimization of selected remedies to guidance on remedy selection, the focus remains on green remediation, or footprint reduction, rather than a full consideration of sustainability. A number of initiatives, frameworks, and tools have been developed, regionally, nationally and internationally to address the need to incorporate a holistic sustainable remediation approach when evaluating and selecting remedial alternatives. The workshop objective is to discuss regulatory drivers, concepts, tools and frameworks for the assessment, selection, and optimization of sustainable remediation options. A range of approaches will be reviewed, using the recently developed sustainability framework applied in the Portland Harbor Superfund Site Sustainability Project (PHSP), as an example of how emerging environmental, economic and social tools for evaluating and communicating the impacts of remedial alternatives can be used in support of decision making. Workshop participants will learn how sustainability concepts can be incorporated into site cleanups. The discussion will identify how these tools can be adapted to small and large-scale sites under a range of regulatory drivers, using a tiered approach. A focus will be the consideration of how differing stakeholder priorities affect outcomes; and how stakeholder value-linked sustainability analysis can identify trade-offs and points of contention, providing a systematic, transparent tool for community engagement. An interactive element will be included, where workshop attendees work through a demonstration of this process.

Workshop 2 is approved for NJ LSRP Regulatory credit.

Continuing Education Credit Offered at This Conference

Types of credits:

1. MA LSP Credits
2. CT LEP Credits
3. NJ LSRP Credits
4. NY PE Credits
5. FL PE Credits
6. NH PEs (select certificate of attendance)
7. Certificate of Attendance

ATTENTION NH PEs - Our Certificate of Attendance is accepted by the board of licensure and certification for NH PEs!

All certificates are mailed by mid-November.

To receive credit you must:

- Be registered to receive the CEU's (pay the $50 administrative charge for CEUs on the registration form). If you are not registered, and would like to receive CEUs, please contact the office or visit the onsite registration desk at the conference.
- Sign in AND out at the session and workshop doors (exception: LSPs sign in and out at the conference desk for the conference and at the workshop doors for workshops)
- Show a picture ID when signing in and out
- Complete and return evaluation form, if required (ex. NY PEs).

Credits are awarded as follows:

- ½ credit per hour of session attendance (LSPs, LEPs, LSRPs)
- 1 credit per hour of session attendance (PEs)
- 1 credit per hour of workshop attendance
- Some workshops may be approved for DEP regulatory credit (see individual workshop descriptions)
- Some workshops or sessions may be excluded from receiving credit (will be noted in workshop or session description in program)

Questions? **Contact the Conference Coordinator at 413-549-5170 or Brenna@aehsfoundation.org**

AEHS Foundation

WORKSHOPS

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Workshop 3 1:00pm – 5:00pm, *Room 164*

Per- and Polyfluoroalkyl Substances (PFAS): The Latest Information

Elizabeth Denly, ASQ CMQ/OE, TRC Environmental Corporation, Lowell, MA
Michael Eberle, TRC Environmental Corporation, Philadelphia, PA
Laura Trozzolo, DABT, TRC Environmental Corporation, Fort Collins, CO
Paul Locke, MassDEP, Boston, MA
James Occhialini, Alpha Analytical Laboratories, Westborough, MA
Kenneth F. Gray, Esq., Pierce Atwood LLP, Portland, ME and Boston, MA

PFAS (Per- and polyfluoroalkyl substances) are a diverse group of man-made chemicals that are resistant to heat, water, and oil. The most prominent PFAS include perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA).

An increasing number of studies indicate PFAS are widespread globally. Their persistence and ability to transport are becoming an increasing area of concern. Resistance to natural attenuation processes in groundwater is a cause for concern for long-distance migration in plumes. Because of this, demand for PFAS testing and analysis has increased. PFAS are also ubiquitous, which presents both a sampling challenge and an important consideration in source attribution by regulators.

This workshop is designed to provide a comprehensive understanding of many different issues and the most up-to-date information associated with PFAS including the following: history and sources of PFAS; regulatory status and future implications; the unique chemistry of PFAS, including precursors; exposure, health effects, and toxicity; sampling and analytical challenges and options; fate and transport; remediation challenges; legal liabilities; data evaluation; and forensics. The presenters were selected based on their intimate knowledge of the issues and their ability to answer real-world questions. Attendees are encouraged to bring questions for discussion about the technical and regulatory challenges faced with PFAS investigations.

Workshop 3 is approved for 2.0 LSP DEP/Regulatory and 2.0 technical continuing education credits (MassDEP LSP Board Course #1608)

Workshop 4 1:00pm – 5:00pm, *Room 176*

Pioneer Valley's Post-Glacial Landscape: A Field Course Throughout the Pioneer Valley of Massachusetts

Brian Yellen, Ph.D., University of Massachusetts Amherst, Amherst, MA

The advance and subsequent melting of the Laurentide Ice Sheet in New England played a dominant role in shaping the sediments and topography of this region. Participants in this course will visit a series of glacial depositional landscapes in the Pioneer Valley of Massachusetts on a four-hour guided bus tour. At each stop, participants will build on their understanding of how glaciers shaped the landscape and what overburden materials to expect in different contexts. Participants will learn tools to quickly gauge site topography and soils to make inferences about subsurface stratigraphy. The instructor will give special attention to hydraulic properties of various sediments and implications for contaminant transport therein.

Relevance to LSP/LEP Needs:

Water and contaminants move through sediments (soils) at dramatically different rates and directions depending on the properties of those sediments. Because the vast majority of overburden in New England is of glacial origin, understanding the imprint of glaciers on the landscape can dramatically improve one's understanding of how groundwater and contaminants will interact with various soils in both the vadose and saturated zones.

Workshop 4 is **not** approved for NJ LSRP credit.

AEHS Foundation Scholarships

Charlena M. Seymour Scholarship: Established in 2014 to recognize women pursuing an advanced degree in the fields of Public and Environmental Health. This award is made annually at the beginning of the Fall semester to individuals who embody qualities that best exemplify Dr. Seymour's life.

David F. Ludwig Memorial Student Travel Scholarship: Established in 2017 in memory of dear friend and respected colleague, Dr. David Ludwig. This annual scholarship is designed to assist students pursuing research in Ecology and Ecological Sciences with travel to conferences or research related expenses. Dr. Ludwig's passion for science, travel, education, and exploration is the inspiration for this award.

Michael E. Miller Student Competition: In 2017, The East Coast Conference Student Competition was renamed in memory of the former Chair of the competition, Michael E. Miller. Mike was an integral part of the Scientific Advisory Board, session planning, and the student competition for many years. He was passionate about the competition and the next generation of environmental scientists who came to showcase their work at the conferences.

For qualifications, application instructions, and deadlines, please visit the website.
Donations toward these scholarships are currently being accepted for the coming year.
For further information, to donate, or to apply for a scholarship, please visit www.aehsfoundation.org/scholarship

PLATFORM SESSIONS

Session 1: 9:00am – 12:00pm, *Room 176*
Environmental Issues in the Caribbean

Session Chairs: Millie Garcia-Serrano, MassDEP, Southeast Region, Lakeville, MA
Ricardo Alvarez, On-Site Environmental, Dorado, PR

9:00 EPA Perspectives on Environmental Issues in the Caribbean
Ariel Iglesias and Catherine McCabe, U.S. Environmental Protection Agency, Region 2, New York, NY

9:30 Application of Toxicogenomics Assay for Water Quality Assessment in Puerto Rico
Yishan Lin, Xin Wen, Gang Shao, Irmarie Cotto, Sheikh Mokhles Rahman, Akram N. Alshawabkeh, Roger W. Giese, and April Z. Gu, Northeastern University, Boston, MA; Ingrid Padilla, University of Puerto Rico, San Juan, PR

10:00 BREAK

10:30 Electroremediation of Groundwater/Groundwater Quality in Puerto Rico
Ljiljana Rajic, Kimberly Hetrick, Yuwei Zhao, Wei Zhou, and Akram Alshawabkeh, Northeastern University, Boston, MA; Mohammad Shokri and Dorothy Vesper, West Virginia University, Morgantown, WV; Ingrid Padilla, University of Puerto Rico, San Juan, PR

11:00 Mitigating the Environmental Impacts of Transportation: Regulatory and Technical Challenges in the Caribbean
Evan Starr, Volpe National Transportation Systems Center, Cambridge, MA

11:30 Navigating Change: RI/FS+RD Superfund Case Study
Brendan MacDonald, CDM Smith, New York, NY

Session 2: 8:30am – 12:00pm, *Room 168*
Regulatory Programs and Policies

Session Chair: Jay Clausen, USACE ERDC-CRREL, Hanover, NH

8:30 An Evaluation of PAHs, Arsenic, and Lead Background Soil Concentrations in Vermont
Kristi Herzer and Trish Coppolino, Vermont Department of Environmental Conservation, Montpelier, VT

9:00 Cost Recovery Options for Emerging Contaminants – Shifting Treatment Costs from Ratepayers to Polluters
Richard Head and Bill Kelly, SL Environmental Law, San Francisco, CA

9:30 Design and Construction of Stormwater BMP Retrofits for the Control of Nitrogen on Cape Cod
Ray Cody, US EPA Region 1, Boston, MA; M. Lundsted, Comprehensive Environmental, Inc., Merrimack, NH

10:00 BREAK

10:30 Forthcoming US EPA Method 3050 Changes
Jay Clausen, USACE ERDC-CRREL, Hanover, NH

11:00 Derecognizing Environmental Liability Using ASTM Guide E3033
Marty Rowland, Third Leg Consultants, Forest Hills, NY

11:30 Upgrading to a Sustainable Way of Life by Upgrading Our Policies
Ellen Moyer, Greenvironment, LLC, Montgomery, MA

Session 2 is approved for NJ LSRP **Regulatory** credit.

Session 3: 8:30am – 12:00pm, *Room 169*
Remediation

Session Chair: Douglas W. Grosse, DWG Consultants, Cincinnati, OH

8:30 New Thinking on the Environmental Impact of PCBs in Building Materials
John Martinelli, Forensic Analytical Consulting Services, Citrus Heights, CA

9:00 Lessons Learned from Thermal Conductive Heating Remediation of Chlorinated Solvents in Low Permeability Formations
Chris Voci, Terraphase Engineering, Conshohocken, PA; Darren Croteau, Terraphase Engineering, Carlsbad, CA; Amber Koster, Terraphase Engineering, Oakland, CA; Grant Geckeler, GEO Environmental Remediation Company, Corona, CA

9:30 Treatment of CBRN Decontamination Effluent
Victor Medina, US Army Corps of Engineers, Engineer Research and Development Center (ERDC), Vicksburg, MS

10:00 BREAK

10:30 Removal of Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) from Fire Training Site Soils
William Kerfoot, Kerfoot Technologies, Mashpee, MA

11:00 Obtaining High-Resolution Data to Demonstrate BOS-100® Performance in Large TCE Plume with Extensive DNAPL
Thomas Harp, LT Environmental, Inc., Arvada, CO

11:30 Using Cloud-Based Tools to Revolutionize Project Implementation Through Adaptive Management
Jessica Hinchliffe and David Carstens, WSP USA, Woburn, MA; Ademola Bakenne and James Sobieraj, WSP USA, Boston, MA; Christine Albertin, WSP USA, Raleigh, NC

POSTER SESSIONS

Authors will be available for individual discussion at their posters on both Tuesday & Wednesday from 3:00pm – 6:00pm
CCA, Room 162, Foyers

Session 4: 9:00am – 12:00pm, *Room 164*
Biomonitoring: Strategies and Uses for Risk Assessment and Stakeholder Communication

Session Chairs: Russ Keenan, Integral Consulting, Inc., Portland, ME
Philip Goodrum, Integral Consulting, Inc., Fayetteville, NY

Biomonitoring data are known as the gold standard for assessing human exposures to chemical substances. Well-designed studies can address questions regarding the range of exposures in a community, factors that contribute to variability in exposure, and changes relative to baseline levels over time. The list of chemicals measured in national, regional, and state biomonitoring programs continues to expand, particularly as funding is directed towards managing potential risks from emerging contaminants in drinking water. However, challenges remain in linking biomonitoring data with levels that are potentially associated with adverse health effects. How can biomonitoring data be used for assessing and managing environmental risk given the uncertainty in toxicological and epidemiological evidence? What can be done to improve its utilization? Are there ways to maximize study participation so that biomonitoring data are representative of the population of interest? Speakers in this session will address these questions based on their perspectives as scientists, public health specialists, and risk assessment practitioners.

9:00 Recruiting and Enrolling a Statewide Sample of Biomonitoring Study Participants
Andrea DiPerna, Marc Nascarella, Jenna Calerbank, Meg Blanchet, and Nicole Daniels, Massachusetts Department of Public Health, Boston, MA

9:30 Biomonitoring Challenges – Examples and Case Studies from a Laboratory Perspective
Patrick Parsons, Christopher Palmer, and Amy Steuerwald, New York State Department of Health, Albany, NY; Sharon Perman and Wendy McKelvey, New York City Department of Health & Mental Hygiene, New York, NY

10:00 BREAK

10:30 Perfluoroalkyl Substance Biomonitoring: Comparing and Contrasting Blood Screening Programs in Two New York State Communities (Hoosick Falls – PFOA; Newburgh – PFOS)
Mark Maddaloni, US EPA Region 2, New York, NY

11:00 Risk Assessment for Lead & Arsenic: How Do Biomonitoring Considerations Fit into the Big Picture?
Christopher Teaf, Florida State University, Tallahassee, FL; Douglas Covert and Michele Garber, HSWMR, Tallahassee, FL

11:30 What Does That Blood Level Mean? The Assumptions Underlying Interpretations of Health Effects from Internal Doses
Phil Goodrum, Integral Consulting, Inc., Fayetteville, NY; Janet Anderson, Integral Consulting, Inc., San Antonio, TX; Sean Hays, Summit Toxicology LLP, Bozeman, MT

PLATFORM SESSIONS

Session 5a: 1:30pm – 3:00pm, *Room 176*

LNAPL and Natural Source Zone Depletion

Session Chair: Steven Gaito, AECOM, Providence, RI

1:30 Bioventing Revisited – Can Enhanced Biodegradation Outperform Hydraulic LNAPL Recovery?
Andrew Kirkman, BP America, Naperville, IL; Jonathon Smith, AECOM, Southfield, MI; Brad Koons, AECOM, Minneapolis, MN; Steven Gaito, AECOM, Providence, RI

2:00 The Effects of Solar Heating in an Urban Environment on Heavy Oil Migration and Discharge
Troy Smith, Maine Department of Environmental Protection, Augusta, ME

2:30 Quantifying Petroleum Biodegradation Rates Using Temperature
Steven Gaito, AECOM, Providence, RI; Jonathon Smith, AECOM, Southfield, MI; Brad Koons, AECOM, Minneapolis, MN

3:00 BREAK

Session 5b: 3:30pm – 5:30pm, *Room 176*

In-Situ Ozone Remediation Update

KERFOOT TECHNOLOGIES

Session Chair: William B. Kerfoot, Kerfoot Technologies, Mashpee, MA

3:30 In-Situ Remediation of High Weight Petroleum Hydrocarbons (C9 – C39) at a U.S. Virgin Islands Site
Ricardo Alvarez, On-Site Environmental, Inc., Dorado, PR; William Kerfoot, Kerfoot Technologies, Mashpee, MA

4:00 Treating Fluorinated Alkane Spills from Circuit Board Manufacturing
Andrew Brolowski, Streamline Environmental Services, Woods Hole, MA; Amy Stanton and William Kerfoot, Kerfoot Technologies, Mashpee, MA

4:30 Ozone-Based ISCO for Destruction of PCBs – Final Report
John Mateo, Blue Lightning Underground Enterprises, LLC, Mt. Holly, NJ

5:00 Hydrocarbon Removal Under Difficult Winter Conditions
David Bennett, Bennett Environmental Associates, Inc., Brewster, MA; Robert Duncanson, Town of Chatham, Chatham, MA

Session 7: 1:30pm – 5:00pm, *Room 169*

Risk Assessment

Session Chair: Christopher Teaf, Florida State University, Tallahassee, FL

1:30 Forensic Analysis of Tissue Samples to Identify Deepwater Horizon Oil Spill Exposure
Gregg Douglas, Bo Liu, Wendy Wong, Eric Litman, and Jeff Hardenstine, NewFields Environmental Forensics, LLC, Rockland, MA

2:00 Update on the Toxicity of 1,4-Dioxane and Potential Regulatory Implications: Impact on Drinking Water Criteria
Norm Forsberg, Arcadis, Clifton Park, NY; Shawn Sager, Arcadis, Raleigh, NC; Christopher Prucha and Louis Bull, Waste Management, Model City, NY; Michael Dourson and Patricia Nance, University of Cincinnati, Cincinnati, OH; Jeri Higginbotham, Kentucky Department for Environmental Protection, Frankfort, KY; Jeff Crum, Hamp, Mathews & Associates, Inc., Bath, MI; Mark Lafranconi, Environmental Resources Management, Cincinnati, OH

2:30 Perfluorooctanoic Acid (PFOA): Environmental Sources, Chemistry, Toxicology & Potential Risks
Christopher Teaf, Florida State University, Tallahassee, FL; Michele Garber, Douglas Covert, and Bruce Tuovila, HSWMR, Tallahassee, FL

3:00 BREAK

3:30 Application of Probabilistic Risk Analysis to Remedial Alternatives at the Portland Harbor Superfund Site
Betsy Ruffle and Gemma Kirkwood-Cohen, AECOM, Chelmsford, MA; Clare Murphy-Hagan, AECOM, Portland, ME; Deborah Edwards, ExxonMobil, Houston, TX

4:00 Development of Water-Effects Ratios (WERs) and Site-Specific Water Quality Criteria (SSC) for Aluminum, Cadmium, and Copper for the Androscoggin River
Patrick Gwinn, John Samuelian, and Elizabeth Rand, Integral Consulting, Inc., Portland, ME

4:30 State of the Art Consensus on How to Evaluate Bioavailability in Contaminated Soil: Guidance from ITRC
Kathryn Durant, Delaware Department of Natural Resources & Environmental Control, New Castle, DE; Claudio Sorrentino, Cal/EPA Department of Toxic Substances Control, Sacramento, CA

Session 6: 1:30pm – 4:30pm, *Room 168*

Sediments

Session Chair: Tim Iannuzzi, Arcadis, Annapolis, MD

1:30 Development of a Passive Lignin Porewater Sampler for Metals
Stephen Clough, Haley & Aldrich, Inc., Bedford, NH

2:00 Factor Analysis and Variability of PCBs in Ambient Air from Contaminated Sediment, New Bedford Harbor
Michael Morris and Jonathan Blount, Jacobs Engineering, Bourne, MA

2:30 The Benefits of Sonic Drilling Techniques for Improved Recovery at Contaminated Sediment Sites
Peter Simon, Philip Simon, and Mark DeLong, Ann Arbor Technical Services, Inc., Ann Arbor, MI; Hugh Scott, MPI Drilling, Picton, ON, Canada

3:00 BREAK

3:30 Evaluation of an Upland Source Control System's Performance in the Portland Harbor Using Groundwater Modeling
Binglei Gong, Anchor QEA, Boston, MA; Pradeep Mugunthan, Anchor QEA, Chicago, IL; John Edwards, Anchor QEA, Bozeman, MT; Mike Riley, Anchor QEA, Olympia, WA; Miao Zhang, Anchor QEA, Seattle, WA; John Renda and Ben Hung, Anchor QEA, Portland, OR; Robert Wyatt, NW Natural, Portland, OR

4:00 Methodology and Testing of As-Placed Organoclay-Based Contaminated Sediment Cap Materials at East Branch of the Grand Calumet River
John Hull, Scott Collins, and John Collins, AquaBlok, Swanton, OH

Session 8: 1:30pm – 5:30pm, *Room 164*

State and Local Government Strategies for Reducing Climate Impacts

Session Chair: Millie Garcia-Serrano, MassDEP, Southeast Region, Lakeville, MA

1:30 Surveillance Tools to Help Understand the Impact of Climate Change on Zoonotic Disease in Massachusetts
Catherine Brown, Deputy State Epidemiologist and State Public Health Veterinarian, Massachusetts Department of Public Health, Boston, MA; Stephen Rich, University of Massachusetts, Laboratory of Medical Zoology, Amherst, MA

2:00 Climate Vulnerability in the Deerfield River Watershed, MA
Katherin McArthur, Massachusetts Department of Transportation, Boston, MA; Paula Rees and Scott Jackson, University of Massachusetts Amherst, Amherst, MA; Stephen Mabee, Massachusetts Geological Survey, Amherst, MA

2:30 Incorporating Chemical Safety into Climate Change Resiliency Planning
Tiffany Skogstrom, Massachusetts Office of Technical Assistance, Executive Office of Energy & Environmental Affairs, Boston, MA

3:00 BREAK

3:30 Human Health Assessment of Climate-Related Changes to Recreational Water Quality
Michael Celona, Kate Adams, Margaret Round, and Marc Nascarella, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA

4:00 Integrated Approaches for Evaluating Climate-Related Changes in Vector-Borne Disease
Kate Adams and Marc Nascarella, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA; Noriko Endo, Osama Mekki Seidahmed, and Elfatih Eltahir, Massachusetts Institute of Technology, Cambridge, MA; Matthew Osborne and Catherine Brown, Massachusetts Department of Public Health, Division of Epidemiology and Immunization, Boston, MA

4:30 Roundtable Discussion: State- and Locally-Based Resources to Support Local Health Adaptation Planning Efforts
Panel Chair: Margaret Round, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA
Wayne Feiden, City of Northampton, Planning & Sustainability, Northampton, MA; Ben Wood, Massachusetts Department of Public Health, Division of Prevention and Wellness, Boston, MA; Soloe Dennis, City of Springfield, Department of Health and Human Services, Springfield, MA; Catherine Ratte, Pioneer Valley Planning Commission, Environment and Land Use Section, Springfield, MA

5:30 Adjourn

Session 8 is <u>not</u> approved for CT LEP credit or NJ LSRP credit.

October 17, 2017 TUESDAY AFTERNOON/EVENING

LUNCHEON

Tuesday, October 17, 2017 12:00 – 1:30pm, *Amherst Room, 10th Floor*

Experts in Natural Resource Damages and Toxic Tort Litigation

Allan Kanner, Esq., Kanner & Whiteley, LLC, New Orleans, LA

Expert testimony plays a critical role in environmental and toxic tort litigation. While most litigation settles before trial, the work of an expert should, from the outset, be prepared with trial in mind. First and foremost, an expert must be able to resolve questions that will assist the trier of fact in making determinations necessary under the law applicable to the case. In addition, an expert must demonstrate a solid scientific foundation in all of his or her opinions. Once armed with the opinions reached in the case, the expert works with the trial team to simplify proof, clarify the presentation and integrate it with other trial themes. This effort should include identification of any perceived or real shortcomings regarding the information available and the approach taken or conclusions reached by the expert. Ongoing communication between the trial team and the expert throughout the discovery and pre-trial litigation is essential.

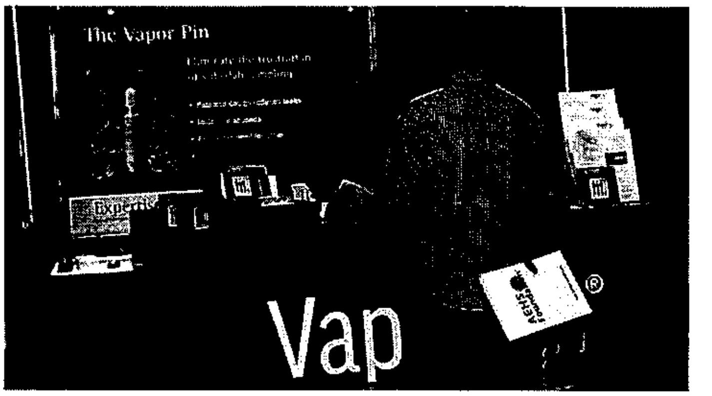
Allan Kanner is the founding member of Kanner & Whiteley, L.L.C.. He received his B.A. from the University of Pennsylvania and his J.D. from Harvard University. Upon graduation from law school, Mr. Kanner clerked for the late Judge Robert S. Vance of the United States Court of Appeals for the Fifth Circuit. Mr. Kanner has had a distinguished thirty-six year career representing individuals, businesses and governmental entities in hundreds of complex, multi-district and high profile cases in both state and federal courts, starting with *In re: Three Mile Island Litig.* and *In re: Louisville Sewer Explosions Litig.* He has won numerous jury verdicts, many of which have established important precedents for other litigants or spurred transformative legislative or regulatory action, has reached multi-million dollar settlements, and has been asked by courts and/or co-counsel to serve in various leadership roles in each. Mr. Kanner represented the state of Louisiana in the Deepwater Horizon oil spill litigation, as well as the state of New Jersey against ExxonMobil in a major natural resource damages case. Mr. Kanner has lectured and written extensively on all aspects of federal litigation and trial practice, Natural Resource Damage Assessments, and Toxic Torts. He has taught law courses at Tulane Law School, Duke University, Yale University, and the University of Texas and authored Environmental and Toxic Tort Trials (Lexis-Nexis) (2d ed.).

EVENING WELCOME & WINE RECEPTION

Tuesday 5:00pm – 7:00pm **CCA (auditorium) and Concourse**

Wine Bar, Refreshments, Light Hors d'Oeuvres

Free to all registered conference attendees



Workshop 5 6:30pm – 9:30pm, *Room 168*

Environmental Forensics Workshop

Gregory S. Douglas, Ph.D., NewFields Environmental Forensics Practice, LLC, Rockland, MA
Eric Litman, B.S., NewFields Environmental Forensics Practice, LLC, Rockland, MA
Katie Flanders, Ph.D., NewFields Environmental Forensics Practice, LLC, Rockland, MA

The field of environmental forensics expands and evolves continuously. Consequently, our understanding about the fate and transport of man-made chemicals in soil, sediment, water, tissue, and air improves as well. This workshop reviews fundamental chemistry and forensic data analysis techniques used in the study of hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), trichloroethylene (TCE), and tetrachloroethylene (PCE). Illustrative case studies will be presented on subjects that include the release of petroleum products, crude oil, tar products, PCBs, and chlorinated solvents. The case studies will demonstrate source identification, age-constraining, and numerical techniques with an emphasis on differentiating point sources in mixed plumes and urban background. These real-world examples will illustrate a tiered data and site analysis approach that maximizes the use of historical and forensic data for chemical delineation and allocation purposes in high and low (background) level situations.

WEDNESDAY MORNING October 18, 2017

PLATFORM SESSIONS

Session 9: 8:30am – 12:00pm, *Room 176*

Pace Analytical

Practical Use of Advanced Analytical Tools for Management of Contaminated Sites

Session Chair: Patrick McLoughlin, Pace Analytical Energy Services, Pittsburgh, PA

8:30 Multiple Lines of Evidence Approaches for Management of Contaminated Sites from 1998 to Today
Pat McLoughlin and Robert Pirkle, Pace Analytical Energy Services, Pittsburgh, PA

9:00 Microbial Community Evolution During In-Situ Aerobic Cometabolic Bioremediation of 1,4-Dioxane and 1,2-DCA
Min-Ying Jacob Chu, Haley & Aldrich, Inc., Phoenix, AZ; Aaron Peacock, Pace Analytical Energy Services, Pittsburgh, PA

9:30 New Innovations in Environmental Science
Stephen Koenigsberg, Civil & Environmental Consultants, Inc., Irvine, CA

10:00 BREAK

10:30 Successful Advanced ISCO Analytical Practices
Matt Burns, WSP USA, Boston, MA; David Carstens, WSP USA, Woburn, MA; Molly Long and Maria Kaplan, WSP USA, Herndon, VA

11:00 Efficient and Auditable Site Monitoring Through Automation of Data Collection, Analysis and Result Delivery
Roelof Versteeg, Subsurface Insights, Hanover, NH; Aaron Peacock, Pace Analytical Energy Services, Pittsburgh, PA

11:30 Sustained Bioaugmentation via In-Situ Bioreactors
Eric Raes, Engineering and Land Planning Associates, Inc., High Bridge, NJ; Dora Taggart, Katherine Clark, and Brett Baldwin, Microbial Insights, Inc., Knoxville, TN; Ryan Beebe, Earth Data Northeast, Inc., Exton, PA; Kerry Sublette, University of Tulsa, Tulsa, OK

Session 11: 8:30am – 12:00pm, *Room 164*

Per- and Polyfluoroalkyl Substances (PFAS) Hot Topics

Session Chair: Ellen Moyer, Greenvironment, LLC, Montgomery, MA

8:30 Limitations of PFAS Data and Recommendations to Obtain Appropriate Data for Environmental Decision Making
Nancy Rothman and Susan Chapnick, NEH, Inc., Skillman, NJ

9:00 The Persistence of Fluorinated Chemicals in Food Wrappers and Consumer Products
David Andrews, Environmental Working Group, Washington, DC

9:30 Perfluorinated Compounds and Impacted Communities: Bridging the Knowledge Gap Between PFAS Contamination and Local Concerns
David Bond and Janet Foley, Bennington College, Bennington, VT

10:00 BREAK

10:30 Potential for PFAS Cross-Contamination from Sampling Equipment, Clothing, and Personal Care Products
James Occhialini, Alpha Analytical, Westborough, MA; Greg Yogus, Alpha Analytical, Inc., Mansfield, MA; Elizabeth Denly, TRC, Lowell, MA

11:00 Per- and Polyfluoroalkyl Substances (PFAS) Remedial Options
Mike Marley, XDD Environmental, Stratham, NH

11:30 Wait, There's More? What's Next in the World of PFAS Toxicology
Janet Anderson, Integral Consulting, Inc., San Antonio, TX

Session 10: 9:00am – 12:00pm, *Room 168*

MassDEP

Advancing the Clean Energy Economy in Massachusetts

Session Chair: Thomas Potter, Massachusetts Department of Environmental Protection, Boston, MA

9:00 UMass Clean Energy Extension: Advancing the Massachusetts Clean Energy Economy with Research, Outreach, and Service
River Strong, UMass Clean Energy Extension, Amherst, MA

9:30 Charging Up Massachusetts: Energy Storage Initiatives in the Commonwealth
Karen Kao, Massachusetts Clean Energy Center, Boston, MA

10:00 BREAK

10:30 Documentation and Decision Making at Solar Array Developments Utilizing Unmanned Aircraft Systems (UASs)
Andrew Bakinowski, Weston & Sampson Engineers, Inc., Foxborough, MA

11:00 Quantifying Wind Turbine Noise
Ethan Brush and James Barnes, Acentech, Inc., Cambridge, MA

11:30 Generation of Bioenergy from Energetic Compounds-Contaminated Wastewater Streams Using Microalgae *Scenedesmus obliquus*
Abhishek RoyChowdhury, Juliana Abraham, Christos Christodoulatos, Yanxia Lin, and Washington Braida, Stevens Institute of Technology, Hoboken, NJ; Per Arienti and Benjamin Smolinski, RDECOM-ARDEC, Wharton, NJ

Session 10 is <u>not</u> approved for CT LEP credit or NJ LSRP credit.

Session 12: 8:30am – 12:00pm, *Room 169*

SURF SUSTAINABLE REMEDIATION FORUM

Sustainability Considerations in Remediation and Restoration

Session Chairs: Gerlinde Wolf, AECOM, Latham, NY
L. Maile Smith, Northgate Environmental Management, Inc., Oakland, CA

8:30 Life Cycle Inventory Data for Use in Assessing Environmental Footprints of Green Remediation Projects
Paul Randall, David Meyer, Wesley Ingwersen, Scott Unger, and Michael Gonzalez, US EPA, Cincinnati, OH; Karen Scheuermann, US EPA, San Francisco, CA

9:00 Geospatial Analysis for Optimization at Environmental Sites
Gail Lipfert, Maine Department of Environmental Protection, Augusta, ME; Ning-Wu Chang, California Department of Toxic Substances Control, Cypress, CA; Harold Templin, Indiana Department of Environmental Management, Indianapolis, IN

9:30 Buses, Brownfields & Bedrooms – A Case Study of the Former Bartlett Yard Bus Garage Remediation
Patrick Lyons and Paul Uzgiris, Weston & Sampson Engineers, Inc., Peabody, MA

10:00 BREAK

10:30 Programmatic Integration and Management of Green and Sustainable Remediation
Lindsay Burton, ExxonMobil Environmental Services Company, Houston, TX; Frank Messina, ExxonMobil Environmental Services Company, Linden, NJ

11:00 Urban Background: The Development, Current Status, and Lessons Learned for the Southeast Regional Study
Sheri Adkins and Christoph Uhlenbruch, Kentucky Department for Environmental Protection, Frankfort, KY

11:30 Using Systems Thinking and Waste Materials to Improve the Sustainability Footprint of a Cleanup – The Drive for a Zero Footprint Cleanup Technology
Paul Favara, CH2M, Gainesville, FL; Jeff Gamlin, CH2M, Englewood, CO

Wednesday, October 18, 2017 12:00 – 1:30pm, *Student Union Ballroom* — LUNCHEON

Integrating Science, Public Policy, and Political Rhetoric

The Honorable Gina McCarthy, Former Administrator of the United States Environmental Protection Agency; Harvard Fellow

Administrator McCarthy will discuss the key environmental challenges we are facing in the country today, the current threats she sees to science, environmental standards, and the continued work of EPA. She will also discuss the future of domestic and international climate action and what it means for clean air, water, and land protections.

Gina McCarthy's 35-year career in public service has been dedicated to environmental protection and public health. As Administrator of the U.S. Environmental Protection Agency under President Barack Obama, she was the nation's leading advocate for common-sense strategies to protect public health and the environment, including efforts to address the challenge of climate change and ensure the protection of the country's water resources. Her leadership led to significant federal, state, and local actions on critical issues related to the environment, economic growth, energy, and transportation. Since leaving Washington, McCarthy has been a fellow at Harvard's Kennedy School of Government's Institute of Politics and the Menschel Senior Leadership Fellow at Harvard's T.H. Chan School of Public Health. She is currently working as an operating advisor at Pegasus Capital Advisors to enhance investment in wellness and sustainability.

October 18, 2017 WEDNESDAY AFTERNOON

PLATFORM SESSIONS

Session 13a: 1:30pm – 3:00pm, *Room 164*

PFAS Fate and Transport

Session Chair: Jennifer Griffith, Northeast Waste Management Officials' Association, Boston, MA

1:30 **Occurrence of PFAS in Environmental Media Associated with AFFF Release Areas at Multiple Installations**
Kerry Robert Tull and Nathan Hagelin, Amec Foster Wheeler, Portland, ME; Sean Gormley, Amec Foster Wheeler, Portland, OR

2:00 **PFAS Fate and Transport – A Heuristic Model for Understanding PFAS in the Environment**
Harrison Roakes, Sanborn, Head & Associates, Inc., Concord, NH; Stephen Zemba, Sanborn, Head & Associates, Inc., Randolph, VT

2:30 **Evaluating Historical Industrial PFOA Emissions through Air Deposition Modeling**
Catherine Beahm, New Hampshire Department of Environmental Services, Concord, NH

3:00 **BREAK**

Session 13b: 3:30pm – 5:00pm, *Room 164*

Analyzing for PFAS

Session Chair: Jennifer Griffith, Northeast Waste Management Officials' Association, Boston, MA

3:30 **Advances in Poly- and Perfluoralkyl Substances (PFAS) Analytical Techniques – Assessing the Hidden Mass**
Allan Horneman, Arcadis, Portland, ME; Jeff Burdick, Arcadis, Newtown, PA; Erika Houtz, Arcadis, San Francisco, CA; Jake Hurst, Arcadis, Leeds, United Kingdom; Ian Ross, Arcadis, Cheshire, United Kingdom

4:00 **Perfluorinated Alkylated Substances Extraction and Analysis in Soils**
Kavitha Dasu, Jonathan Thorn, Robert Lizotte, and Kevin McInerney, Battelle, Norwell, MA

4:30 **Current Status for the Analysis of Polyfluoroalkyl Substances (PFAS) in Environmental Samples**
Charles Neslund, Eurofins Lancaster Laboratories Environmental, LLC, Lancaster, PA

Session 15: 1:30pm – 5:00pm, *Room 168*

Remediation Partners

Synergistic Remediation Technology Solutions

Session Chair: Richard Cartwright, Cartwright Consulting, East Amherst, NY

1:30 **In Situ Chemical Reduction with ZVI and ZVI-Sulfide**
Richard Raymond and Michael Lee, Terra Systems, Inc., Claymont, DE

2:00 **Improving Remedial Actions Through Integrated Use of Direct-Push High-Resolution Site Characterization (HRSC) Technologies**
Eric Garcia, ASC Tech Services, Rancho Cordova, CA

2:30 **FROG-5000: The Next Generation of the World's Most Portable Gas Chromatograph**
Patrick Lewis, Defiant Technologies, Inc., Albuquerque, NM

3:00 **BREAK**

3:30 **Successful Implementation of CHP Within a Sensitive and Active Brownfield Property**
Jim Wilson, Geo-Cleanse International, Inc., Matawan, NJ; Will Moody, Provectus Environmental Products, Freeport, IL

4:00 **Optimization and Performance of Aqueous Phase ZVI Remediation Amendments for In-Situ Chemical and Biological Reduction**
John Freim and James Harvey, OnMaterials, Escondido, CA

4:30 **Innovative Solution for Petroleum Releases in Eco-Sensitive Areas**
Thomas Merski, Universal Remediation, Pittsburgh, PA

Session 14: 1:30pm – 5:00pm, *Room 169*

SURF

Climate Change and Resiliency Within Sustainable Remediation

Session Chairs: Barbara Maco, Wactor & Wick LLP, Oakland, CA
Thomas Potter, Massachusetts Department of Environmental Protection, Boston, MA

1:30 **Establishing an Integrated Climate Change Strategy for Massachusetts Executive Order 569**
Ann Lowery and Thomas Potter, MassDEP, Boston, MA

2:00 **Massachusetts Climate Change Mitigation and Adaptation for Site Assessment and Remediation**
Thomas Potter, MassDEP, Boston, MA

2:30 **Overview of ASTM's Standard Guides on Climate Resiliency Planning and Strategy and Climate Resiliency in Water Resources**
Stephanie Fiorenza, BP America, Houston, TX; Helen Waldorf, ASTM, Boston, MA

3:00 **BREAK**

3:30 **Impacts of Extreme Climate Events on Residual Contamination Under Sustainable Remediation**
Haruko M. Wainwright, Bhavna Arora, and Boris Faybishenko, Lawrence Berkeley National Laboratory, Berkeley, CA; Konstantin Lipnikov and David Moulton, Los Alamos National Laboratory, Los Alamos, NM; Carol Eddy-Dilek and Miles Denham, Savannah River National Laboratory, Aiken, SC; Arianna Libera and Felipe de Barros, University of Southern California, Los Angeles, CA

4:00 **Progress in SURF's Technical Initiative for Climate Change and Resilience Within Sustainable Remediation**
Barbara Maco, Wactor & Wick LLP, Oakland, CA

4:30 **Panel Discussion**

Session 14 is **not** approved for CT LEP credit. Session 14 is approved for NJ LSRP **Regulatory** credit.

Session 16: 1:30pm – 5:00pm, *Room 176*

Remediation Geology: Focus on Geology to Improve Decision-Making and Outcomes

Session Chair: James Cummings, US EPA, Washington, DC

1:30 **Environmental Sequence Stratigraphy: A Focus on Geology for Improved Remediation Decision-Making**
Rick Cramer, Mike Shultz, and Colin Plank, Burns & McDonnell, Brea, CA; Herb Levine, US EPA, San Francisco, CA

2:00 **Influence of Erosional Geologic Complexity on DNAPL Distribution and Plume Characteristics in Fractured Sedimentary Rocks**
Jessica Meyer, Colby Steelman, Andrew Buckley, and Beth Parker, G360 Institute for Groundwater Research - University of Guelph, Guelph, ON, Canada

2:30 **Managing Data for Dynamic Site Conceptual Models**
Dave Rich, Geotech Computer Systems, Centennial, CO; James Cummings, US EPA, Washington, DC; Joseph Quinnan, Arcadis G&M of Michigan, LLC, Brighton, MI

3:00 **BREAK**

3:30 **Characterization of Crystalline Bedrock Sites to Enable Effective Remedial Decision Making**
Larry Mastera, ERM, Boston, MA

4:00 **Design Verification Program – Lessons Learned from Pre-Application Assessments at In Situ Remediation Sites**
Craig Sandefur, Regenesis, San Clemente, CA

4:30 **Make Your Hand Grenade a Laser: Lessons to Improve In-Situ Remediation Outcomes and Maximize Each Dollar Spent**
Paul Dombrowski, ISOTEC Remediation Technologies, Lawrenceville, NJ; William Caldicott and Prasad Kakarla, In-Situ Oxidative Technologies, Inc., Lawrenceville, NJ

WORKSHOP

Workshop 6 6:30pm – 9:30pm, *Room 164*

Per- and Polyfluoroalkyl Substances (PFAS) Remediation Workshop

Michael Marley, M.Sc., CT LEP, XDD Environmental, Stratham, NH
Ellen Moyer, Ph.D., P.E., Greenvironment, LLC, Montgomery, MA
Raymond G. Ball, Ph.D., P.E., L.S.P., EnChem Engineering, Inc., Newton, MA

PFAS are contaminants of emerging concern increasingly detected in ground, surface, and drinking water. These synthetic chemicals are associated with a variety of products including firefighting foams, carpeting, non-stick cookware, and food wrappings.

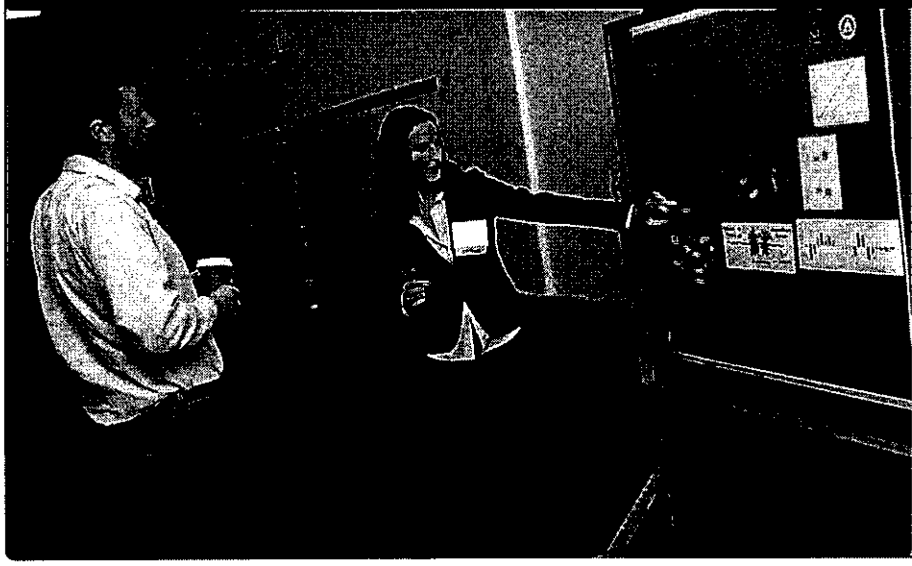
This workshop will cover PFAS physical-chemical properties relevant to remediation, and ex-situ and in-situ options for remediating PFAS in soil and water. Knowledge and experience in PFAS remediation is evolving fast. The workshop will present the most up-to-date information about remediating PFAS using physical, chemical, and biological technologies, covering both technologies that show promise as well as those that are not expected to be effective. Cutting edge technologies using advanced carbon, synthetic resins, alternative natural adsorbents, and advanced oxidation, among others, will be described.

Participants can use this understanding to identify technologies that are likely to be appropriate for a particular site early on in the site characterization process. Integrating key data collection for site-specific remedial options into the characterization phase can minimize project costs and schedule by reducing the number of rounds of fieldwork. The presenters will suggest the key data appropriate to each viable or promising PFAS remedial technology in the toolbox. Participants can consider this guidance as they characterize PFAS sites with an eye toward likely future site-specific remedial actions.

Laboratory treatability studies are often critical for technology selection and design. They typically pay back the time and cost involved many times over by improving remediation efficiency and success. Treatability study methods, benefits, and limitations for PFAS remediation will be discussed.

Case studies at the bench and field scale will illustrate both long- and short-chain PFAS remediation effectiveness. Case studies will include a comparison of carbon and ion-exchange resin treatment, and chemical oxidation of PFAS intermixed with chlorinated solvents at an Air Force base, among others.

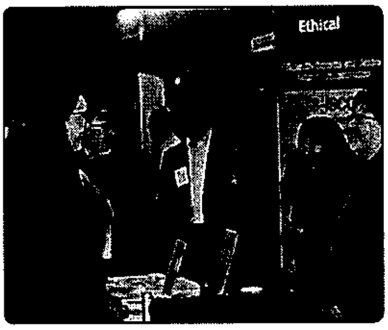
POSTER SESSIONS



Authors will be available for individual discussion at their posters on both Tuesday & Wednesday from 3:00pm – 6:00pm

CCA, Room 162, Foyers

EVENING SOCIAL



Wednesday 5:00pm – 7:00pm
CCA (auditorium) and Concourse

Host Bar (limited duration)
Refreshments & Light Hors d'Oeuvres
Free to all registered conference attendees

THURSDAY MORNING October 19, 2017

PLATFORM SESSIONS

Session 17: 9:00am – 12:00pm, *Room 164*
PFAS: State Case Studies, Policy Developments, and Lessons Learned Panel
Session Chair: Jennifer Griffith, Northeast Waste Management Officials' Association, Boston, MA

During this panel-style session, each speaker will present his/her state's experience with PFAS, including case studies, policy developments, future directions, and lessons learned. Following the presentations, they will all participate in a Q&A panel. Bring your questions!

9:00 Proposed New Regulations and Expectations for Notifications, Assessment, and Cleanup of PFAS in Massachusetts
Paul Locke, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup, Boston, MA

9:30 Per- and Polyfluoroalkyl Substances in New Hampshire: Update on NHDES Investigations and Next Steps
Lea Anne Atwell, New Hampshire Department of Environmental Services, Hazardous Waste Remediation Bureau, Concord, NH

10:00 BREAK

10:30 Vermont's PFAS Experience
Richard Spiese, Vermont Department of Environmental Conservation, Waste Management and Prevention Division, Montpelier, VT

11:00 Rhode Island's Experience with PFAS in Drinking Water
Amy Parmenter, Rhode Island Department of Health, Center for Drinking Water Quality, Providence, RI

11:30 Q & A Panel
Representatives from CT DEEP, MassDEP, NH DES, NYS DEC, RI DOH, VT DEC, and EPA

Session 18: 9:00am – 12:00pm, *Room 168*
Vapor Intrusion
Session Chair: Janine Commerford, Haley & Aldrich, Boston, MA

9:00 Use of Mass Loading Assessment to Characterize Vapor Intrusion Potential
Theresa Gabris and Helen Dawson, Geosyntec Consultants, Washington, DC; William Wertz, Geosyntec Consultants, Inc., Castleton, NY; Todd McAlary, Geosyntec Consultants, Inc., Toronto, ON, Canada; Darius Mali, Geosyntec Consultants, Inc., Guelph, ON, Canada; Daniel Carr, Sanborn, Head and Associates, Inc., Dayton, ME

9:30 Ensuring Long-Term Protectiveness of HVAC Engineering Controls for VI Mitigation of Large Buildings
David Shea and Bradley Green, Sanborn, Head & Associates, Inc., Concord, NH

10:00 BREAK

10:30 Update on Vertical Screening Distances for Assessing Vapor Intrusion Risks at Petroluem UST Sites
Matthew Lahvis, Shell, Spring, TX

11:00 Multiple Lines of Evidence, Including CSIA, to Differentiate an Indoor Source from Vapor Intrusion
Safaa Dergham and Carol Serlin, Ramboll Environ, Irvine, CA; Devon Rowe, Ramboll Environ, Vancouver, WA; Blayne Hartman, Hartman Environmental Geoscience, Solana Beach, CA

11:30 The Fast and the Curious: Observations from an Expedited VI Investigation and Mitigation Effort
John Fitzgerald, MassDEP, Wilmington, MA

Session 19: 9:00am – 12:00pm, *Room 169*
Site Investigation
Session Chair: Matthew Burns, WSP USA, Boston, MA

9:00 Heavy Metal Detection Using Electrochemistry Coupled with Surface-Enhanced Raman Scattering (SERS)
Connor Sullivan, Guinevere Strack, and Pradeep Kurup, University of Massachusetts, Lowell, MA

9:30 Characterizing Reactive Iron Mineral Coatings in Redox Transition Zones
Han Hua, Xin Yin, and Lisa Axe, New Jersey Institute of Technology, Newark, NJ

10:00 BREAK

10:30 Scaling In Situ Geologic Data for Conceptual Site Modeling
David Carstens, WSP USA, Woburn, MA; Jessica Hinchliffe, WSP USA, Boston, MA; Allen Waldman, WSP USA, San Jose, CA

11:00 A Moving Target: Cleanup of a Former Firing Range on the Shore of Lake Erie
Amy Rosenstein, Lexington Environmental Risk Group, LLC, Lexington, MA; Michael Dorman, Earth Resources Technology, Inc., Laurel, MD

11:30 Vapor Intrusion Source Investigation Technique to Support Rapid Response Scenarios
David Jensen, Geosyntec Consultants, Acton, MA; Todd Creamer, Geosyntec Consultants, Portsmouth, NH

Session 20: 9:00am – 12:00pm, *Room 176*
Advances in In-Situ Remediation
Session Chair: Paul Dombrowski, ISOTEC Remediation Technologies, Lawrenceville, NJ

9:00 Evaluation of Extensive Groundwater Remedial Actions for Chlorinated Ethanes/Ethenes and Selection of In-Situ Chemical Oxidation for Chloroethane Polishing
Yasemin Kunukcu and Nidal Rabah, TRC Environmental Corporation, New Providence, NJ

9:30 Development of Klozur SP with a Built-in Activator: Overcoming the Challenges of Storage and Mixing While Maintaining Treatment Effectiveness
Brant Smith and Ravi Srirangam, PeroxyChem, Philadelphia, PA; Ian Horner and Brianna Desjardins, PeroxyChem, Tonawanda, NY

10:00 BREAK

10:30 Karst Bedrock Remediation of PCE in Kentucky
Duane Guilfoil, AST Environmental, Midway, KY

11:00 Zero Valent Iron Reactivity Testing and Project Design
Patrick Randall, Hepure, Claymont, DE

11:30 A Comparison Study of the Delivery and Performance of Injected Powdered and Liquid Activated Carbon
Richard McGregor, InSitu Remediation Services Ltd., St George, ON, Canada

POSTER PRESENTATIONS October 17 & 18, 2017

Posters may be viewed throughout the day on Tuesday, October 17th and Wednesday, October 18th.
Authors will be available for individual discussion at their posters from 3:00pm – 6:00pm each day.
Refreshments and hors d'oeuvres will be served during the poster sessions.
CCA, Room 162 and Foyers

THE FOLLOWING POSTERS ARE LOCATED IN THE CAMPUS CENTER AUDITORIUM (CCA):

Biochar Soil Amendment for Sustainable Rhizosphere Nutrient Management
Kamran Abdollahi and Zhu Ning, Southern University, Baton Rouge, LA

Engineering *Camelina sativa* for Improved Seed and Oil Yields via Manipulating Triacylglycerol Synthesis Pathway and the Associated Molecular and Biochemical Consequences STUDENT
Hesham Abdullah and Om Parkash Dhankher, University of Massachusetts Amherst, Amherst, MA; Danny Schnell, Michigan State University, East Lansing, MI

The Potential Utilization of Grey Water for Irrigation: A Case Study on KNUST Campus STUDENT
Victoria Adjei, Hohai University, Nanjing, Jiangsu, China

Environmental Restoration Wiki – Tech Transfer in the 21st Century
Ed Alperin, Draper Aden Associates, Raleigh, NC; Allison Stenger and Robert Borden, Solutions-IES, Inc., Raleigh, NC

Sulfate Enhanced Bioremediation of Non-Chlorinated Hydrocarbons: Full Scale Application
Ed Alperin and Brad Elkins, EOS Remediation, Raleigh, NC; Mike Branson, Solutions-IES, Raleigh, NC

Fast Track Remediation Case Studies
Matthew Ambrusch, Omer Uppal, and Angelo Falabella, Langan Engineering & Environmental Services, Parsippany, NJ; Imtiyaz Khan, Matthew Wenrick, and Stewart Abrams, Langan Engineering & Environmental Services, Lawrenceville, NJ

Review of PAH Bioaccumulation Factors Used by USEPA in Derivation of Human Health Water Quality Criteria
Paul Anderson, Arcadis, Chelmsford, MA; Jacqueline Iannuzzi, Arcadis, Annapolis, MD; Michele Buonanduci, Arcadis, Broomfield, CO

A Review of Historic and Current Site Closure at Disposal Sites with Vapor Intrusion
Dean Bebis, Tighe & Bond, Westwood, MA

Multi-Faceted Remediation Strategy for Tetrachloroethene in a Complex Urban Environment
Alice Blayney and Julianna Connolly, Geosyntec Consultants, Brookline, MA; Erin Kirby, Geosyntec Consultants, Bedford, NH; Douglas Larson, Carl Elder, and Christopher Arsenault, Geosyntec Consultants, Acton, MA

Development of a Cost-Effective LNAPL Site Closure Strategy
Todd Bridgeo and Prasanta Bhunia, Weston & Sampson Engineers, Inc., Peabody, MA; Rick McCullough, Massachusetts Department of Transportation, Boston, MA

Bioremediation Treatment of Overburden and Bedrock in a Heavily Wooded Wetland
Dustin Bytautas, AECOM, Rocky Hill, CT; A. Curtis Weeden, Jr., AECOM, Amherst, NH; Michelle Snyder and Paul Dombrowski, AECOM, Chelmsford, MA

Tracking a Petrogenic Source with Pyrogenic Compounds: PAH Apportionment for Severely Weathered Crude Oil
Deborah Chiavelli, Anchor QEA, Woodcliff Lake, NJ; Mike Rury, Anchor QEA, Amesbury, MA; Peter Simon and Philip Simon, Ann Arbor Technical Services, Inc., Ann Arbor, MI

Bioremediation of Diesel-Polluted Soil STUDENT
Olivia Chitayat and Rachel Thiet, Antioch University New England, Keene, NH

Adjusting Analyte Concentrations in Groundwater Samples Using Potassium Bromide to Account for Drilling Water Dilution
Dariusz Chlebica, David Adilman, Christopher Arsenault, and Carl Elder, Geosyntec Consultants, Acton, MA; Bruce Thompson and John Hunt, De Maximis, Inc., Windsor, CT

Combined Surfactants and Hydrogen Peroxide Application for NAPL Removal
Geeta Dahal, Dan Socci, and Jennifer Holcomb, EthicalChem, South Windsor, CT

Use of Modern Characterization Tools to Optimize Thermal Treatment System Designs
Rob Danckert, Cascade Drilling, LP, Northborough, MA; Amber Bonarrigo, TerraTherm, Gardner, MA

Heavy Metal Attenuation Using Hemp (*Cannabis sativa L.*)
Gautham Das, Katherine Asciutto, and Audrey Iodice, Wentworth Institute of Technology, Boston, MA

Bacterial Degradation of Tetracycline: Metabolic Profiling and Biochemical Pathway Analysis
Rupali Datta and Susan Bagley, Michigan Technological University, Houghton, MI; Dibyendu Sarkar and Saumik Panja, Stevens Institute of Technology, Hoboken, NJ; Aparupa Sengupta, Rutgers University, New Brunswick, NJ

Optimization of Bioethanol Production from Lignocellulosic Biomass Using Vetiver Grass (*Chrysopogon zizanioides*) Grown on Metal-Contaminated Stamp Sands in Upper Peninsula, Michigan
Rupali Datta, Michigan Technological University, Houghton, MI; Dibyendu Sarkar and Virinder Sidhu, Stevens Institute of Technology, Hoboken, NJ; Emily Geiger, Finlandia University, Hancock, MI

Implementation of a Hybrid Poplar Phytoremediation Program for Trichloroethene at an Arid Fractured Bedrock Site
Safaa Dergham, Carol Serlin, and Erik Pearson, Ramboll Environ, Irvine, CA; Devon Rowe, Ramboll Environ, Vancouver, WA; Seema Turner, Ramboll Environ, Los Angeles, CA; John Freeman, Intrinsyx Technologies Corporation, Moffett Field, CA; Christopher Cohu, Phytoremediation and Phytomining Consultants United, Moffett Field, CA

Low Temperature Evaporative Desorption Technology As a Remedial Measure for On-Site Soil Treatment
Brian Desmarais, Reterro, Inc., Livermore, CA; Joseph Muzzio, Reterro, Inc., Pleasanton, CA

Characterization of Urban Surficial Soils Using Particle Size Distribution and Metals Analysis
Jack Duggan, Dan Alix, and Phillip Curtsmith, Wentworth Institute of Technology, Boston, MA

Temporal Variation of Aromatic and Aliphatic Hydrocarbons in Fresh Gasoline from Volatilization
Jack Duggan, Sofjola Bala, Maggie Cameron, Thomas Redznak, Benjamin Lutz, Ryan Ferriter, and Phillip Curtsmith, Wentworth Institute of Technology, Boston, MA

Jet Injection Emplaced mZVI Treatment of TCE in Clay Till: Two Years of Performance Monitoring
Dylan Eberle and Chapman Ross, Geosyntec Consultants, Acton, MA; Neal Durant, Geosyntec Consultants, Washington, DC; William Slack, FRx, Cincinnati, OH; Peder Johansen, Capital Region of Denmark, Hillerød, Region Hovedstaden, Denmark; Eline Begtrup Weeth and Torben Højbjerg Jørgensen, COWI A/S, Odense City, Odense, Denmark

Full-Scale Enhanced Anaerobic Bioremediation of Two Low Permeability Source Areas
Heather Fariello, APTIM, Latham, NY; Mark Harkness, General Electric Global Research, Niskayuna, NY; Thomas Antonoff and Damian Foti, General Electric, Albany, NY

PCE and TCE Source Identification: A Multiple-Parameter Approach
Katherine Flanders, Stephen Emsbo-Mattingly, and Eric Litman, NewFields Environmental Forensics Practice, LLC, Rockland, MA; James Occhialini, Alpha Analytical Laboratories, Westborough, MA; Andy Rezendes, Alpha Analytical, Mansfield, MA

Data-Driven Decision Management: A Values-Focused Approach to Enable Traceable Decision Analytics for Adaptive Climate Resilience
Aharon Fleury, Neptune and Co., Inc., Lakewood, CO

Use of Permeable Reactive Barrier to Bioremediate a Petroleum Hydrocarbon Groundwater Plume
Duane Guilfoil, AST Environmental, Inc., Midway, KY; Mike Mazzarese, AST Environmental, Inc., Golden, CO

Application of the Biotic Ligand Model to Derive Acute and Chronic Site-Specific Water Quality Criteria for Copper in the Little Androscoggin River
Patrick Gwinn, Integral Consulting, Inc., Portland, ME

Use of a Novel Biomarker, Botryococcane, to Monitor Biodegradation of Lacustrine-Sourced Crude Oils
Jeff Hardenstine and Gregg Douglas, NewFields Environmental Forensics, LLC, Rockland, MA; Sara McMillen, Chevron Energy Technology Company, San Ramon, CA; Robert E. Hoffmann, Chevron Canada, Calgary, AB, Canada; Roopa Kamath, Chevron Energy Technology Company, Houston, TX; Deyuan Kong, Chevron Energy Technology Company, Richmond, CA

Injectable Activated Carbon Reactive Barriers: Remedial Progress and Lessons Learned STUDENT
Sara Haupt, Erik M. Beloff, Richard A. Carlone, and Edward A. Summerly, GZA, Providence, RI; Karen Kinsella, GZA, Glastonbury, CT; John C. Osborne and Bernard G. Fenelon, GZA, Waukesha, WI

Influence of Suspended Sediments on Electrochemical Remediation of Karst Groundwater STUDENT
Kimberly Hetrick, Ljiljana Rajic, and Akram Alshawabkeh, Northeastern University, Boston, MA; Dorothy Vesper and Mohammad Shokri, West Virginia University, Morgantown, WV; Ingrid Padilla, University of Puerto Rico, San Juan, PR

Evaluating the Shutdown of Sub-Slab Depressurization Systems Downgradient of a Former Drum Burial Site
Shahen Huda, Joseph Jeray, and Chapman Ross, Geosyntec Consultants, Acton, MA; Julianna Connolly, Geosyntec Consultants, Brookline, MA

Drinking Water Guidelines for PFOS and PFOA – Toxicological Basis and Decision-Making Implications
Julie Kabel, AECOM, Manchester, NH; Usha Vedagiri, AECOM, Oakland, CA; Betsy Ruffle, AECOM, Chelmsford, MA

Using 'Big Data' Techniques to Optimize Soil Remediation
Tomasz Kalinowski, AECOM, East Syracuse, NY; Cameron Dixon, AECOM, Boston, MA; Christopher Brownfield, AECOM, Morrisville, NC; Scott Mikaelian, AECOM, Piscataway, NJ; Mark Terril, Jody Overmyer, and Richard Feinberg, PPG, Monroeville, PA

ERH Remediation of Shale Bedrock – Central New Jersey
Mark Kluger, Chris Blundy, and Emily Crownover, TRS Group, Inc., Longview, WA

Influence of Soil Characteristics on the Bioluminescence Activity of a Bioreporter Strain Used for Monitoring Toluene Analog Pollutants
In Chul Kong, Eun Jin Lee, Hyeun Jin Jang, Xin Yang, and Moon Hee Lee, Yeungnam University, Gyungsan, Kyungbuk, Republic of South Korea; Kyung-Seok Ko, KIGAM, Daejeon, Chungnam, Republic of South Korea

Legionnaires' Disease Prevention: A Novel Approach to Analyzing Data and the Risk of Amplification
David Krause, Alexis Jones, and Shaiasia Itwaru-Womack, Forensic Analytical Consulting Services, Tallahassee, FL; Megan Canright, Forensic Analytical Consulting Services, San Diego, CA

PFAS Analytical Data: Potential Data Quality Issues
Lisa Krowitz, TRC Environmental Corporation, Lowell, MA

Advancing Urban Site Remediation Using Aerobic Bioaugmentation and Strategic Direct Push Application
Keri Lauer and Jarrod Yoder, Woodard & Curran, Andover, MA

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Use of PIANO Data for Differentiation of Gasolines Based on Source and Regionality
Robert Lizotte, Kevin McInerney, and Jonathan Thorn, Battelle, Norwell, MA

Development of Approach for Removing Highly Viscous DNAPL from a Well at a Former MGP Site
James Marolda, Brown and Caldwell, Upper Saddle River, NJ

Denitrifying Permeable Reactive Barriers: Bench-Scale Studies and Implementation of the First In-Situ EVO PRB on Cape Cod
Julianne Marrion, Thomas Parece, and Betsy Shreve-Gibb, AECOM, Chelmsford, MA; Mark Owen, AECOM, Pocasset, MA; Paul Dombrowski, ISOTEC Remediation Technologies, Lawrenceville, NJ; Michael Temple, In-Situ Oxidative Technologies, Inc., Lawrenceville, NJ; James Begley, MT Environmental Restoration, Plymouth, MA; Richard Raymond and Michael Lee, Terra Systems, Inc., Claymont, DE

Comparison of Dry Oxygen Scavengers for Preparing Anaerobic Injection Waters for EISB
Brendan McShane and William Newman, RNAS Remediation Products, Brooklyn Center, MN

PAH Mobilization from Coal Tar-Based Asphalt Rejuvenators
Caroline Meyer, Seth MacDonald, and John Bergendahl, Worcester Polytechnic Institute, Worcester, MA

Control of Methane During ERD and ISCR to Lower Greenhouse Gases for a Sustainable Remediation
Will Moody and Jim Mueller, Provectus Environmental Products, Freeport, IL

Temporal and Spatial Evaluation of Two PCB Groundwater Plumes Based on Homolog Distributions
Wendy Moore, Arcadis, Syracuse, NY; Jeffrey Holden, GEI Consultants, Inc., Ithaca, NY

Design and Implementation of Air Sparge Systems – Innovative Approaches to Overcome Area-Specific Contstraints
Nadira Najib, Andrew Quinn, Kale Novalis, Angelo Falabella, Omer Uppal, and Matthew Ambrusch, Langan Engineering & Environmental Services, Parsippany, NJ

Diagnostics and Retrofit of Non-Functional Remediation Systems
Nadira Najib, Matthew Ambrusch, Imtiyaz Khan, Matthew Wenrick, and Stewart Abrams, Langan Engineering & Environmental Services, Lawrenceville, NJ; Angelo Falabella and Omer Uppal, Langan Engineering & Environmental Services, Parsippany, NJ

Degradation of 4-Chlorophenol in Aqueous Solution Using Sono-Electro-Fenton Reaction
Roya Nazari, Ljiljana Rajic, and Akram Alshawabkeh, Northeastern University, Boston, MA

A Technique for Determining Total Oxidizable Precursors (TOP) of Perfluroalkyl Compounds
Charles Neslund, Eurofins Lancaster Laboratories Environmental, LLC, Lancaster, PA

Green and Sustainable Campus – The i-Tree Eco Modeling Project at Southern University
Zhu Ning, Southern University, Baton Rouge, LA; Michaela Gleason, Louisiana State University, Baton Rouge, LA

A Comparison of the New MassDEP VPH by GC/MS Method with the Original VPH Procedure by GC-FID
James Occhialini, Mitchell Ostrowski, and Joseph Watkins, Alpha Analytical, Westborough, MA; Richard Rago, Haley & Aldrich, Inc., Rocky Hill, CT

Computational Fluid Dynamics Modeling of Vapor Intrusion Mitigation Using Sub-Slab Depressurization with Multiple Collection Points STUDENT
Ana Oliveira and Eric Suuberg, Brown University, Providence, RI

Removal of Ciprofloxacin and Tetracycline by Vetiver Grass from Nutrient Amended Secondary Wastewater Matrix STUDENT
Saumik Panja, Dibyendu Sarkar, and Abhishek RoyChowdhury, Stevens Institute of Technology, Hoboken, NJ; Rupali Datta, Michigan Technological University, Houghton, MI

Step-Wise Approach to In-Situ Thermal Remediation of Trichloroethene in Granitic Bedrock
Erik Pearson and Carol Serlin, Ramboll Environ, Irvine, CA; Gorm Heron, TerraTherm, Keene, CA

Emerging Contaminant 1,4-Dioxane in Our Drinking Water
Michael Pierdinock and Kevin Paradise, Lightship Engineering, LLC, Plymouth, MA

Laboratory Study of Metals Treatment by Permeable Reactive Barrier and Engineered Wetland
Donald Pope, Ryan Thomas, Christa Bucior, Sophia Dore, and Alan Weston, GHD, Niagara Falls, NY

Orthogonal Functions and Hybrid Functions for Problems in Environmental Modeling and Remote Sensing
Mohsen Razzaghi, Mississippi State University, Mississippi State, MS

Green Remediation Technology for Prevention of Erosion and Metal Leaching from Acid Mine Drainage-Impacted Soil
Abhishek RoyChowdhury and Dibyendu Sarkar, Stevens Institute of Technology, Hoboken, NJ; Rupali Datta, Michigan Technological University, Houghton, MI

A Green BMP for Mitigation of Nutrients and Metals in Stormwater: Greenhouse Column Study
Dibyendu Sarkar and Virinder Sidhu, Stevens Institute of Technology, Hoboken, NJ; Kirk Barrett, Manhattan College, Riverdale, NY; Rupali Datta, Michigan Technological University, Houghton, MI

Ecological Risk Assessment of an Abandoned Shoreline Landfill in the Intertidal Marine Environment
John Schaffer, Tetra Tech, Inc., Parsippany, NJ

Advanced Petroleum Biomarker Analysis for Use in Source Identification
Stephanie Schultz, Jonathan Thorn, Kevin McInerney, and Robert Lizotte, Battelle, Norwell, MA

Horizontal Wells: Avoiding Obstructions and Minimizing Site Disruptions
Michael Sequino, Directional Technologies, Inc., Wallingford, CT; Seth Croy, Directional Technologies, Inc., Miramar Beach, FL

Performance of Reductant Amended Backfill for Groundwater Remediation at a Former Chromate Ore Processing Facility
Sachin Sharma, AECOM, Piscataway, NJ; Lucas Hellerich, AECOM, Rocky Hill, CT

Effect of Compost and Plant Cover on Sustainable Restoration of Soils Contaminated by Copper Mining Activities
Virinder Sidhu and Dibyendu Sarkar, Stevens Institute of Technology, Hoboken, NJ; Emily Geiger, Finlandia University, Hancock, MI; Rupali Datta, Michigan Technological University, Houghton, MI

Bench-Scale Evaluation of the Formation and Reactivity of Iron Sulfide Minerals for Treatment of Chlorinated Solvents
Brant Smith, Ravi Srirangam, Josephine Molin, and Fayaz Lakhwala, PeroxyChem, Philadelphia, PA; Alan Seech, PeroxyChem, Corona Del Mar, CA; Daniel Leigh, PeroxyChem, Walnut Creek, CA

Importance of Surfactant Selection in Remedial Applications
Dan Socci, EthicalChem, South Windsor, CT

Electrical Resistance Heating Remediation Using High Degree Angled Electrodes at an Active Manufacturing Facility
Lauren Soos, TRS Group, Inc., Hollis, NH; Tracy Edwards, Hull & Associates, Inc., Mason, OH

In Situ Thermal Remedy Procured Under MATOC/PRAC Contract Vehicle to Ensure Closure at New Jersey Superfund Site
Lauren Soos, Michelle Nanista, Emily Crownover, Chris Blundy, and Andrew Small, TRS Group, Inc., Longview, WA; Will Torres, TerranearPMC, Exton, PA

Developing Background Concentrations of Metals and PAHs in Soil in an Urban Railroad Right-of-Way
Joseph Spencer and Todd Bridgeo, Weston & Sampson Engineers, Inc., Peabody, MA

Long-Term Molar Trend of CVOCs Post Phased ISCR Approach in a Historically Stalled Shallow Aquifer
Ravi Srirangam and Fayaz Lakhwala, PeroxyChem, Philadelphia, PA; Damian Vanetti and Ian McNamara, GHD, Cazenovia, NY

THE FOLLOWING POSTERS ARE LOCATED IN THE FOYER AREAS:

A Disposable Sensor for the On-Site Detection of Lead and Cadmium STUDENT
Connor Sullivan, Guinevere Strack, Michaela Fitzgerald, and Pradeep Kurup, University of Massachusetts Lowell, Lowell, MA

What You Should Think About When Considering ISCO with Permanganate: Information from Practitioners with 20+ Years' Experience
Stephanie Turkot, GZA GeoEnvironmental, Inc., Fairfield, NJ; Troy Lizer, Carus Corporation, Peru, IL; Jim Wilson, Geo-Cleanse International, Inc., Matawan, NJ

Numerical Allocation of Pyrogenic and Petrogenic PAH in Contaminated Soils and Sediments
Allen Uhler and Kerylynn Krahforst, NewFields Environmental Forensics Practice, LLC, Rockland, MA

Evaluation of Monitored Natural Attenuation to Address Legacy Contamination Along a Tidal Estuary
David Winslow, Melissa Dulinski, and Sandra Huber, GZA GeoEnvironmental, Inc., Fairfield, NJ

Soil: Water Fate and Transport of Three Antibiotics in Laboratory Batch Studies Using Beef Lagoon Water STUDENT
Katherine Woodward, Tufts University, Boston, MA

Sustainable Use of Contaminated Soils with Chromium, Copper, Cadmium, and Arsenic Based on Leaching Characteristics
Pei-Yao Wu, Mei Shiou Hung, Yu-Jen Liang, and Chien Jung Lai, Industrial Technology Research Institute, Hsinchu, Taiwan; Ping-Hsiung Ni, Shyh-Wei Chen, Jen Wang, and Jen-Shen Chou, Taiwan Environmental Protection Administration, Taipei, Taiwan

The Effects of Aged Petroleum Hydrocarbon Contaminants in Soil on Bioventing Remediation STUDENT
Mei Xiao and Richard Zyner, University of Guelph, Guelph, ON, Canada

Identifying Redox Transition Zones in the Subsurface STUDENT
Xin Yin, Han Hua, and Lisa Axe, New Jersey Institute of Technology, Newark, NJ

Electro-Fenton Reaction: Performance Under Different Groundwater Flow and Current Intensities STUDENT
Yuwei Zhao, Northeastern University, Boston, MA

Drastic Enhancement of H2O2 Electrogeneration by Green Electrochemical Modification of Graphite Felt in Low Conductivity, Acid-Free Electrolyte STUDENT
Wei Zhou, Northeastern University, Boston, MA

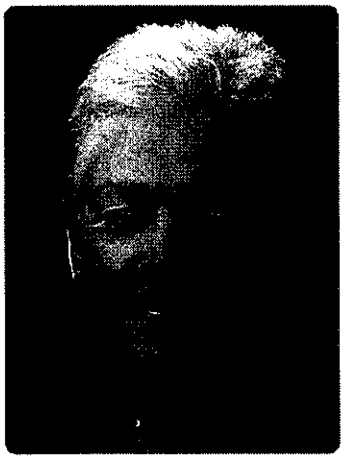
LIFETIME ACHIEVEMENT AWARDS

The Annual International Conference on Soils, Sediments, Water, and Energy is pleased to announce the recipients of the Lifetime Achievement Award. This award is presented to individuals who have shown significant contributions to the field as well as outstanding environmental stewardship. This year's winners are Halina Szejnwald Brown, Clark University and The Honorable Gina McCarthy, Former Administrator, United States Environmental Protection Agency; Harvard Fellow.

Halina Szejnwald Brown is Professor Emerita of Environmental Science and Policy at Clark University and Associate Fellow at Tellus Institute. She came to the U.S. at age 20 as a refugee from Poland. With a doctoral degree in chemistry, during the 1980s Brown was a chief toxicologist at the Massachusetts Department of Environmental Protection, advising the commissioner on the agency's environmental health policy. Since coming to Clark in1987, Brown's research and teaching has evolved in several directions. She published and consulted widely on new methods of risk assessment and led a pioneering study of how U.S. multinational corporations managed hazards in their facilities in India and Thailand. She conducted a study of the institutionalization of Global Reporting Initiative (GRI), a global model for civil regulation based on information disclosure. During the 1990s Brown worked in Poland studying the relationship between air pollution and lung cancer, and the transition of the environmental and occupational regulatory system to market economy and democracy.

Since 2000 the theme of Brown's work has been the interface between technology, policy and culture in a transition to sustainable and prosperous future. Working in the U.S. and Europe, Brown has studied technological innovations systems and socio-technical transitions. In 2008 she co-founded the knowledge network Sustainable Consumption Research and Action Initiative (SCORAI) and is its board member. Brown was a visiting professor at University of Utrecht, Delft University, and Central European University; served on numerous committees of the National Academy of Sciences; and is a Fellow of the American Association for the Advancement of Science and a Fellow of the International Society for Risk Analysis.

Brown co-chairs Citizens' Commission on Energy in her home town of Newton, MA. She co-authored four books: Corporate Environmentalism in a Global Economy; Effective Environmental Regulation: Lessons from Poland's Experience; Innovations in Sustainable Consumption; and Social Change and the Coming of Post-consumer Society.



Gina McCarthy's 35-year career in public service has been dedicated to environmental protection and public health. As Administrator of the U.S. Environmental Protection Agency under President Barack Obama, she was the nation's leading advocate for common-sense strategies to protect public health and the environment, including efforts to address the challenge of climate change and ensure the protection of the country's water resources. Her leadership led to significant federal, state, and local actions on critical issues related to the environment, economic growth, energy, and transportation. Since leaving Washington, McCarthy has been a Fellow at Harvard's Kennedy School of Government's Institute of Politics and the Menschel Senior Leadership Fellow at Harvard's T.H. Chan School of Public Health. She is currently working as an operating advisor at Pegasus Capital Advisors to enhance investment in wellness and sustainability.

MICHAEL E. MILLER STUDENT COMPETITION

We are proud to announce the 14th Annual Student Competition for best student presentation at the conference. One $1000.00 cash prize and two $500.00 cash prizes will be awarded to the three best poster presentations. Winners will be announced on Wednesday. See posting at registration desk.

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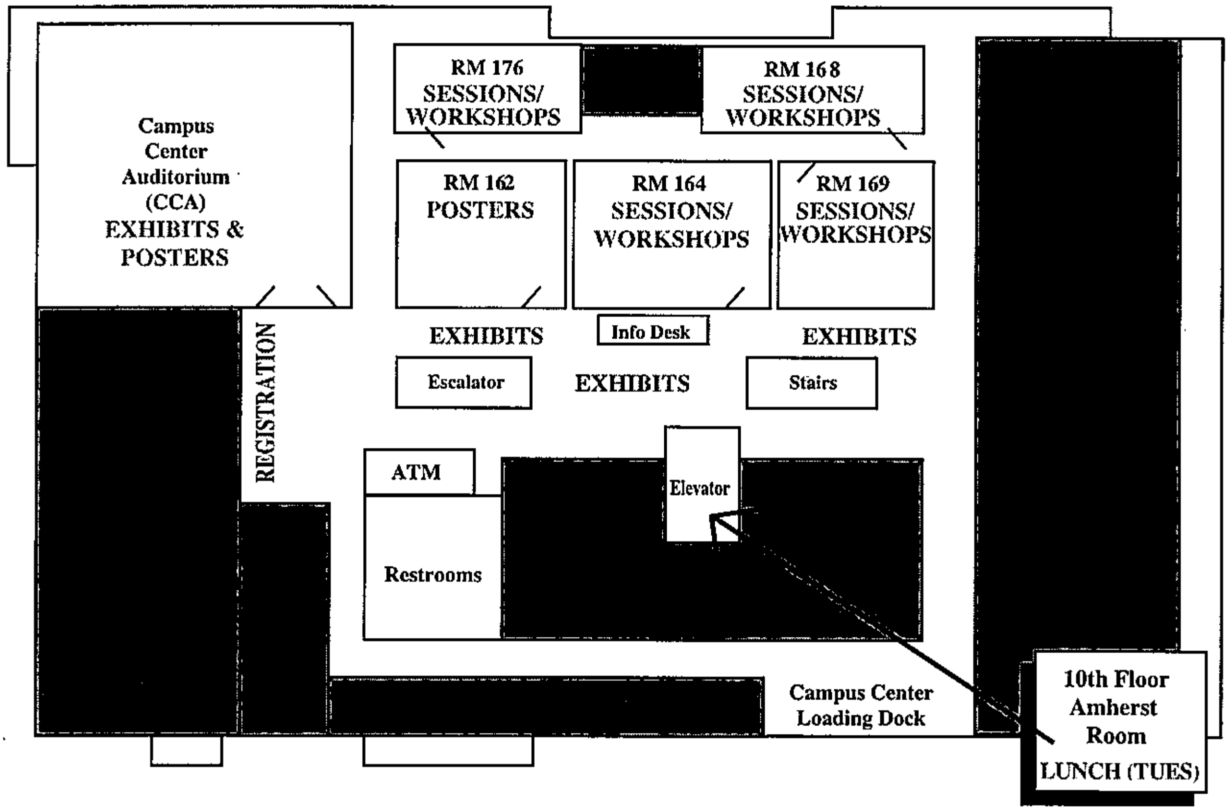

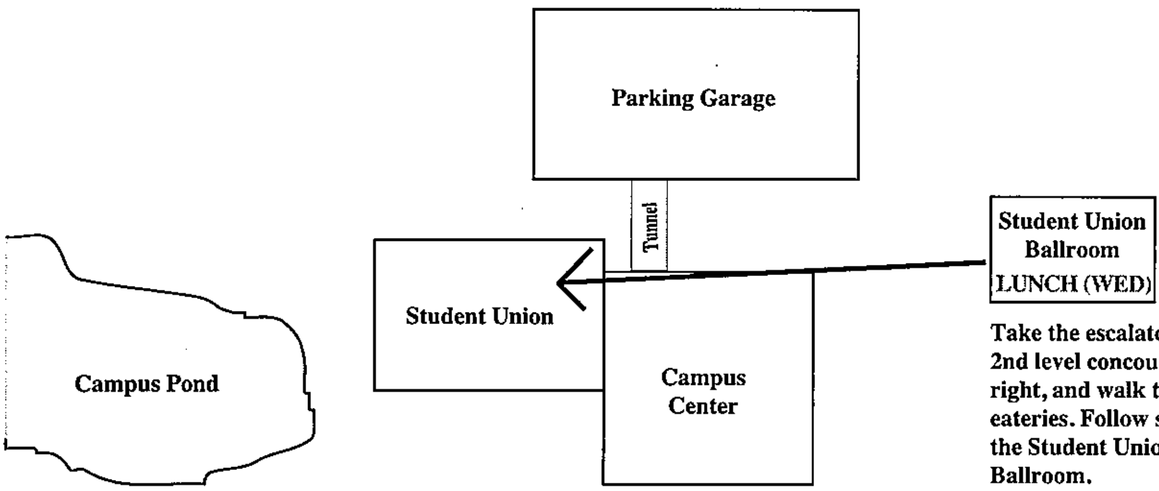

Take the escalator to 2nd level concourse, turn right, and walk toward eateries. Follow signs to the Student Union Ballroom.

CONFERENCE at a GLANCE

Monday, October 16, 2017 (Monday is workshops only)

Registration: 10:00am – 5:00pm

Workshop 1 (1:00pm – 4:00pm) Environmental Forensics – The Integration of Various Fingerprinting Techniques to Evaluate Who Was Responsible for a Spill or Release of Organic Contaminants, *Rm. 168*

Workshop 2 (1:00pm – 5:00pm) Sustainable Remediation: Frameworks, Tools, and Case Studies, *Rm. 169*

Workshop 3 (1:00pm – 5:00pm) Per- and Polyfluoroalkyl Substances (PFAS): The Latest Information, *Rm. 164*

Workshop 4 (1:00pm – 5:00pm) Pioneer Valley's Post-Glacial Landscape: A Field Course Throughout the Pioneer Valley of Massachusetts, *Rm. 176*

Tuesday, October 17, 2017

Registration: 7:30am – 7:00pm | **Exhibit Hall Hours:** 9:00am – 7:00pm

Morning Platform Sessions
8:30/9:00am – 12:00pm, *Sessions are concurrent*
Session 1: Environmental Issues in the Caribbean, *Rm. 176*
Session 2: Regulatory Programs and Policies, *Rm. 168*
Session 3: Remediation, *Rm. 169*
Session 4: Biomonitoring: Strategies and Uses for Risk Assessment and Stakeholder Communication, *Rm. 164*

LUNCHEON:
12:00pm – 1:30pm
Amherst Room, 10th Floor
Speaker: Allan Kanner, Esq., Kanner & Whiteley, LLC, New Orleans, LA
Experts in Natural Resource Damages and Toxic Tort Litigation

Afternoon Platform Sessions
1:30pm – 4:30/5:00/5:30pm, *Sessions are concurrent*
Session 5a: LNAPL and Natural Source Zone Depletion, *Rm. 176*
Session 5b: In-Situ Ozone Remediation Update, *Rm. 176*
Session 6: Sediments, *Rm. 168*
Session 7: Risk Assessment, *Rm. 169*
Session 8: State and Local Government Strategies for Reducing Climate Impacts, *Rm. 164*

Poster Session 3:00pm – 6:00pm, *CCA, Rm. 162, Foyers*

Wine/Welcome Reception 5:00pm – 7:00pm, *exhibit areas, 1st floor*

Evening Workshop
Workshop 5 (6:30pm – 9:30pm) Environmental Forensics Workshop, *Rm. 168*

Wednesday, October 18, 2017

Registration: 7:30am – 7:00pm | **Exhibit Hall Hours:** 9:00am – 7:00pm

Morning Platform Sessions
8:30/9:00am – 12:00pm, *Sessions are concurrent*
Session 9: Practical Use of Advanced Analytical Tools for Management of Contaminated Sites, *Rm. 176*
Session 10: Advancing the Clean Energy Economy in Massachusetts, *Rm. 168*
Session 11: Per- and Polyfluoroalkyl Substances (PFAS) Hot Topics, *Rm. 164*
Session 12: Sustainability Considerations in Remediation and Restoration, *Rm. 169*

LUNCHEON:
12:00pm – 1:30pm
Student Union Ballroom
Speaker: Gina McCarthy, Former Administrator of the US EPA; Harvard Fellow
Integrating Science, Public Policy, and Political Rhetoric

Afternoon Platform Sessions
1:30pm – 5:00pm, *Sessions are concurrent*
Session 13a: PFAS Fate and Transport, *Rm. 164*
Session 13b: Analyzing for PFAS, *Rm. 164*
Session 14: Climate Change and Resiliency Within Sustainable Remediation, *Rm. 169*
Session 15: Synergistic Remediation Technology Solutions, *Rm. 168*
Session 16: Remediation Geology: Focus on Geology to Improve Decision-Making and Outcomes, *Rm. 176*

Poster Session 3:00pm – 6:00pm, *CCA, Rm. 162, Foyers*

Social 5:00pm – 7:00pm, *exhibit areas, 1st floor*

Evening Workshop
Workshop 6 (6:30pm – 9:30pm) Per- and Polyfluoroalkyl Substances (PFAS) Remediation Workshop, *Rm. 164*

Thursday, October 19, 2017

Registration: 7:30am – 12:00pm | **Exhibit Hall Hours:** 9:00am – 12:00pm

Morning Platform Sessions
9:00am – 12:00pm, *Sessions are concurrent*
Session 17: PFAS: State Case Studies, Policy Developments, and Lessons Learned Panel, *Rm. 164*
Session 18: Vapor Intrusion, *Rm. 168*
Session 19: Site Investigation, *Rm. 169*
Session 20: Advances in In-Situ Remediation, *Rm. 176*

Exhibit Hall Hours:

TUESDAY
9:00am – 7:00pm

WEDNESDAY
9:00am – 7:00pm

THURSDAY
9:00am – 12:00pm

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The 33rd Annual International Conference on Soils, Sediments, Water and Energy

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ABSTRACT BOOK

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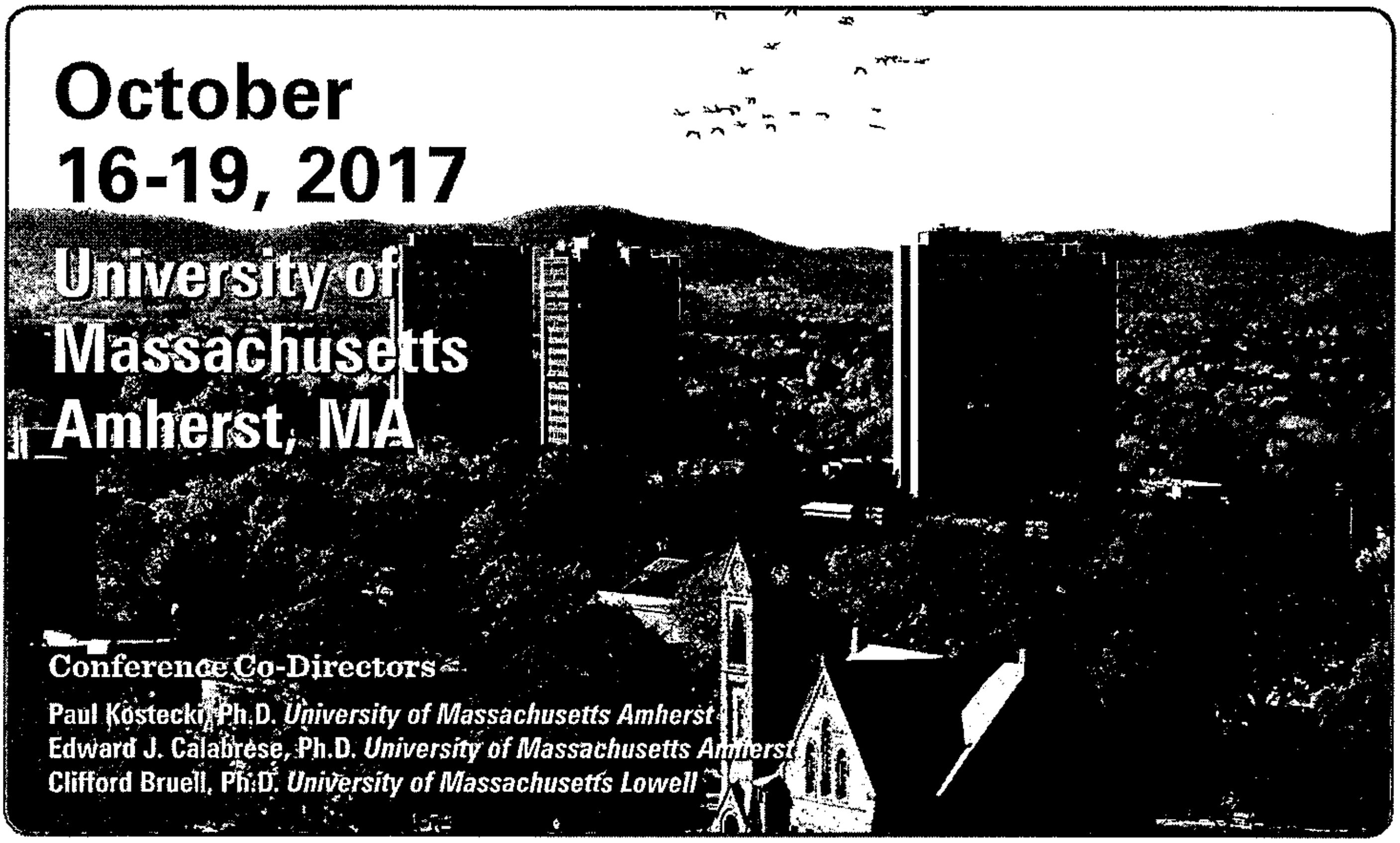

October 16-19, 2017

University of Massachusetts Amherst, MA

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Paul Kostecki, Ph.D. *University of Massachusetts Amherst*

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Ariel Iglesias, Deputy Director, Clean Air and Sustainability Division and Catherine McCabe, U.S. Environmental Protection Agency, Region 2, New York, NY *(abstract missing/not available)*

Application of Toxicogenomics Assay for Water Quality Assessment in Puerto Rico
Yishan Lin, Xin Wen, Gang Shao, Irmarie Cotto, Sheikh Mokhles Rahman, Akram N. Alshawabkeh, Roger W. Giese, and April Z. Gu, Northeastern University, Boston, MA; Ingrid Padilla, University of Puerto Rico, San Juan, PR

Electroremediation of Groundwater/Groundwater Quality in Puerto Rico
Ljiljana Rajic, Kimberly Hetrick, Yuwei Zhao, Wei Zhou, and Akram Alshawabkeh, Northeastern University, Boston, MA; Mohammad Shokri and Dorothy Vesper, West Virginia University, Morgantown, WV; Ingrid Padilla, University of Puerto Rico, San Juan, PR

Mitigating the Environmental Impacts of Transportation: Regulatory and Technical Challenges in the Caribbean
Evan Starr, US DOT - Volpe National Transportation Systems Center, Cambridge, MA

Navigating Change: RI/FS+RD Superfund Case Study
Brendan MacDonald, CDM Smith, New York, NY

Application of Toxicogenomics Assay for Water Quality Assessment in Puerto Rico

Yishan Lin, Xin Wen, Gang Shao, Irmarie Cotto, Sheikh Mokhles Rahman, Ingrid Padilla, Akram N. Alshawabkeh, Roger W. Giese, and April Z. Gu

Novel approaches are urgently needed to examine the combined risks of environmental pollutant mixtures present in aquatic systems to human health and potential toxicity mechanisms. As part of the PROTECT (Puerto Rico Testsite for Exploring Contamination Threats) program, this study aimed to provide a fast initial screening and assessment of the potential ecological and health impacts of contaminant mixtures in Puerto Rico groundwater samples. For the first sampling event, 15 groundwater samples (well or spring water) were collected along the north coast of Puerto Rico. Organic substances in these samples enriched via polar solid phase extraction (SPE) were subjected to both untargeted chemical screening on GC-MS and *in vitro* quantitative toxicogenomics assays for molecular toxicity measurement based on translational changes of 148 biomarkers in five stress libraries of the yeast *S. cerevisiae* that occur in response to exposures to pollutant mixtures. The results revealed different overall and pathway-specific molecular toxicity levels (Protein Effect Level Index, PELI) and distinct toxicity profiles (3-D altered protein expression profiles) among the water samples. For example, the MIT well sample showed the highest PELI value in protein stress, whereas the POL sample showed the highest general and oxidative stresses. This corresponds well with distinct composition of chemical mixture between the two samples, such as the highest number of organics detected in the MIT sample, including pesticides, anesthesia and phthalates. Correlation analysis between chemical analysis and toxicity endpoints showed that the occurrence of pesticides such as terbacil, heptachlor, atrazine and aldrin was significantly correlated with protein damage ($R > 0.8$, $p < 0.01$) This study demonstrated that this fast, new *in vitro* toxicogenomics assay can be a cost-effective tool for groundwater monitoring, which can help identify chemicals that may have adverse health impacts and provide insights into potential toxicity mechanisms associated with complex pollutant mixtures in aquatic environments.

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April Z. Gu, Northeastern University, 360 Huntington Avenue, Boston, MA, United States, 02115, april@coe.neu.edu

Presenting Author: Yishan Lin

Electroremediation of Groundwater/Groundwater Quality in Puerto Rico

Ljiljana Rajic, Kimberly Hetrick, Yuwei Zhao, Wei Zhou, Mohammad Shokri, Dorothy Vesper, Ingrid Padilla, and Akram Alshawabkeh

The North Coast karst aquifer system of Puerto Rico is a highly productive and vital water resource for human consumption and local ecosystems, but it is also distinctly vulnerable to contamination. Evidence of historical contamination of karst groundwater in the region implies that the terrain has a strong propensity to store and release contaminants, even after long periods of time, and indicates a community need for the implementation of proper water resource management plans and remedial actions. Still, due to the complex nature of karst aquifers, many conventional groundwater remediation technologies are unfeasible for successful implementation, and new approaches need to be developed and optimized. Electrochemical processes present advantages and can be optimized for karst aquifers due to easy manipulation and control of groundwater chemistry and ability for *in situ* application as well as its low cost. The process uses low-level direct current through electrodes immersed in wells, allowing manipulation of groundwater chemistry through electrolysis and the creation of conditions favorable for either reduction or oxidation of the contaminants. Here we will present the results from studies conducted to evaluate the controlling parameters for generation and performance efficiency of electrochemically-induced oxidation mechanisms for removal of trichloroethylene (TCE): (i) electro-Fenton reaction using inert electrodes and palladium catalyst or electrogeneration of hydrogen peroxide by direct oxygen reduction at the carbon cathodes, (ii) the influence of real groundwater conditions on electro-Fenton performance (i.e., suspended sediments, humic substances, carbonates, high flow rates), and (iii) using variable electrode modes to induce coupled transformation processes (i.e., polarity reversal, bipolar mode).

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Dorothy Vesper, West Virginia University, Morgantown, WV, United States, 26506, Dorothy.Vesper@mail.wvu.edu

Ingrid Padilla, University of Puerto Rico, San Juan, PR, United States, 00931, Ingrid.Padilla@upr.edu

Akram Alshawabkeh, Northeastern University, 360 Huntington Avenue, Boston, MA, United States, 02115, aalsha@coe.neu.edu

Presenting Author: Ljiljana Rajic

Mitigating the Environmental Impacts of Transportation: Regulatory and Technical Challenges in the Caribbean

Evan Starr

Volpe National Transportation Systems Center is a federal agency with the U.S. Department of Transportation that is 100 percent funded by sponsor projects, partnering with public and private organizations to assess and respond to the needs of the transportation community. Volpe supports the Federal Aviation Administration (FAA) in various capacities, including the Environmental Cleanup (ECU) and Facilities Decommissioning (FD) programs. FAA developed the ECU Program to address the cleanup of contaminated sites where FAA maintains liability due to past site operations or waste disposal activities. In managing these sites, FAA is required to comply with numerous Federal, state, and local environmental regulations including the U.S. Environmental Protection Agency's (EPA's) Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA). Meanwhile, FAA's FD program's primary responsibility is for the disposal of real property and site restoration at FAA sites that are now decommissioned. FAA operates a network of over 100 air traffic facilities and visual and electronic aids located throughout the Caribbean. Working in the Caribbean can pose certain challenges with unique requirements that are not always common with continental-U.S. sites. This presentation will focus on discussing specific examples from environmental and decommissioning projects in the U.S. Virgin Islands and Puerto Rico. Identifying necessary regulatory involvement or permitting is an important step in the project planning phase and difficulties can result in project schedule delays or cost-overruns. In addition to project management aspects, there are several technical challenges that can impact project development, implementation, and materials disposal. Evaluating in-situ technologies or processes is an important consideration due to the remote location for many sites and cost impacts from traditional methods. Understanding the regulatory and technical challenges of working in the Caribbean can improve project efficiency and cost-effectiveness while successfully mitigating the environmental impacts from transportation.

Evan Starr, US DOT - Volpe National Transportation Systems Center, 55 Broadway, Cambridge, MA, United States, 02142, Tel: 617-494-3974, evan.starr@dot.gov

Presenting Author: Evan Starr

Navigating Change: RI/FS+RD Superfund Case Study

Brendan MacDonald

Responding to changing conditions – physical, regulatory, environmental, administrative – is a constant challenge over the life of a project. To cost-effectively reach objectives and meet schedule while minding stakeholder priorities, project managers need to keep an open mind and resources flexible. This challenge is magnified in an island environment, where resources are often fewer and each effort is leveraged. Case study will show collaboration among multiple stakeholders and dynamic approaches to implementation, and funding helped create and maintain momentum and prioritize remedial investigation and design at an active, contentious Superfund site.

Brendan MacDonald, CDM Smith, 14 Wall Street, New York, NY, United States, 10005, Tel: 212-377-4527, macdonaldbc@cdmsmith.com

Presenting Author: Brendan MacDonald

Session 2: Regulatory Programs and Policies

An Evaluation of PAHs, Arsenic, and Lead Background Soil Concentrations in Vermont
Kristi Herzer and Trish Coppolino, Vermont Department of Environmental Conservation, Montpelier, VT

Cost Recovery Options for Emerging Contaminants – Shifting Treatment Costs from Ratepayers to Polluters
Richard Head and Bill Kelly, SL Environmental Law Group, San Francisco, CA

Design and Construction of Stormwater BMP Retrofits for the Control of Nitrogen on Cape Cod
Ray Cody, US EPA Region 1, Boston, MA; M. Lundsted, Comprehensive Environmental, Inc., Merrimack, NH

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Derecognizing Environmental Liability Using ASTM Guide E3033
Marty Rowland, Third Leg Consultants, Forest Hills, NY

Upgrading to a Sustainable Way of Life by Upgrading Our Policies
Ellen Moyer, Greenvironment, LLC, Montgomery, MA

An Evaluation of PAHs, Arsenic, and Lead Background Soil Concentrations in Vermont

Kristi Herzer and Trish Coppolino

The State of Vermont Department of Environmental Conservation (VTDEC) conducted a statewide surface soil study. The purpose of the study was to determine concentrations of polycyclic aromatic hydrocarbons (PAHs), arsenic, and lead from locations presumed to not have release sources of these compounds. Based on legislation House Bill 269 the VTDEC was tasked with establishing background concentrations of these contaminants of concern in order to support future decisions regarding the management of soils encountered during development projects. Both rural and urban lands were sampled, and property access was granted prior to field work. A total of 130 shallow surface soil samples were collected spatially throughout Vermont with 17 duplicate samples collected for quality assurance/quality control evaluation. Sample location examples included municipal parks, school yard grassed areas, cemeteries, and state lands. Sample locations were not chosen if the site was a former industrial property, or had obvious signs of soil staining, a history of fire, or petroleum storage. A Phase I Environmental Site Assessment was not conducted on any of the sample location properties. Soil samples were submitted under chain of custody to a National Environmental Laboratory Accreditation Program (NELAP) certified laboratory for analysis. Data were compiled into a database that geocoded to a web-based mapping application to spatially visualize the sampling locations. Statistical analysis was conducted utilizing the Environmental Protection Agency's statistical software, ProUCL 5.0. Each data set of analytical results (arsenic, lead, and TEQ PAHs) was evaluated to determine whether the data reflected a statistically significant separation as a result of discernable land use patterns. Results of the statistical analysis were that the arsenic data set yielded a single statewide background threshold value. Lead and TEQ PAHs, however, had a statistically significant delineation of data, and thus a rural and urban Background Threshold Value was calculated for these analytes.

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Cost Recovery Options for Emerging Contaminants – Shifting Treatment Costs from Ratepayers to Polluters

Bill Kelly and Richard Head

Remediation efforts to provide high-quality drinking water come at a significant financial burden to water utilities and public entities. Whether addressing a regulated drinking water constituent or an emerging contaminant of concern, it becomes increasingly challenging to deliver affordable water. While every case must be evaluated on its facts, legal precedence has been set for recovering the costs of cleaning up contaminated drinking water and shifting treatment costs from ratepayers to polluters. Under the theory of "products liability" manufacturers of chemicals responsible for contamination are held accountable for the associated treatment costs— including but not limited to replacement or treatment of affected well, capital costs, well connection and distribution system costs, operation and maintenance costs for the lifetime of affected wells, and protection against future uncertainty through the inclusion of contamination contingency clauses in settlement documents. By including a legal review of cost recovery options as part of their systematic approach to evaluate remediation efforts water utilities may be able to lessen their financial burden associated with providing high-quality drinking water. This presentation will detail the legal review process that can be undertaken by a utility interested in pursuing cost recovery options for regulated or emerging contaminants. The factors to consider when evaluating manufacturer liability will be reviewed. General resource commitments and timelines for undertaking this process will also be particularized. To see the legal review process in context a case study from the State of New Hampshire will be deconstructed; twenty-two major oil companies were sued for adding MTBE to New Hampshire's gasoline knowing that it would contaminate the State's drinking water supplies resulting in over $372 million in settlements and jury verdict which helped fund the creation of an MTBE Remediation Bureau in the State's Department of Environmental Services.

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Design and Construction of Stormwater BMP Retrofits for the Control of Nitrogen on Cape Cod

Ray Cody and M. Lundsted

The U.S. EPA, with WaterVision LLC and Comprehensive Environmental Inc., designed and constructed two innovative stormwater best management practice (BMP) subsurface gravel wetland retrofits for control of nitrogen discharges from municipal small separate storm sewer systems (MS4s) on Cape Cod. Stormwater runoff, generated from rain and snowmelt, carries nitrogen and other pollutants from hard surfaces like streets, parking lots, driveways, and rooftops into nearby waterbodies. This runoff is a significant source of pollution to the waters of Cape Cod. Excess nitrogen degrades water quality, a process referred to as eutrophication. Removing nitrogen from stormwater improves the water quality and ecological health of Cape Cod's estuaries and coastal waters. The BMPs were modified based on a small-scale prototype developed by the UNH Stormwater Center. The BMPs were constructed in Barnstable (Hyannis) and Chatham during the spring, summer and fall of 2015. The BMPs each consist of an extended aeration zone to promote adsorption and oxidization to nitrate ($NO3^-$), followed by an anaerobic zone for denitrification to N_2. The difficulty in removing nitrogen from stormwater (unlike wastewater treatment) is the large quantity of volume of water compared to the concentration of nitrogen. Yet stormwater is a key source of nitrogen loading to coastal areas because although the concentrations in stormwater compared to wastewater are low, the volume is much greater and more widespread. The BMPs will be monitored to assess performance in 2017 and beyond. This presentation will describe the BMP siting, design and construction; the treatment process; benefits; unit costs; and preliminary results.

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Forthcoming USEPA Method 3050 Changes

Jay Clausen

Over the past 4 years a US EPA working group has been involved in updating Method 3050B, which was last updated in 1989. Method 3050C is planned to be promulgated in FY17. Changes to Method 3050 include incorporating the latest analytical technologies and extraction methods. In addition, the method addresses poor recovery elements such as tungsten, and the quality control section was updated to include new procedures. The sample preparation section has been extensively rewritten. New tables have been added comparing recoveries of different analytes and methods. Finally, a new Appendix was added covering the collection and processing of soil samples containing metallic residues.

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Derecognizing Environmental Liability Using ASTM Guide E3033

Marty Rowland

The 1960's environmental movement began when soil, air, land, and water contamination was recognized by the average citizen. The process of recognition of environmental and human risks was then codified in regulations and later used by accounting boards to identify specific financial obligations toward reducing those risks. The challenge today is developing an accepted practice for de-recognition of such risks so that financial obligations, large and small, can be terminated or reduced for just cause. In 2016, ASTM, the consensus standards-setting organization, published standard guide E3033-Beneficial Use of Landfills and Chemically Impacted Sites that identified eight uses of land that could be found acceptable (i.e., protective of human health and safety) by an Environmental Professional after careful review, assessment, and documentation through the use of four forms, each characterizing an increasing level of pre-derecognized risk. Form 1 covers those conditions where such risks are significant but can be sufficiently reduced (i.e., brought to de minimis levels) through simple removal actions (i.e., cleaning up low volume spills or results of airborne contaminant deposition) and capping without subsequent engineering or institutional controls. Form 2 covers sites where these controls are necessary, Form 3 covers land uses associated with the growing or marketing of agricultural produce, and Form 4 covers sites where significant removal actions have taken place, are in process, and/or have well-defined obligations regarding site security, monitoring, and media measurements (i.e., engineering and institutional controls). Through the use of E3033 and its four forms, land with environmental liabilities can be characterized as well defined and continuing or of de minimis risk upon having an identified land use be found acceptable, thereby lowering financial risk through the placement of value on the judgment of the Environmental Professional, whose livelihood and reputation are put at risk.

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Upgrading to a Sustainable Way of Life by Upgrading Our Policies

Ellen Moyer

Policies reflect a society's values and goals. Antiquated U.S. policies have us on a collision course with environmental realities, resulting in climate change, species extinction, pollution, and other crises. One way or another, big change is coming. We can sit on the sidelines absorbing increasingly severe impacts. Or we can reverse the damaging trends and improve future prospects by modernizing our policies. Policy changes can get us onto a sustainable trajectory, which is one that can continue indefinitely without depleting or degrading vital resources or endangering Earth's species.

This presentation illustrates how policy changes can address climate change, arguably the most dire of our environmental problems. While climate change may seem insurmountable and overwhelming, solutions stand at the ready that are technically easy to implement, don't require citizens to sacrifice, and end up improving other areas besides the climate such as health, jobs, and the economy. However, timely implementation requires changing our policies. Example policy changes include: promoting energy conservation and efficiency, advancing cleaner energy technologies, eliminating counterproductive taxpayer-funded subsidies that reward climate-damaging behaviors, and providing access to contraception so that unwanted pregnancies can be avoided. These simple measures alone would go a long way toward solving our climate problem.

We often assume that adopting a sustainable way of life will be hard and unpleasant or that doing so will hurt the economy. However, by applying wise and beneficial policies we can upgrade to a sustainable way of life that generates greater health and happiness while creating an economic boom. Changing policies requires clear goals, determination, and a "can do" attitude. Historical precedents will be described. We have many reasons to hope for and expect success, especially considering that it is our amazing success to date that led to the crises we now face.

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Session 3: Remediation

New Thinking on the Environmental Impact of PCBs in Building Materials
John Martinelli, Forensic Analytical Consulting Services, Citrus Heights, CA

Lessons Learned from Thermal Conductive Heating Remediation of Chlorinated Solvents in Low Permeability Formations
Chris Voci, Terraphase Engineering, Conshohocken, PA; Darren Croteau, Terraphase Engineering, Carlsbad, CA; Amber Koster, Terraphase Engineering, Oakland, CA; Grant Geckeler, GEO Environmental Remediation Company, Corona, CA

Treatment of CBRN Decontamination Effluent
Victor Medina, US Army Corps of Engineers, Engineer Research and Development Center (ERDC), Vicksburg, MS

Removal of Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) from Fire Training Site Soils
William Kerfoot, Kerfoot Technologies, Mashpee, MA

Obtaining High-Resolution Data to Demonstrate BOS-100® Performance in Large TCE Plume with Extensive DNAPL
Thomas Harp, LT Environmental, Inc., Arvada, CO

Using Cloud-Based Tools to Revolutionize Project Implementation Through Adaptive Management
Jessica Hinchliffe and David Carstens, WSP USA, Woburn, MA; Ademola Bakenne and James Sobieraj, WSP USA, Boston, MA; Christine Albertin, WSP USA, Raleigh, NC

New Thinking on the Environmental Impact of PCBs in Building Materials

John Martinelli

Buildings constructed, renovated and/or repaired between 1950 and 1978 are likely to contain a variety of building materials containing polychlorinated biphenyls (PCBs). The environmental health risks associated with PCBs in dielectric oil spills, fires and waste sites where PCBs spills have been well documented. Recent studies show that the impact of PCBs in building materials such as exterior caulks and sealants is not as well defined. Enforcement actions by US EPA 40CFR761 as it relates to PCBs in building materials has evolved and has come to the forefront with recent events like those in Malibu High School that had high profile Hollywood headliners such as Cindy Crawford and Ed Begley, Jr. demanding increased testing of building materials for PCBs. Local regulatory actions are also in play including the San Francisco Bay Regional Water Quality Control Board's PCB Total Maximum Daily Load Limit that calls for a tenfold reduction in the amount of PCBs released during cleanups. Identifying locations of PCB containing building materials, their impact to the substrates with which they contact, 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.

This session will discuss the current best management practices for PCBs in building materials, sampling and laboratory analysis methods, notification requirements, cost implications and ongoing operational concerns associated with renovation and demolition projects where PCBs are present in building materials.

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Lessons Learned from Thermal Conductive Heating Remediation of Chlorinated Solvents in Low Permeability Formations

Chris Voci, Darren Croteau, Amber Koster, and Grant Geckeler

Chlorinated solvent remediation strategies for low permeability settings must overcome limitations in the ability to remove volatile organic compounds from the subsurface via mass transfer or establish subsurface contact with the contaminants through injection of materials to affect their biological or chemical transformation in situ. This case study presents a tetrachloroethene (PCE) release in a low permeability formation that was remediated using in-situ thermal remediation (ISTR). We explore how ISTR can overcome treatment challenges by exploiting multiple chemical and physical characteristics of the contaminants and altering the physical subsurface.

PCE was released at a commercial site resulting in soil and groundwater contamination to approximately 35 feet below ground surface (bgs) and sub-slab vapor and indoor air PCE concentrations above commercial screening levels. The objective of the remediation was to treat the entire 800-square-foot PCE source area (approximately 1,040 cubic yards of material) to eliminate the indoor vapor intrusion risk rapidly and return the space to commercial lease.

An ISTR system using natural gas-fired thermal conductive heating (TCH) with multi-phase extraction was installed inside the 2,800-ft^3 space. TCH uses heater wells to generate subsurface heat that propagates via thermal conduction. Subsurface contaminant volatilization and steam stripping are the primary mechanisms for contaminant mobilization due to PCE's high vapor pressure and low boiling point. In addition to mass transfer, chemical transformations including hydrolysis, chemical reduction, and enhanced biological degradation occur during heating.

After three months of ISTR treatment, groundwater PCE concentrations decreased 98%. Of 36 post-treatment soil samples collected to measure performance, two samples from one boring had PCE exceedances. Focused heating and effluent extraction was performed for one additional month to complete treatment. A second round of soil sampling demonstrated that PCE concentrations were below the laboratory reporting limit of 4 µg/kg at all locations. Regulatory closure is currently being pursued.

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Treatment of CBRN Decontamination Effluent

Victor Medina

The Army maintains extensive decontamination capabilities (DECON) to mitigate chemical, biological, radiological and nuclear (CBRN) attacks. The Army currently has no capability to treat and/or recycle the effluent from its aqueous based decontamination operations. This effluent is extremely hazardous and poses a major handling, logistical, and political burden.

An effective on-site effluent treatment approach would allow for a more rapid return to operational readiness after an attack and provide better civilian support capabilities in homeland defense scenarios. The effluent can safely be discharged into the environment or even reused for more decontamination.

The presentation will consist of two parts. The first part will briefly cover our approach to estimate constituents that would likely be found in a decontamination effluent, such as CBRN constituents like chemical warfare agents or radiological particles, associated contaminants like sediments, oils and greases, and decontamination chemicals like surfactants and/or bleach. The second portion of the talk will focus on the development of a treatment system for decontamination effluent, including unit processes for treating the various constituents expected in the effluent. We anticipate having results of testing individual components of the system as well as integrated testing results. We will also present concepts for monitoring and controlling the system, as well as ideas for integrating the system into existing decontamination scenarios. The presentation will conclude with our plans for continuing and completing the project.

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Removal of Perfluoroalkyl and Polyfluoroalkyl Substances (PFASs) from Fire Training Site Soils

William Kerfoot

Perfluoroalkyl compounds have been used in fire-fighting foams and are found adsorbed in soils from the sites. Rainwater leaches the compounds downward when porous sandy soils dominate the applied regions. Usually the soils also contain the remnants of the fuels which were ignited and subjected to elevated temperatures. A series of tests were conducted on example contaminated soils with different delivery methods using peroxide-activated nanobubble ozone slurries.

Analytical tests from slotted-screen injection in the contaminated soil showed PFOS and PFOA removal of 98.5 and 92.3%, respectively, within two-day long exposure. Fluorotelomer sulfonates of two isotopes, 6:2 and 8:2, showed removal efficiencies over 98%. There was no indication of PFC byproducts from partial breakdown. Acidity control was performed. Very shallow regions of burnt wood may have to be separated, crushed, and treated.

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Obtaining High-Resolution Data to Demonstrate BOS-100® Performance in Large TCE Plume with Extensive DNAPL

Thomas Harp

A high-resolution data approach was implemented at an urban industrial facility where trichloroethene (TCE) was used as a cleaning solvent. The site was underlain by alluvium and sedimentary bedrock where dense-non-aqueous-phase-liquid (DNAPL) pooled at the interface. BOS-100®, an immiscible, activated carbon solid injectate, was used to remediate the site. Solute transport was dictated by the density of the DNAPL and by the heterogeneity, anisotropy, variance in matrix density, grain size, and gradient of the aquifer. Facies changes in the matrix caused concentrations to vary by orders-of-magnitude in distances of only several millimeters. This inherent complexity warranted quantitative, high-resolution data to construct an accurate conceptual site model and to demonstrate remedy performance.

The program was tailored to track and confirm mass reduction as a result of BOS-100® performance. In total, 1,291 continuous soil samples were analyzed from 186 borings and 5,515 groundwater samples were analyzed from 1,349 monitoring wells.

The greatest value of the high-resolution, performance-monitoring approach was in areas of DNAPL or high-concentration soil and/or dissolved-phase impacts. The sequence was to use (continuous) soil and groundwater data to design a discrete and accurate remedial design; inject BOS-100®; complete confirmatory/performance borings to observe remedy distribution and evaluate if "the target was hit" (or to make adjustments to subsequent injections, accordingly); analyze corresponding groundwater samples; and calculate mass reduction. The sequence was repeated until cleanup goals were met in target areas.

The project was a success because of the effectiveness of BOS-100® and the quantity and quality of data gathered to demonstrate treatment performance. The DNAPL portion of the plume was reduced from concentrations of up to 254,770,000 micrograms per kilogram TCE in soil and 1,280,000 micrograms per liter TCE in groundwater to closure levels. The dissolved-phase plume was also mitigated and site-closure monitoring began in 2014. A No Action Determination was granted in 2016.

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Using Cloud-Based Tools to Revolutionize Project Implementation Through Adaptive Management

Jessica Hinchliffe, Christine Albertin, Ademola Bakenne, James Sobieraj, and David Carstens

A case study is presented of a recent large and complex remediation project in Darlington, South Carolina, where a cloud-based project management tool was developed to optimize soil management strategies. By enabling adaptive high resolution soil management during project implementation, the amount of soil requiring higher-cost management strategies was minimized and the environmental footprint of the cleanup was significantly reduced as compared to the footprint of traditional project management approaches.

The remedy included excavation followed by consolidation/capping, treatment, and/or disposal of more than 13,000 cubic yards of PCB- and/or VOC-impacted soil, divided into six different soil management categories based on contaminants present, their respective concentrations, and the applicable regulatory programs (TSCA, RCRA). Each soil management category required a different management approach (ranging from consolidation and capping, to onsite ex situ thermal treatment to remove VOCs before backfilling onsite, to offsite disposal at one of several disposal facilities) and associated cost, both financial and environmental.

The complexity of the project, the amount of data generated during construction, and the potential for a constantly shifting scope of work required extreme diligence during project implementation, and led the project team to radically alter their traditional project management approach. The project management tool developed allowed the project team to identify, share, and act on information in real time, enhanced their communication with the client, and enabled the project to be implemented efficiently and successfully in terms of cost and environmental footprint.

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Session 4: Biomonitoring: Strategies and Uses for Risk Assessment and Stakeholder Communication

Recruiting and Enrolling a Statewide Sample of Biomonitoring Study Participants
Andrea DiPerna, Marc Nascarella, Jenna Calerbank, Meg Blanchet, and Nicole Daniels, Massachusetts Department of Public Health, Boston, MA

Biomonitoring Challenges – Examples and Case Studies from a Laboratory Perspective
Patrick Parsons, Christopher Palmer, and Amy Steuerwald, New York State Department of Health, Albany, NY; Sharon Perman and Wendy McKelvey, New York City Department of Health & Mental Hygiene, New York, NY

Perfluoroalkyl Substance Biomonitoring: Comparing and Contrasting Blood Screening Programs in Two New York State Communities (Hoosick Falls – PFOA; Newburgh – PFOS)
Mark Maddaloni, US EPA Region 2, New York, NY

Risk Assessment for Lead & Arsenic: How Do Biomonitoring Considerations Fit into the Big Picture?
Christopher Teaf, Florida State University, Tallahassee, FL; Douglas Covert and Michele Garber, HSWMR, Tallahassee, FL

What Does That Blood Level Mean? The Assumptions Underlying Interpretations of Health Effects from Internal Doses
Phil Goodrum, Integral Consulting, Inc., Fayetteville, NY; Janet Anderson, Integral Consulting, Inc., San Antonio, TX; Sean Hays, Summit Toxicology LLP, Bozeman, MT

Recruiting and Enrolling a Statewide Sample of Biomonitoring Study Participants

Andrea DiPerna, Jenna Kiridley, Meg Blanchet, Nicole Daniels, and Marc Nascarella

The Massachusetts Department of Public Health (MDPH) has established a statewide biomonitoring effort with funding and technical support provided through a Cooperative Agreement with the US Centers for Disease Control and Prevention. The Biomonitoring Massachusetts Study is focused on determining levels of PCBs and select metals in three specific participant groups: (1) a representative sample of adult Massachusetts residents; (2) individuals in communities with a high risk of potential exposure; and (3) individuals exposed through episodic exposure events or acute chemical emergencies. This presentation will describe the lessons learned and best practices focused on recruiting and enrolling a study participants as part of or statewide sampling effort.

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Biomonitoring Challenges – Examples and Case Studies from a Laboratory Perspective

Patrick Parsons, Christopher Palmer , Amy Steuerwald, Sharon Perman, and Wendy McKelvey

Human biomonitoring for exposure to mercury (Hg), a highly toxic element, is achieved by measuring its concentration in blood and urine. While the former yields information on both inorganic and organomercury species, the latter provides information on exposure to inorganic Hg. Previous population-based biomonitoring studies in New York City adults in 2004 resulted in health department policies and programs that were designed to reduce levels of Hg exposure. In 2013, a follow-up study sought to understand changes in exposures over a 10-year period in relation to public health actions. Blood (n=1,811) and urine (n=1,840) specimens from a representative sample of NYC adults who participated in the 2004 NYC Health and Nutrition Examination Survey (NYC HANES 2004) were analyzed for mercury content using a biomonitoring method based on ICP-MS. Results indicated that the geometric mean blood Hg levels was higher for NYC by a factor of three compared to national levels. Geometric mean urine Hg in NYC was higher for Caribbean-born blacks and Dominicans than for non-Hispanic whites or other racial/ethnic groups. Sources of Hg exposure included contaminated fish and skin care products. A follow-up biomonitoring study (NYC HANES 2013-2014) was conducted a decade later that included assessments of blood (n=1,266) and urine (n=1,520) mercury levels among the civilian, non-institutionalized adult population (aged 20 years and older) residing in the five boroughs of NYC. The analyses for Hg were conducted using the same ICP-MS biomonitoring methods in the same laboratory in the New York State Department of Health's Wadsworth Center. A preliminary assessment suggests the reduction in NYC blood mercury levels was greater than the national decline, but decreases in NYC urine mercury levels were similar to NHANES. The importance of using well-established analytical methods that are under good control are critical to monitoring trends over a 10-year period.

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Perfluoroalkyl Substance Biomonitoring: Comparing and Contrasting Blood Screening Programs in Two New York State Communities (Hoosick Falls – PFOA; Newburgh – PFOS)

Mark Maddaloni

The availability of biological sampling advances an exposure assessment from the point of actual or potential exposure to a contaminant in the environment (e.g., air, water, soil) to a measure of internalized dose. Blood lead (Pb), a well-established biomarker of both exposure and effect, serves as a useful yardstick for which the utility of other biological sampling regimens can be assessed. It is within this context that two recent biological sampling programs for perfluorinated compounds are considered. Contamination of production wells for the municipal water supply in Hoosick Falls, New York with perfluorooctanoic acid (PFOA), and the primary reservoir for the City of Newburgh, New York with perfluorooctane sulfonate (PFOS), have resulted in actions taken to reduce/eliminate exposure from the water source, and the institution of blood sampling programs in these two communities for PFOA and PFOS, respectively. Results from the blood sampling programs indicate that both communities have significantly higher blood levels of PFOA (Hoosick Falls) and PFOS (Newburgh) compared to the general population background (National Health and Nutrition Examination Survey). Beyond a comparison with background, what other useful information do these costly and complicated biological sampling programs provide? The presentation will explore the role of biokinetic modeling as a surrogate for obtaining measured results, and the clinical significance of individual sampling results in medical assessment/management. A novel use of individual blood PFOA/PFOS sampling results will also be considered: to serve in identifying outliers for potential clinical intervention to lower blood levels employing an FDA approved drug (cholestyramine) for treating hypercholesterolemia.

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Risk Assessment for Lead & Arsenic: How Do Biomonitoring Considerations Fit into the Big Picture?

Douglas Covert, Christopher Teaf, and Michele Garber

Exposure to lead and arsenic in environmental and occupational circumstances can occur as a result of ingestion, inhalation, and, to a much lesser extent, from dermal contact. Risk evaluation procedures typically use measurement data for air, soils, food, and other media, along with consensus risk-based calculations, to assess potential risk and to develop health-based criteria to guide site management or remediation decisions. Such risk-based calculations can yield highly restrictive cleanup goals or criteria, given the conservative nature of the toxicological guidance values and the typical default exposure assumptions. Biomonitoring of fluids and tissues for lead and arsenic concentrations (e.g., blood, urine) can be a useful adjunct to calculated risk-based targets, and, in the case of lead, tissue target concentrations (i.e., blood lead) actually form the basis for a number of target soil values that are in present use. Some interesting disconnects also can be observed when comparing decisions made on the basis of conventional health based criteria (e.g., for soils) versus decision made on the basis of observed elevations (or lack thereof) in biomonitoring results for potentially exposed populations. Examples of some interesting side-by-side case studies will be presented to illustrate the issue. One part of the explanation for such observations, at least in the case of soils, lies in the fact that, with few exceptions, risk-based calculations for these two substances do not incorporate a term to distinguish soil bioavailability from bioavailability observed in other media.

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What Does that Blood Level Mean? The Assumptions Underlying Interpretations of Health Effects from Internal Doses

Philip Goodrum, Janet Anderson, and Sean Hays

Biomonitoring data such as concentrations of chemicals in human blood have routinely been used to assess national trends in exposure and to identify communities for which exposures are consistently elevated compared to national averages. Measured concentrations in people are often viewed as more informative exposure metrics than estimates based on exposure, uptake, and kinetic models; however, from a risk assessment perspective, for most chemicals, challenges remain in linking biomonitoring data with statements about the magnitude and likelihood of adverse health effects. Traditionally, reference doses (RfD) and associated human health drinking water threshold levels are calculated from and compared with administered or oral ingestion dose rather than internal dose. However, internal dose measurements and human biomonitoring data are being used more frequently to derive RfDs and drinking water threshold levels. The use of human serum data from biomonitoring studies to calculate a threshold level requires chemical-specific or default assumptions about how a chemical is absorbed, metabolized, distributed, and eliminated. A shift in calculating RfDs towards a focus on internal dosimetry is accompanied by an expectation that we will have greater confidence in the internal dose-response relationship. It is not clear that this is always the case. This presentation will propose a decision making framework for assessing relative uncertainties in dosimetric approaches. Key factors and important data needs will be highlighted, including chemical persistence (biological half-life); frequency, duration, and magnitude of exposure; availability of animal toxicology data that includes internal dose metrics; and an understanding of interspecies differences in metabolic and physiologic processes that affect both dose and response. Examples based on perfluoroalkyl compounds in drinking water will be presented for which approaches using compartmental models and biokinetic slope factors can be compared with traditional methods based on administered dose.

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Session 5a: LNAPL and Natural Source Zone Depletion

Bioventing Revisited – Can Enhanced Biodegradation Outperform Hydraulic LNAPL Recovery?
Andrew Kirkman, BP America, Naperville, IL; Jonathon Smith, AECOM, Southfield, MI; Brad Koons, AECOM, Minneapolis, MN; Steven Gaito, AECOM, Providence, RI

The Effects of Solar Heating in an Urban Environment on Heavy Oil Migration and Discharge
Troy Smith, Maine Department of Environmental Protection, Augusta, ME

Quantifying Petroleum Biodegradation Rates Using Temperature
Steven Gaito, AECOM, Providence, RI; Jonathon Smith, AECOM, Southfield, MI; Brad Koons, AECOM, Minneapolis, MN

Bioventing Revisited – Can Enhanced Biodegradation Outperform Hydraulic LNAPL Recovery?

Steven Gaito, Brad Koons, Jonathon Smith, and Andrew Kirkman

Light nonaqueous-phase liquid (LNAPL) associated with historical fuel releases are present in the subsurface at many environmental sites. Research on Natural Source Zone Depletion (NSZD) rates at petroleum-affected sites has demonstrated that the rate of natural LNAPL depletion is typically significant. Research studies and measurements made by practitioners have shown that the rate of LNAPL mass depletion by NSZD is often greater than what can be or has been achieved through active LNAPL recovery efforts. These findings suggest that enhancing NSZD may be more effective than hydraulic LNAPL recovery, even at sites where LNAPL transmissivity measurements indicate that LNAPL is hydraulically recoverable.

Conceptual models of NSZD that are reinforced by empirical data collected at LNAPL sites show that the soil gas above the LNAPL/air interface is rich in methane and depleted of oxygen. These observations indicate that there is an anaerobic zone in the vadose zone that typically coincides with a portion of the LNAPL smear zone. Inducing oxygen flow into these methane-rich zones through bioventing is a viable approach to accelerate NSZD.

Bioventing is not a novel technology; bioventing and bioventing rate testing has existed since the 1990's when EPA published a two-volume guidance document on implementation. While the remediation science has not changed, the conceptual model for LNAPL biological depletion and the petroleum hydrocarbon biodegradation signal observed in biovent field tests and full-scale operation have changed markedly since the 1990's.

Bioventing is a potentially cost-effective alternative to hydraulic recovery that not only degrades the mobile fraction (limits of hydraulic recovery) but also the residual fraction of LNAPL. Additionally, the observation that the biologically-mediated processes responsible for LNAPL depletion do not appear rate limited under most circumstances indicates that mass removal through enhanced biological depletion can be sustained over longer periods of time than for hydraulic recovery technologies.

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The Effects of Solar Heating in an Urban Environment on Heavy Oil Migration and Discharge

Troy Smith

The discharges of Heavy oil (Number 6, bunker fuel) to surface water in urban settings represent an ongoing challenge in Maine. This legacy problem stems from historic use of large quantities of oil at urban mill complexes during the 1900's. The mills were strategically located near rivers and streams that were used for hydropower. Heavy oil was typically transported in heated steel piping from railroad tanker cars to large cement or steel bunker tanks. The oil was later distributed within the mill complexes through heated steel piping.

Investigations often find heavy oil as residual hardened tar-like material in the subsurface. The residual oil has a very high viscosity and will not flow or migrate very far under normal soil temperatures (10°C) and atmospheric pressures (100 kPa). However, we also find heavy oils in the subsurface as a mass of non-aqueous phase liquid (NAPL) with lower viscosities than the tar-like material. This lower viscosity NAPL has the ability to produce oil sheens and oil blebs that are lighter than water and capable of migrating hundreds of feet in groundwater. We have struggled to determine how heavy oil can produce both high viscosity tar-like material and lower viscosity NAPL capable of migrating hundreds of feet.

An investigation of a mill complex in Lewiston, Maine discovered that groundwater temperatures influence heavy oil migration. We observed a correlation between seasonal increases in groundwater temperature resulting from solar heating and the observation of oil sheens and oil blebs in surface water. The groundwater temperatures 10-feet below the water table increased up to 19°C from a seasonal low of 6°C as a result of solar heating of pavement and subsurface fill materials. The seasonal fluctuations recorded in three wells are reproducible over three seasons and correlate well with oil observations in the nearby Androscoggin River.

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Quantifying Petroleum Biodegradation Rates Using Temperature

Steven Gaito, Jonathon Smith, and Brad Koons

Quantification of petroleum LNAPL biodegradation rates can play a key role in development and implementation of an appropriate LNAPL site management strategy, whether for the purpose of assessing the effectiveness of bioremediation technologies (e.g., bioventing), or for establishing rates of natural source zone depletion (NSZD).

The biodegradation reactions responsible for altering the composition of soil gas (e.g., oxygen utilization and/or carbon dioxide production) also release heat. The excess heat from biodegradation creates thermal anomalies that can be resolved through subsurface temperature profiling within existing wells, or from dedicated sensors buried in soil. Given the relative simplicity and cost-effectiveness of data collection, thermal profiling in support of petroleum biodegradation studies has gained considerable attention in recent years. However, models for translating temperature data into biodegradation rates are in the developmental phase.

An energy balance model is presented and applied to quantify rates of biodegradation. Temperature signals unrelated to petroleum biodegradation processes, such as seasonal variability in radiant heating and cooling at ground surface, are filtered out of the analysis, and the model allows for input of thermal properties of soil and aquifer matrices. Example applications of the model are provided for case study sites to quantify NSZD rates, and rates of biodegradation associated with bioventing. Temperature data inputs were collected using dataloggers in monitoring wells, and thermistors buried in the ground to demonstrate the applicability of in-well temperature monitoring.

The use of temperature data can serve as a cost-effective means of quantifying petroleum biodegradation rates associated with either NSZD or active bioremediation, providing an alternative approach where methods based on soil gas flux are impractical. The presentation will discuss the development and use of the thermal model to quantify biodegradation rates along with the findings of sensitivity evaluations and estimation of background soil temperatures at a site.

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Session 5b: In-Situ Ozone Remediation Update

In-Situ Remediation of High Weight Petroleum Hydrocarbons (C9 – C39) at a U.S. Virgin Islands Site
Ricardo Alvarez, On-Site Environmental, Inc., Dorado, PR; William Kerfoot, Kerfoot Technologies, Mashpee, MA

Treating Fluorinated Alkane Spills from Circuit Board Manufacturing
Andrew Brolowski, Streamline Environmental Services, Woods Hole, MA; Amy Stanton and William Kerfoot, Kerfoot Technologies, Mashpee, MA

Ozone-Based ISCO for Destruction of PCBs – Final Report
John Mateo, Blue Lightning Underground Enterprises, LLC, Mt. Holly, NJ

Hydrocarbon Removal Under Difficult Winter Conditions
David Bennett, Bennett Environmental Associates, Inc., Brewster, MA; Robert Duncanson, Town of Chatham, Chatham, MA

In-Situ Remediation of High Weight Petroleum Hydrocarbons (C9 – C39) at a U.S. Virgin Islands Site

Ricardo Alvarez and William Kerfoot

A spill of fuel oil combined with lubricating oil occurred in a near shoreline area of sand and gravel. Although the area was shallow (1 m) to groundwater, concrete slabs were laid across the area for a propane tank and generator, limiting the capacity to remove the contaminated soil and some floating product. To meet the time requirements of the client, biological-compatible, in-situ chemical oxidation with coated microbubble ozone (BISCO) sparging was chosen for the use.

By maintaining ozone and ozone/peroxide (Perozone®) concentrations within ranges compatible with bacteria action and use of pulsed sequential gas introduction, bacterial populations flourish during ozone sparging. The combination of a free-radical first step predigests bacterial-resistant, long-chain carbon compounds (aliphatics) and substitutes oxygen on the alkane or alkene short chains, preparing the mixture for rapid bacterial action with enhanced oxygen from the stage one reaction and air (20%). The critical mass proportion of ozone to oxygen approaches 1:200 for oxygen delivered or 1:15 for oxygen dissolved for stage one, and close to 2.5 total oxygen to 1 hydrocarbon for stage two.

A site mass program was run to compute the total mass of TPH which existed in the ground and groundwater at the site. Fifteen injection wells were used. For normal pH, we have previously used a partitioning ratio of 1:100 for dissolved TPH versus adsorbed (on soil) TPH. Here we found a ratio of 1:800, probably due to longer chain length (C36 compared to C12).

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Treating Fluorinated Alkane Spills from Circuit Board Manufacturing

William Kerfoot, Amy Stanton, and Andrew Brolowski

Ozone sparging has been found to be very effective in treating chlorinated and fluorinated ethanes in soil and groundwater. Trichlorotrifluorothane (Freon) has been found to be most rapidly decomposed when treated by microscopic ozone bubbles during an in-situ injection pilot test conducted in Hawthorne, California.

A variety of halogenated alkenes and alkanes occurred as contaminants at the site. The five major compounds were trichloroethene (TCE), cis-1,1 Dichloroethene (cis-1,1 DCE), cis-1,2 Dichloroethene (cis-1,2 DCE), 1,1,1 Trichloroethane (1,1,1,TCA), and Trichlorotrifluoroethane (TCTFE).

The site was occupied by a commercial electronics supplier which had spills from circuit board manufacture. The predominant soils are a silty fine sand. During the two-month pilot testing, a single recirculation well was used to inject microbubble ozone into the shallow aquifer. The injection spargewell was located 97 ft. (30 m) from the recovery well.

Bench-scale batch tests were performed to compare reactivities with PCE, cis-1,2 DCE, 1,1,1 TCA, and methylene chloride. The Freon was not originally expected. Based on the bench-scale tests, best removals were achieved with DCE, cis-DCE, followed by TCE and then 1,1,1 TCA. During the pilot test, TCTFE was found to have the most rapid removal among the treated compounds.

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Ozone-Based ISCO for Destruction of PCBs – Final Report

John Mateo

A full-scale implementation of in-situ chemical oxidation using ozone was completed for the destruction of Poly Chlorinated Biphenols (PCBs), as authorized by a US EPA Demonstration Permit under 40 CFR 761:60(e).

For this demonstration project, PCBs were entrained in a petroleum hydrocarbon mass estimated to contain upwards of 54,000 lbs of Total Petroleum Hydrocarbons (TPHs). PCB loadings were estimated to be approximately 3,100 lbs. The estimated size of the impacted/treatment area is approximately 60,000 square feet. The depth of PCB and petroleum hydrocarbon impact extends from the surface to approximately 24 feet below grade surface.

Baseline soil sample results at a contaminated site in New Jersey indicated that PCB concentrations occur up to 14,000 PPM. Predominant PCB Aroclors include 1242, 1248 and 1260. After completing four years of operation and injection of approximately 0.23 M lbs of ozone and 3.3 M lbs of oxygen into the treatment area through one hundred (100) points, PCB mass was reduced by 92%, the overall site concentrations were reduced to < 1 PPM in the vadose zone and < 15 PPM in the saturated zone (including elevated, isolated areas) and groundwater PCB concentrations in all the monitoring wells located in the heart of the target area were decreased to non-detect.

A synopsis of the full-scale remedial action will be presented, including an evaluation of the performance results collected from biannual soil sampling and quarterly groundwater programs throughout the project performance period.

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Hydrocarbon Removal Under Difficult Winter Conditions

David Bennett and Robert Duncanson

The Town of Chatham requested Bennett Environmental Associates conduct a groundwater cleanup beneath the old fire/police/community center complex. The project had tight time constraints between razing of the buildings in October and start of new construction in the spring.

Environmental assessment indicated a plume of contaminated groundwater under the subject property with volatile petroleum hydrocarbon and target analyte concentrations greater than the applicable GW-3, Method 1 – Risk Characterization Standards attributed to unleaded gasoline. The likely source was a former fueling facility located in front of the community center.

To save the Town additional excavation costs, the decision was made to cover tubing with hay bales and black plastic tarping with minimal burial. Heated air was injected into conduits carrying the horizontal tubing. A pilot test was run with injecting Perozone® through paired tubing to a Spargepoint® carrying ozone gas and peroxide which confirmed effective removal. The system was expanded to 23 points

During a three-month period, the area was hit by over three Nor'easters, delivering over two feet of snow and winds at times in excess of 60 miles per hour. Treatment continued during this period despite the severe weather conditions.

By March, only a small zone remained which had not met GW-3 conditions. Regression curves of best fit showed total xylene trends meeting GW-3 standards in MW-2S and MW-12S. With 100 days' operation, an estimated 1,950 kg of hydrocarbons as carbon were removed.

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Session 6: Sediments

Development of a Passive Lignin Porewater Sampler for Metals
Stephen Clough, Haley & Aldrich, Inc., Bedford, NH

Factor Analysis and Variability of PCBs in Ambient Air from Contaminated Sediment, New Bedford Harbor
Michael Morris and Jonathan Blount, Jacobs Engineering, Bourne, MA

The Benefits of Sonic Drilling Techniques for Improved Recovery at Contaminated Sediment Sites
Peter Simon, Philip Simon, and Mark DeLong, Ann Arbor Technical Services, Inc., Ann Arbor, MI; Hugh Scott, MPI Drilling, Picton, ON, Canada

Evaluation of an Upland Source Control System's Performance in the Portland Harbor Using Groundwater Modeling
Binglei Gong, Anchor QEA, Boston, MA; Pradeep Mugunthan, Anchor QEA, Chicago, IL; John Edwards, Anchor QEA, Bozeman, MT; Mike Riley, Anchor QEA, Olympia, WA; Miao Zhang, Anchor QEA, Seattle, WA; John Renda and Ben Hung, Anchor QEA, Portland, OR; Robert Wyatt, NW Natural, Portland, OR

Methodology and Testing of As-Placed Organoclay-Based Contaminated Sediment Cap Materials at East Branch of the Grand Calumet River
Scott Collins and John Collins, AquaBlok, Swanton, OH

Development of a Passive Lignin Porewater Sampler for Metals

Stephen Clough

The best available science has shown that porewater is the "best predictor of toxicity" (and therefore risk) as the bioavailable fraction of sediment resides in this medium. Most ecological risk assessments continue to use total (bulk) sediment concentrations to assess risk. Biologically based endpoints can be costly to perform and results are often difficult to interpret without additional toxicity identification evaluation(s). A review of porewater samplers for metals revealed a strong need for a rapid, reliable screening tool for the measurement of divalent metals in sediment porewater. Using information from early metal binding experiments, we have conducted successful pilot studies using lignin, a natural polymer that has been shown to effectively bind divalent metals. Dose-dependent studies showed that the modified (calcium substituted) lignin has a high capacity for the binding of copper, cadmium, lead and zinc and that the polymer would not become saturated under naturally occurring ranges of pH or at concentrations encountered in contaminated sediments.

Time-dependent studies show that the modified lignin will rapidly bind divalent metals and therefore deployment periods would be short; Cu > Zn > Cd (strongest to weakest). Early binding experiments (using a polysulfone hardening agent) to form passive sampler "strips" of solidified lignin showed uptake of metals at low concentrations is strongly linear ($r = 0.99$). Experiments using this new sampler "in situ" also show that uptake is correlated with metal concentrations in porewater. These initial field studies show that a lignin-based porewater sampler has strong potential to rapidly screen sediments for metals in porewater. This would significantly reduce investigation costs while gaining information on the relative distribution (and bioaccessibility) of metals of metals in sediments.

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Factor Analysis and Variability of PCBs in Ambient Air from Contaminated Sediment, New Bedford Harbor

Michael Morris and Jonathan Blount

A long-term air monitoring program has been conducted as part of the remediation effort for PCB-contaminated sediments at the New Bedford Harbor Superfund Site. Air data have been collected since 1999 and are used to determine the impact of remedial activities on the quality of air around the harbor. Air samples are collected on a monthly basis and analyzed for polychlorinated biphenyls (PCBs), the primary contaminant of concern in the harbor sediments. Site specific short- and long-term risk levels and triggers have been determined for residential and industrial settings. A multivariate factor analysis of available PCB, meteorological, and site characteristic data was conducted to determine the impact of dredging operations on PCB concentrations in ambient air. Factor loadings indicated that air temperature, humidity, wind speed, wind direction, solar radiation, and tidal magnitudes accounted for 77 to 92 percent of the variability in the data set. Of these, temperature and solar radiation had the greatest effect, accounting for between 33 and 42 percent of the total variability. Conversely, dredging activities only accounted for 5 to 9 percent of the variability in the data set. These results indicate that meteorological conditions are the most important variables in determining changes in PCB concentrations at monitoring locations around the harbor. Active dredging of the contaminated sediments only accounts for a minor portion of the variability and is usually the 7th or 8th factor identified. As concentrations of PCBs in sediments in the harbor continue to decrease, the release of PCBs to the atmosphere due to dredging activities will continue to decrease in importance.

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The Benefits of Sonic Drilling Techniques for Improved Recovery at Contaminated Sediment Sites

Peter Simon, Philip Simon, Mark DeLong, and Hugh Scott

The primary sampling objectives of any contaminated sediment investigation typically include: (1) obtain portions of the sediment bed that are representative of the in-situ conditions; (2) conduct sampling with sufficient accuracy to properly define lateral and vertical extent of contamination, thereby providing reliable information to properly evaluate risks and remedial alternatives.

A number of problems can arise from traditional sediment sampling techniques that can compromise the underpinning of the entire investigation. Actual site investigation datasets were reviewed to evaluate the effectiveness of various sampling techniques commonly employed at contaminated sediment sites.

Production rates, percent recovery and the ability to achieve target depths for manual coring, sonic drilling, and vibracore drilling techniques were compared from cores collected to evaluate contaminated sediments within rivers located in the central mid-west. River sediment types included organic silts and other fine grained sediments, as well as coarse grained sediments with buried slab wood, logs and saw dust layers left from historic logging operations. Limitations to some of the sampling methods included the presence of buried wood layers, logs, coarse gravel and cobbles. The ability to reach the underlying glacial till was recorded for each core.

The effectiveness of each sampling technique was evaluated by monitoring percent recovery of each core, quality of the core samples, production rates, ability to reach target depths, and the ability to reach underlying glacial till when present. Sampling techniques used to collect sediment cores included: Vibracore, check valve sampler, piston sampler, Soggy Bottom Sampler and Geoprobe®. Sonic drilling methods were found to increase percent recovery, core quality, and production rates, and achieve greater sampling depths, over manual and other mechanically-assisted sediment coring techniques.

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Evaluation of an Upland Source Control System's Performance in the Portland Harbor Using Groundwater Modeling

Binglei Gong, Pradeep Mugunthan, John Edwards, Mike Riley, John Renda, Miao Zhang, Ben Hung, and Robert Wyatt

The Record of Decision for the Portland Harbor Superfund site involves remediation of an approximately 10-mile stretch of the lower Willamette River. In order for the shoreline and in-water remedy to be successful, controlling the discharge of contaminated groundwater from upland sites adjacent to the river is necessary. A hydraulic control and containment (HC&C) system has been installed at a former manufactured gas plant adjacent to the Willamette River to prevent migration of contaminated groundwater to the river. The HC&C system uses a series of control wells connected to a programmable logic controller to regulate pumping rates in real time in order to maintain an inward gradient from the tidally influenced river to the site.

A three-dimensional groundwater flow model (MODFLOW) was developed to serve as a mechanistic tool to support the evaluation of system-wide hydraulic containment under a range of operating conditions. The transient model was calibrated and validated for both wet and dry conditions using high-frequency groundwater level data from an extensive network of 88 shoreline and upland wells equipped with transducers and quarterly data from 25 upland monitoring wells. The model successfully reproduced changes in groundwater levels in response to tidally varying river stage and HC&C pumping. Particle tracking simulations were performed in MODPATH based on steady-state flow model simulations under dry and wet conditions to evaluate the extent of the hydraulic capture zone in the alluvium water-bearing zones upland and underneath the Willamette River. The model will be applied during the long-term operation of the HC&C system to support evaluations related to changes in extraction rates and other operational parameters.

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Methodology and Testing of As-Placed Organoclay-Based Contaminated Sediment Cap Materials at East Branch of the Grand Calumet River

John Collins and Scott Collins

Background. The design for the East Branch of the Grand Calumet River (EBGCR) project called for an active cap consisting of organoclay materials having certain minimum sorptive properties (partition coefficients – K_d values) for two target dissolved phase PAH contaminants. Based on modeling and design performed by Tetra Tech, organoclay was selected as the reactive/adsorptive material for the cap. J.F. Brennan placed the materials with their proprietary broadcast spreader system. Natural Resource Technology (NRT) performed monitoring and quality control during subaqueous installation of the cap materials in accordance with project specifications. After installation of the active layer, NRT collected additional samples of as-placed cap materials. SAO Environmental Consulting was engaged to oversee laboratory sorption testing to evaluate the relative sorption characteristics of both manufactured and as-placed product samples.

Approach/Objectives. This presentation will provide an overview of placement and on-site quality control activities surrounding placement of the EBGCR active cap. In addition, the approach, methodology, and results for laboratory sorption testing of the active capping product will also be provided. The objective of the additional laboratory-based work in this study was to determine possible detrimental impacts that either the manufacturing process (incorporating CETCO's organoclay powder material into a coated particle) or the act of placing the product in the river may have had on the organoclay sorption capability.

Results/Summary. Data demonstrates that the project approach for delivering active-treatment materials to the sediments provided a result that supports the modeling assumptions which were incorporated into the EBGCR remedial design and enables full-scale application of active capping materials in a manner that allows verification of both the quantity and post-placement material properties.

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Session 7: Risk Assessment

Forensic Analysis of Tissue Samples to Identify Deepwater Horizon Oil Spill Exposure
Gregg Douglas, Bo Liu, Wendy Wong, Eric Litman, and Jeff Hardenstine, NewFields Environmental Forensics, LLC, Rockland, MA

Update on the Toxicity of 1,4-Dioxane and Potential Regulatory Implications: Impact on Drinking Water Criteria
Norm Forsberg, Arcadis, Clifton Park, NY; Shawn Sager, Arcadis, Raleigh, NC; Christopher Prucha and Louis Bull, Waste Management, Model City, NY; Michael Dourson and Patricia Nance, University of Cincinnati, Cincinnati, OH; Jeri Higginbotham, Kentucky Department for Environmental Protection, Frankfort, KY; Jeff Crum, Hamp, Mathews & Associates, Inc., Bath, MI; Mark Lafranconi, Environmental Resources Management, Cincinnati, OH

Perfluorooctanoic Acid (PFOA): Environmental Sources, Chemistry, Toxicology & Potential Risks
Christopher Teaf, Florida State University, Tallahassee, FL; Michele Garber, Douglas Covert, and Bruce Tuovila, HSWMR, Tallahassee, FL

Application of Probabilistic Risk Analysis to Remedial Alternatives at the Portland Harbor Superfund Site
Betsy Ruffle and Gemma Kirkwood-Cohen, AECOM, Chelmsford, MA; Clare Murphy-Hagan, AECOM, Portland, ME; Deborah Edwards, ExxonMobil, Houston, TX

Development of Water-Effects Ratios (WERs) and Site-Specific Water Quality Criteria (SSC) for Aluminum, Cadmium, and Copper for the Androscoggin River
Patrick Gwinn, John Samuelian, and Elizabeth Rand, Integral Consulting, Inc., Portland, ME

State of the Art Consensus on How to Evaluate Bioavailability in Contaminated Soil: Guidance from ITRC
Kathryn Durant, Delaware Department of Natural Resources & Environmental Control, New Castle, DE; Claudio Sorrentino, Cal/EPA Department of Toxic Substances Control, Sacramento, CA

Forensic Analysis of Tissue Samples to Identify Deepwater Horizon Oil Spill Exposure

Gregg Douglas, Bo Liu, Wendy Wong, Eric Litman, and Jeff Hardenstine

The Deepwater Horizon (DWH) oil spill is unique because unlike most oil spills, a substantial fraction of the oil released from the Macondo well was deposited on the deep seafloor. As part of the Natural Resource Damage Assessment (NRDA) following the oil spill, tissue samples of benthic macrofauna that live in and on the deep seafloor were collected and chemically analyzed to determine the extent to which this sensitive ecosystem was exposed to the Macondo oil. Polycyclic aromatic hydrocarbons (PAH) and biomarker compounds (triterpane and steranes) were measured in whole and dissected tissue samples to identify the chemical fingerprint of any oil present within the tissue.

The reliable analysis of marine tissue samples requires an effective cleanup step to separate the biogenic compounds (e.g., oils and fats) from the compounds of concern (e.g., PAHs). This step both lowers the method detection limit and provides improved analytical resolution. In addition to tissue related matrix issues, source oil signatures are altered by exposure route, environmental weathering and metabolism by the organism. In this study we report on the forensic evaluation of deep benthic macrofauna tissue samples collected from the spill zone deep benthic sediments following the DWH oil spill. The objective of this work was to develop a reliable approach to identify petroleum residuals in the deep benthic macrofauna tissue samples, and to the degree possible, determine the spatial extent of exposure attributable to the spilled Macondo oil. The results of this study showed that the red crab hepatopancreas samples provided the most sensitive and diagnostic chemical fingerprints by which to assess oil exposure. The highest exposures of red crabs to Macondo oil occurred closest to the well although exposures up to 14 km southwest of the well were identified.

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Update on the Toxicity of 1,4-Dioxane and Potential Regulatory Implications: Impact on Drinking Water Criteria

Shawn Sager, Norman Forsberg, Christopher Prucha, Louis Bull, Michael Dourson, Jeri Higginbotham, Patricia Nance, Jeff Crum, and Mark Lafranconi

1,4-Dioxane is emerging as a water resource contaminant of interest because of its presence in many industrial and commercial products as well as its historical use as a solvent and as a stabilizer for solvents (e.g., 1,1,1- trichloroethane). Due to its high solubility, 1,4-dioxane is frequently detected in groundwater at low part per billion levels. The United States Environmental Protection Agency (US EPA) revised its cancer evaluation for liver tumors in rodents in 2010 (US EPA 2010), concluding that 1,4-dioxane is likely to be carcinogenic to humans. US EPA justified developing a cancer risk assessment approach by also concluding that the available toxicological data were insufficient to adequately support a non-linearized cancer mode of action (MOA) for 1,4-dioxane. Applying these conclusions to the derivation of ground water quality criteria yields sub-part-per-billion levels. Scientific investigations by Dourson et al. (2014) and the Alliance for Risk Assessment (ARA) were performed specifically to determine if MOA data gaps identified by US EPA (2010) could be resolved. These investigations demonstrate that 1,4-dioxane causes liver tumors in rodents through a regenerative cell proliferation MOA. This cancer MOA shows a threshold of exposure below which tumors do not form and supports the use of a non-linear low-dose extrapolation procedure for estimating risks with the most-sensitive tumor endpoint. This presentation will summarize recent advances in the understanding of 1,4-dioxane's cancer MOA and discuss the impact of the new information on establishing risk-based drinking water quality criteria. To this end, US EPA's current approach for predicting potential impacts of low-dose exposure via development of liver tumors is compared to an alternative approach supported by additional scientific evidence that adequately protects against potential cancer risks. The results are used to derive a drinking water quality criterion that is over 1,000 times greater than that derived using US EPA's current linearized modeling approach.

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Perfluorooctanoic Acid (PFOA): Environmental Sources, Chemistry, Toxicology & Potential Risks

Michele Garber, Christopher Teaf, Douglas Covert, and Bruce Tuovila

Attention regarding perfluoroalkyl compounds (PFCs) has increased in recent years, in part due to recognition of widespread environmental presence, recognition of a chemical structure that confers resistance to degradation, and reported health concerns. Historical common exposure sources include food, drinking water, occupational circumstances, and products in commerce (e.g., carpeting, clothing, paper products). Early-2000s data showed perfluorooctanoic acid (PFOA) was present in blood samples from nearly all of U.S. general population (>99%). Alterations in industrial manufacturing processes, increased regulatory scrutiny, and advanced water treatment options have reduced the reported human body burden of PFCs in the U.S., including that for PFOA. Tissue levels of PFOA have exhibited a substantial decrease (~60%) between the 1999-2000 and the 2011-2012 NHANES monitoring by the Centers for Disease Control and Prevention (CDC). Notable variation was observed between gender and ethnic groups. The presence of PFOA tissue concentrations indicates some levels of exposure, but does not speak to what the source of that exposure may be. With respect to both non-cancer and potential cancer effects putatively associated with reported blood levels of PFCs, statements concluding no effects or insufficient information to suggest adverse effects outweigh a consistent conclusion about the occurrence of human health effects. In the last several years, a number of state and federal agencies have developed drinking water health advisories or guideline values for drinking water exposure in the sub-ppb range. In 2016, a US EPA Health Advisory of 0.07 ppb was released, in contrast to a 2016 Health-based Value from Health Canada of 0.2 to 30 ppb. Further work is necessary to distinguish in transparent fashion between those levels that are set on a conservative basis to protect human health and the levels that may be associated with adverse effects. The two are not synonymous.

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Application of Probabilistic Risk Analysis to Remedial Alternatives at the Portland Harbor Superfund Site

Betsy Ruffle, Deborah Edwards, Gemma Kirkwood-Cohen, and Clare Murphy-Hagan

In early 2017, US EPA Region 10 (EPA) released its Record of Decision (ROD) for the Portland Harbor Superfund Site with projected clean-up costs over $1 billion. Despite acknowledged uncertainty in risk and remedy effectiveness, an explicit evaluation of uncertainty was not performed. A probabilistic risk assessment (PRA) was performed to explicitly evaluate variability and uncertainty in Site risk and the risk reduction that may be achieved by remedial alternatives. The PRA focused on the risk-driving contaminant and exposure pathway, which is consumption of fish containing PCBs by tribal, subsistence, and recreational anglers. Probability distributions were fit to exposure parameters including fish consumption rate and tissue concentration using recent empirical and modeled smallmouth bass data sets. Based on the PRA, baseline risks/hazards for 99% of the angler populations are below the RME risks estimated in the RI and similar to risks posed by near upriver background. Current baseline risks/hazards for 90% of subsistence anglers and 95% of recreational anglers already meet EPA's interim risk targets (10^{-4} cancer risk and noncancer HI of 10). When coupled with spatial data evaluation, the PRA indicates that remediation of much less acreage than EPA's selected remedy achieves equivalent risk reduction and risk management targets for the vast majority of anglers. Further risk reduction is limited by background which poses risks in excess of EPA's long-term targets of 10^{-5} and HI of 1, and fish consumption advisories will remain regardless of the remedy selected. The application of PRA provides a framework that may be used in future analyses of risk and remedy evaluation as new data focused on reducing uncertainty and improving the overall understanding of the Site and target populations are generated.

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Development of Water-Effects Ratios (WERs) and Site-Specific Water Quality Criteria (SSC) for Aluminum, Cadmium, and Copper for the Androscoggin River

Patrick Gwinn, John Samuelian, and Elizabeth Rand

Development of site-specific ambient water quality criteria (SSC) can effectively achieve wastewater discharge permitting compliance while still protecting receiving water quality. Water-effect ratios (WERs), which quantify the differences in chemical bioavailability and toxicity between receiving water and laboratory water used in developing the AWQC, were developed for aluminum, cadmium, and copper for the Androscoggin River in Maine.

Under Section 304(a) of the Clean Water Act, the U.S. Environmental Protection Agency (EPA) develops and publishes national ambient water quality criteria (AWQC) for aquatic life based primarily on toxicity bioassays conducted in synthetic laboratory waters. While state regulatory agencies use these criteria to develop surface water discharge permits, EPA has long recognized in its regulations that these national guidance values may be modified "to reflect site specific conditions" (40 CFR 131.11(b)(1)). Development of site-specific ambient water quality criteria (SSC) can effectively achieve wastewater discharge permitting compliance while still protecting receiving water quality. Among several approaches to modifying national criteria to reflect state- or site-specific surface water and ecological conditions is the water-effect ratio (WER), which quantifies the differences in chemical bioavailability and toxicity between the receiving surface water and the laboratory water used in developing the AWQC. Following procedures stipulated in EPA guidance and Chapter 584(3)B of the Maine Department of Environmental Protection (DEP) rules, WERs and SSC were developed for aluminum, cadmium, and copper for the Androscoggin River. The methods and results of these WER studies, as well as the protectiveness of the proposed SSC, will be discussed in this presentation.

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State of the Art Consensus on How to Evaluate Bioavailability in Contaminated Soil: Guidance from ITRC

Kathryn Durant and Claudio Sorrentino

The Bioavailability in Contaminated Soil (BCS) guidance from the Interstate Technology and Regulatory Council (ITRC) will focus on lead, arsenic, and polycyclic aromatic hydrocarbons (PAHs). It will be a consensus-based, easy-to-read, web-based document that will represent the shared knowledge of representatives from state and federal regulatory agencies, the private sector, academia, and tribal and public stakeholders. It also will provide detailed information on available bioavailability and bioaccessibility tests, including what the user should consider to make informed decisions for a specific site.

The BCS guidance will include case studies that will show how bioavailability of lead, arsenic and PAHs has been evaluated at sites. It will discuss the challenges, how these challenges were overcome, and the lessons learned. In vivo methods can provide us with insights into site-specific bioavailability; however, the high cost and duration of these in vivo studies severely limit their applicability to a small number of large sites where there are considerable resources available and a long timeline. In the past few years, various groups have developed in vitro methods to measure bioaccessibility as a surrogate for bioavailability. These in vitro methods are available for arsenic (As) and lead (Pb), and their relatively low cost and turnaround time allow for the inclusion of site-specific bioavailability considerations for lower-budget sites. However, not all in vitro methods will necessarily work well with all types of soils and chemical forms of the contaminant. Accordingly, the decision on the suitability of any one method to determine bioaccessibility should take into consideration site-specific conditions.

We realize that a one-size-fits-all approach is not possible for evaluating the bioavailability of contaminants in soil, but the new ITRC guidance will provide tools to help make informed decisions.

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Session 8: State and Local Government Strategies for Reducing Climate Impacts

Surveillance Tools to Help Understand the Impact of Climate Change on Zoonotic Disease in Massachusetts
Catherine Brown, Deputy State Epidemiologist and State Public Health Veterinarian, Massachusetts Department of Public Health, Boston, MA; Stephen Rich, University of Massachusetts, Laboratory of Medical Zoology, Amherst, MA

Climate Vulnerability in the Deerfield River Watershed, MA
Katherin McArthur, Massachusetts Department of Transportation, Boston, MA; Paula Rees and Scott Jackson, University of Massachusetts Amherst, Amherst, MA; Stephen Mabee, Massachusetts Geological Survey, Amherst, MA

Incorporating Chemical Safety into Climate Change Resiliency Planning
Tiffany Skogstrom, Massachusetts Office of Technical Assistance, Executive Office of Energy & Environmental Affairs, Boston, MA

Human Health Assessment of Climate-Related Changes to Recreational Water Quality
Michael Celona, Kate Adams, Margaret Round, and Marc Nascarella, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA

Integrated Approaches for Evaluating Climate-Related Changes in Vector-Borne Disease
Kate Adams and Marc Nascarella, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA; Noriko Endo, Osama Mekki Seidahmed, and Elfatih Eltahir, Massachusetts Institute of Technology, Cambridge, MA; Matthew Osborne and Catherine Brown, Massachusetts Department of Public Health, Division of Epidemiology and Immunization, Boston, MA

Roundtable Discussion: State- and Locally-Based Resources to Support Local Health Adaptation Planning Efforts
Panel Chair: Margaret Round, Massachusetts Department of Public Health, Environmental Toxicology Program, Boston, MA

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Catherine Ratte, Pioneer Valley Planning Commission, Environment and Land Use Section, Springfield, MA

Surveillance Tools to Help Understand the Impact of Climate Change on Zoonotic Disease in Massachusetts

Catherine Brown and Stephen Rich

The Massachusetts Department of Public Health (MDPH) is developing translational tools to support local climate change intervention and adaptation strategies. A key feature of this effort is the implementation of the CDC's Building Resilience Against Climate Effect (BRACE) framework to assist communities in evaluating the local health effects of climate change. Through previous local health capacity assessments, MDPH has identified the development of tools to assist with vectorborne disease as a specific priority to reduce climate change related risks. This presentation will describe a review of state-based and crowd-sourced surveillance activities, mosquito control efforts, public information, and risk communication related to vectorborne disease control in Massachusetts. For example, MDPH, in collaboration with the State Reclamation and Mosquito Control Board (SRMCB) and regional mosquito control projects (MCP), conducts surveillance for mosquito-borne viruses that pose a risk to human health. Namely, there are two mosquito-borne diseases of concern for transmission in Massachusetts, eastern equine encephalitis (EEE) virus, which was identified as a cause of human disease in 1938, and West Nile virus (WNV), which has been present in Massachusetts since 2000. Surveillance currently focuses on West Nile and eastern equine encephalitis viruses, which are found in the local environment and are capable of causing serious illness and death in humans, horses, and other mammals. This presentation will also describe an approach to use crowd sourced passive surveillance in an academic (extension service) laboratory for monitoring tick-borne diseases. This aspect of the presentation will describe how public testing services of ticks and tick-borne diseases can be coupled with online interactive tools for climate change planning at the local level.

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Climate Vulnerability in the Deerfield River Watershed, MA

Katherin McArthur, Paula Rees, Scott Jackson, and Stephen Mabee

The landscape of narrow valleys and rushing streams that makes up much of inland New England is vulnerable to the impacts of extreme rainfall events. There is a history of severe flooding damage, ranging from Tropical Storm Irene in 2011 back to the Great Hurricane of 1938, impacting communities throughout the region. The risk to transportation infrastructure, which is often located close to water, is particularly acute, and extreme rainfall events are predicted to become more common in coming years due to the effects of climate change. In order to better understand that risk, the Massachusetts Department of Transportation (MassDOT) completed an in-depth pilot study of the Deerfield River Watershed, focusing on road-stream crossings. This study included field visits to nearly every crossing in the watershed, and investigated structural, hydraulic, and geomorphic risks of failure, along with ecological connectivity and impact on emergency medical services. The five individual elements were evaluated for each crossing, and an overall scoring system was developed to serve as a screening tool indicating crossing structures that are vulnerable to extreme weather events under both current and future climatic conditions. All results will be publicly available via a web tool, and MassDOT is currently investigating the possibility of extending some elements of the analysis state-wide.

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Incorporating Chemical Safety into Climate Change Resiliency Planning

Tiffany Skogstrom

Heat waves, flooding, intense storms, power outages and other climate change weather events pose a significant threat to communities where large toxic chemical users reside when critical infrastructure and services fail or are damaged. Through a grant from the US Environmental Protection Agency (EPA), the Massachusetts Office of Technical Assistance (OTA), and Regional Planning Agencies (RPAs) are hosting workshops to build awareness and educate city officials, community leaders, Local and Regional Emergency Planning Councils, and businesses about the toxic chemicals stored, used, and transported through their communities. OTA's Community Resilience and Chemical Safety program aims to provide RPAs, first responders, and others with expertise in chemical safety and identifying toxics users in their community while providing Massachusetts businesses with free, non-regulatory, and confidential assistance with toxics use reduction. OTA will demonstrate a new online mapping tool to identify toxics users in relation to climate change-related vulnerability factors such as flood and hurricane, as well as environmetal justice areas. In this way, OTA will work with stakeholders to prevent potential climate change related chemical disasters and bolster safer communities by educating community leaders about their vulnerabilities to chemicals within their vicinities, and by building toxics use reduction into local emergency preparedness and planning frameworks.

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Human Health Assessment of Climate-Related Changes to Recreational Water Quality

Michael Celona, Kathryn Adams, Margaret Round, and Marc Nascarella

Beaches in Massachusetts are required to be monitored regularly for fecal indicator bacteria during the summer season, and the resulting recreational water quality data provide a rich resource for understanding the relationship between climate and health. As a result of climate change, Massachusetts is expected to experience higher air and water temperatures and more frequent and intense rainfall events during the summer months. Climate change impacts may result in increased beach usage while at the same time increasing pathogen levels in the water and increasing human disease risk. We use a novel approach to assess these future climate impacts on recreational water quality and human disease using Virtual Beach, the United States Environmental Protection Agency's water quality modeling tool, to generate statistical models to predict current and future bacteria levels at one popular, urban Massachusetts beach. The model predicted bacterial concentrations using measured rainfall and water temperature for both dry and wet days during the 2011 to 2015 beach seasons and for projected conditions in 2025, 2055, and 2085. The modeling of future beach water quality indicates that increased rainfall during the 21st century will likely result in decreased water quality leading to increased numbers of GI illness on days following rain events, while on dry days, the increase in water temperature may reduce the incidence of GI illness. These findings indicate that communities and other beach operators can use modeling tools like Virtual Beach to help identify future climate-related health issues, and show the value of existing environmental monitoring programs and the need for additional resources to inform more effective monitoring and health-based intervention programs.

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Integrated Approaches for Evaluating Climate-Related Changes in Vector-Borne Disease

Kathryn Adams, Osama Seidahmed, Noriko Endo, Elfatih A. B. Eltahir, Matthew Osborne, Catherine Brown, and Marc Nascarella

Climate change brings many challenges for the control of mosquitoes and vectorborne disease. Increased temperatures and increased precipitation in the future are expected to alter the length of the active season for mosquitoes in Massachusetts, increase available habitat, and facilitate the migration and establishment of species of mosquitoes capable of introducing dangerous new viruses to the region. In this presentation, we will discuss an integrated approach that will help predict future mosquito-borne disease risk and inform mosquito control efforts in the Commonwealth. We will describe longstanding efforts to track and predict changes in mosquito habitat, species prevalence, season, and range and their implications for arbovirus transmission, and include surveillance of the currently common mosquito populations (such as *Culex Pipiens*, a carrier of West Nile Virus) and small established populations of *Aedes Albopictus*. We will also describe laboratory experiments designed to understand and parameterize the climate and weather conditions that enable *A. Albopictus* to survive New England winters, reproduce, establish, and spread. Finally, we will discuss how this information is being used in conjunction with climate predictions to build mechanistic models that will predict mosquito prevalence and behavior given changing climate conditions.

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Roundtable Discussion: State- and Locally-Based Resources to Support Local Health Adaptation Planning Efforts

Margaret Round, Wayne Feiden, Soloe Dennis, Ben Wood, and Catherine Ratte

Climate change is expected to impact human health by exacerbating many of the existing health conditions and contributing to emerging diseases. While climate change is a global problem, the health impacts from projected increases in heat events; poor air quality; sea level rise; coastal and inland flooding; vector-, food- and water-borne diseases; and extreme weather events will be most evident at the local level. Mitigation and adaptation strategies for addressing the underlying vulnerabilities have co-benefits that can lead to reductions in the existing burden of disease and enhance community resilience. Recognizing that local health departments are often the first to respond in addressing chronic health concerns of vulnerable residents, the Massachusetts Department of Public Health (MDPH) is developing translational tools to support local health-based intervention and adaptation strategies. This Panel Session will feature presentations by our key state, local and regional partners on a wide range of activities to reduce climate impacts at the local level, including informing planning initiatives by integrating climate-related vulnerabilities; supporting healthy community design initiatives to improve community health and increase resilience to climate impacts; advancing stakeholder engagement in climate action and resilience planning; and promoting social justice in municipal climate action planning process.

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Session 9: Practical Use of Advanced Analytical Tools for Management of Contaminated Sites

Multiple Lines of Evidence Approaches for Management of Contaminated Sites from 1998 to Today
Pat McLoughlin and Robert Pirkle, Pace Analytical Energy Services, Pittsburgh, PA

Microbial Community Evolution During In-Situ Aerobic Cometabolic Bioremediation of 1,4-Dioxane and 1,2-DCA
Min-Ying Jacob Chu, Haley & Aldrich, Inc., Phoenix, AZ; Aaron Peacock, Pace Analytical Energy Services, Pittsburgh, PA

New Innovations in Environmental Science
Stephen Koenigsberg, Civil & Environmental Consultants, Inc., Irvine, CA

Successful Advanced ISCO Analytical Practices
Matt Burns, WSP USA, Boston, MA; David Carstens, WSP USA, Woburn, MA; Molly Long and Maria Kaplan, WSP USA, Herndon, VA

Efficient and Auditable Site Monitoring Through Automation of Data Collection, Analysis and Result Delivery
Roelof Versteeg, Subsurface Insights, Hanover, NH; Aaron Peacock, Pace Analytical Energy Services, Pittsburgh, PA

Sustained Bioaugmentation via Insitu Bioreactors
Eric Raes, Engineering and Land Planning Associates, Inc., High Bridge, NJ; Dora Taggart, Katherine Clark, and Brett Baldwin, Microbial Insights, Inc., Knoxville, TN; Ryan Beebe, Earth Data Northeast, Inc., Exton, PA; Kerry Sublette, University of Tulsa, Tulsa, OK

Multiple Lines of Evidence Approaches for Management of Contaminated Sites from 1998 to Today

Patrick McLoughlin and Robert Pirkle

The "Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water" (EPA, 1998) used the three lines of evidence approach set out by OSWER: 1) historical groundwater assessments showing attenuation, 2) geochemical and/or hydrogeologic data supporting the assertion that the attenuation is going to meet the required clean-up levels in the appropriate time frame, and 3) data from field or microcosm studies directly demonstrating the occurrence of a particular attenuation process. In 1998 neither compound specific isotope analysis (CSIA) nor molecular based microbiology tools were available, yet the protocol was written to direct the use of these tools as the third line of evidence.

When the protocol was first introduced, microcosms were done for a small number of sites, but they were very expensive and often inconclusive. This meant monitored natural attenuation (MNA) was mostly for sites where the geochemical, hydrogeologic and attenuation data all clearly supported the choice of MNA as a remedy. However, nearly 20 years later, CSIA and molecular biology provide very powerful and affordable tools. Those tools make use of the third line of evidence much more routine.

In 1998 it was thought the biodegradation of chlorinated solvents was almost exclusively through reductive dechlorination. In 2010 Gossett reported oxidation of vinyl chloride in very low dissolved oxygen concentrations. Using CSIA and molecular biology it is often found that oxidation produces attenuation beyond what geochemical indicators for reductive dechlorination suggest. The use of this third line of evidence has expanded the number of sites where MNA can be used.

Several case studies are presented in which CSIA and molecular biology were used to assess oxidation and co-metabolism as well reduction. Properly accounting for these mechanisms expands the number of sites where MNA can be used and can help reduce the high energy demands, intrusion and expense of remediation.

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Microbial Community Evolution During In-Situ Aerobic Cometabolic Bioremediation of 1,4-Dioxane and 1,2-DCA

Min-Ying Jacob Chu and Aaron Peacock

The Air Force Civil Engineer Center supported a field demonstration project to test the effectiveness of in-situ aerobic cometabolic biodegradation (ACB) of 1,4-dioxane (1,4-D) and co-contaminants, including 1,2-dichlorothane (1,2-DCA) and trichloroethene (TCE) in shallow groundwater at the former McClellan Air Force Base. The groundwater in the test area is aerobic and contains 1,4-D (~50 ug/L), 1,2-DCA (~10 ug/L), and TCE (~4 ug/L). The site-specific cleanup goals for these constituents are 6.1, 0.5, and 5 ug/L, respectively. The results of this field test show that the in-situ ACB bioreactor stimulated through propane and oxygen addition was able to treat 1,4-D and 1,2-DCA below their site-specific cleanup goals (>90% treatment efficiency for all three compounds). During the field testing, the microbial community evolution in the treatment zone was assessed through functional genes and microbial community analysis of samples of native sediments, groundwater, and microbial samplers collected in the testing area. The results show that an increase in propane monooxygenase activity in groundwater along with propane addition. The concentrations of the 1,4-D metabolic degradation functional gene remained low, suggesting that metabolic 1,4-D biodegradation was insignificant and that ACB was responsible for observed degradation. The DNA sequencing results of several groundwater samples showed that the dominant genera that might contribute to the observed ACB activity include: *Azoarcus*, *Herbaspirillum*, *Hydrogenophaga*, *Mycobacterium*, *Pseudomonas*, and *Rhodocyclus*. Among them, *Herbaspirillum*, *Hydrogenophaga*, and *Mycobacterium* were detected in an in-situ cometabolic propane sparging study conducted at the site 15 years ago. Many bacterial strains in the genera *Mycobacterium* and *Pseudomonas* reported in the literature were capable of metabolically degrading short-chain alkanes and cometabolically degrading chloroethenes, MTBE, and TBA. Since *Azoarcus*, *Herbaspirillum*, *Hydrogenophaga*, *Mycobacterium*, and *Pseudomonas* are common soil bacterial genera, biostimulation is likely viable to treat 1,4-D and CVOCs in the low concentration range (<100 µg/L) at many sites.

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New Innovations in Environmental Science

Stephen Koenigsberg

A whole series of innovations in the environmental industry, such as microbiological tools, CSIA and flux discharge analysis, are now well established and, if anything, underutilized. The focus of this presentation is on a new wave of innovation. Some of the prominent topics that are surfacing include multi-criteria decision analysis, "big data" applications, novel ways to manage the full destruction of emerging contaminants with sensitive endpoint requirements and the use of sensors as part of the "internet of all things." We have chosen to address the latter two items listed, specifically a novel chemical reduction and/or oxidation capability referred to as Advanced Remediation Catalysis (ARC) and a unique sensor package called MiProbe, for the measurement of redox, metabolic turnover and metabolic gas evolution.

Accelerated Remediation Catalysis (ARC) can rapidly reduce concentrations of virtually any dissolved phase contaminant by chemical reduction or oxidation. It is primarily designed to address groundwater effluents, although there are industrial applications. Nested within this is a central objective to address very problematic emerging contaminants such as 1,4-D and PFASs, where treatment options are limited. The operational components include reductants and/or oxidants in the gas phase, an inexpensive catalyst and the application of shear forces that dramatically accelerate reaction times. The overall detention time for completion of most reactions, from ppm levels to ND, has been about 10 to 15 minutes.

The MiProbe microbial sensor system is now available for the characterization of contaminated sites focusing on microbial activity and source zone reduction. The primary objective is to support natural source zone depletion (NSZD) strategies by examining carbon dioxide and methane evolution in relation to mass loss. Other collateral measurements such as redox potential, with unique sensitivities, are integrated into the system. Some derivative applications include the use of the sensors to map the redox potential of a site both before and after chemical intervention to drive efficiencies, as sentinels for plume expansion management and the evaluation of bioavailability in sediments as part of monitored natural recovery (MNR).

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Successful Advanced ISCO Analytical Practices

Matthew Burns, David Carstens, Molly Long, and Maria Kaplan

For most remediation sites, a thorough conceptual site model (CSM) is needed to define the scope of the problem and to begin a remedial feasibility evaluation. In addition to the physical characteristics and contaminant fate and transport information commonly measured during remedial investigations, in situ chemical oxidation (ISCO) requires additional treatment-specific data collection activities for successful design, application, and post-treatment monitoring. To complicate pre-design investigations further, ISCO is increasingly implemented as a combined remedy with other technologies, such as bioremediation, to overcome limitations related to the rapid decomposition characteristic of most oxidants. The advantages of a combined remedy approach include long-term management of rebound caused by partitioning and matrix back diffusion. The combined remedy approach increases the need for advanced site characterization and further compounds analytical challenges associated with successful ISCO implementation. This presentation will focus on conventional and advanced analytical diagnostics that increase the likelihood of achieving remedial goals at ISCO sites.

The authors have adopted a fail small / succeed big approach for ISCO and combined remedy applications. The approach leverages conventional and advanced diagnostics as predictive tools that provide actionable data to define the efficacy and mechanism of a contemplated treatment strategy. Bench testing, when completed in a manner that is scalable, is a key strategy that defines the relationship between amendment dose and treatment efficacy, while identifying potential site-scale concerns such as the generation of undesirable intermediates, mobilization of metals, and hazardous off gassing. At pilot- and full-scale, confounding performance assessment factors such as quantifying treatment efficiency concurrent with rebound and assessing destruction efficiency by discrete treatments of a combined remedy can be overcome by using advanced molecular diagnostics such as compound specific isotope analysis (CSIA) and quantitative polymerase chain reaction procedures. These conventional and advanced diagnostic procedures will be discussed using examples from several sites.

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Efficient and Auditable Site Monitoring Through Automation of Data Collection, Analysis and Result Delivery

Roelof Versteeg and Aaron Peacock

Cost efficient, auditable and near real time site monitoring is needed for both operational and regulatory purposes. The ability to semi automatically collect large amounts of heterogeneous data (bio geochemical, hydrological, geophysical and remote sensing) which provides information on site evolution has increased at the same time as the cost of such data collection has decreased. However, capabilities to effectively process, analyse and use this data have lagged behind, and in many cases users are drowning in data and are managing data using inadequate tools.

We will describe and demonstrate a new cloud based, modular and extensible software framework. This framework (PAF – Predictive Assimilation Framework) is implemented using a client server model where the software client is either a standard browser or a smartphone (Android/IOS. The server performs real time data collection (using both push and pull mechanisms), data ingestion ad qa/qc and processing. The the software client retrieves data from the server for visualization and analysis purposes. PAF can ingest geochemical, hydrological, geophysical and remote sensing data from a wide variety of sources, and can run a variety of numerical models and analysis tools (such as Modflow, PEST, PFLOTRAN, E4D and so on) automatically. PAF users and data are organized by projects, in which each user has project specific permissions. Users can set alarms, share graphs and automatically generate reports. PAF is fully integrated with novel fully autonomous electrical resistivity hardware developed by Subsurface Insights. PAF is currently in use by the US Department of Energy and multiple private companies. PAF is provided under a SAAS (Software as a service) model.

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Sustained Bioaugmentation via Insitu Bioreactors

Eric Raes, Dora Taggart, Katherine Clark, Brett Baldwin, Ryan Beebe, and Kerry Sublette

Background/Objectives. The current study describes the use and performance of an in situ bioreactor (ISBR) in promoting reductive dechlorination of trichloroethylene (TCE) in a bedrock monitoring well, and other case studies.

Approach/Activities. The study site is a former chemical distribution facility where a deep, fractured aquifer had been impacted predominately by TCE (1,230 µg/L). An ISBR unit was installed in an existing monitoring well to promote reductive dechlorination. The ISBR was deployed in an existing monitoring well at a depth of 60 ft. BGS. Groundwater samples were routinely obtained at a depth of 140 ft. 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 depths of 60, 85, 105 and 140 ft. BGS

Results/Lessons Learned. Prior to ISBR deployment, cis-1,2-dichloroethylene (cDCE) was detected (133 µg/L) but vinyl chloride and ethene concentrations were below detection limits suggesting reductive dechlorination was limited under existing conditions. 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. Overall, the results conclusively demonstrated that the ISBR successfully enhanced anaerobic bioremediation throughout the saturated thickness of the monitoring well and indicated that ISBRs can be an effective remediation approach even in a deep, fractured bedrock aquifer.

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Session 10: Advancing the Clean Energy Economy in Massachusetts

UMass Clean Energy Extension: Advancing the Massachusetts Clean Energy Economy with Research, Outreach, and Service
River Strong, UMass Clean Energy Extension, Amherst, MA

Charging Up Massachusetts: Energy Storage Initiatives in the Commonwealth
Karen Kao, Massachusetts Clean Energy Center, Boston, MA

Documentation and Decision Making at Solar Array Developments Utilizing Unmanned Aircraft Systems (UASs)
Andrew Bakinowski, Weston & Sampson Engineers, Inc., Foxborough, MA

Quantifying Wind Turbine Noise
Ethan Brush and James Barnes, Acentech, Inc., Cambridge, MA

Generation of Bioenergy from Energetic Compounds-Contaminated Wastewater Streams Using Microalgae *Scenedesmus obliquus*
Abhishek RoyChowdhury, Juliana Abraham, Christos Christodoulatos, Yanxia Lin, and Washington Braida, Stevens Institute of Technology, Hoboken, NJ; Per Arienti and Benjamin Smolinski, RDECOM-ARDEC, Wharton, NJ

UMass Clean Energy Extension: Advancing the Massachusetts Clean Energy Economy with Research, Outreach, and Service

River Strong

The transition to a clean energy economy is critical for Massachusetts to meet its greenhouse gas reduction commitments and provides an opportunity for new economic development in the Commonwealth. UMass Clean Energy Extension (CEE) provides a unique model and resource to help accelerate the adoption of clean energy technologies across the state. Established in 2014 with support from the Massachusetts Department of Energy Resources, CEE strategically mobilizes its staff, its partners, and the resources across the UMass community to foster state market opportunities, address market barriers, and unleash private sector activities. CEE's programmatic efforts are organized into four activity areas:

1. *Market Analysis & Outreach:* This area provides a focus on strategic research, analysis, and reporting related to determining the characteristics, extents, and dynamics of potential Massachusetts clean energy markets.
2. *Collaborative Applied Research:* This area provides a focus on supporting the UMass research mission and expanding the public knowledgebase that supports the advancement and adoption of energy efficiency and renewable energy.
3. *Technical Assistance & Advisory Services:* This area provides a focus on providing direct assistance to CEE's client-base as provided by CEE faculty and staff specialists.
4. *Education & Workforce Development:* This area provides a focus on providing workforce development, education, and skills training opportunities to UMass students and other potential clean energy workers in the clean energy sector.

This session will describe the unique role that CEE plays as an interface between the state's government, communities, institutions, and business sector in advancing the Massachusetts clean energy economy. We'll also explore specific CEE clean energy projects and initiatives, share results from our work to-date, and take a look at future plans and directions.

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Charging Up Massachusetts: Energy Storage Initiatives in the Commonwealth

Karen Kao

In 2015, the Baker-Polito Administration announced a two-phase, $10 million dollar Energy Storage Initiative ("ESI"). The ESI aims to advance the energy storage segment of the Massachusetts clean energy industry by expanding storage technology markets, assigning value to storage benefits, accelerating the development of storage technologies, and attracting and supporting energy storage companies throughout the Commonwealth. In phase one of ESI, the Massachusetts Clean Energy Center partnered with the Department of Energy Resources on *State of Charge,* a comprehensive energy storage study to obtain a broad view of energy storage technologies that will inform future policy and programs. In phase two of ESI, energy storage demonstration projects will be solicited through the Advancing Commonwealth Energy Storage Program, an initiative informed and designed by the recommendations coming out of *State of Charge*.

In addition to ESI, the Massachusetts Clean Energy Center is also supporting a number of other energy storage and energy resilience initiatives, from a Solar Plus Storage for Manufacturers Program to an engineering design study for an energy storage system on Moon Island, a Boston Harbor Island where the Boston Fire Department trains, to help support the development of energy storage fire safety codes, standards, and training content.

This presentation will provide an overview of the multitude of energy storage initiatives in the Commonwealth.

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Documentation and Decision Making at Solar Array Developments Utilizing Unmanned Aircraft Systems (UASs)

Andrew Bakinowski

Documentation and decision making at solar array developments can be greatly enhanced through the use of UASs. A UAS, or drone, can cover large areas of the development in a short amount of time, speeding up data collection for documentation purposes. Drones have high resolution cameras that produce a detailed record and at the same time provide a unique elevated perspective of the development of a solar array.

Drone photography provides a rapid assessment of construction progress, and allows an overhead view of specific components such as racking, inverters, transformers and switch gear. Periodic flights document the progress of the work including array layout, and in some cases, provide information needed to make field adjustments.

Industry professionals are quickly adopting the technology, and including it in their existing workflows with substantial benefits. The results of the precision aerial photogrammetry are high resolution, geospatially referenced, full color 3D models that are gathered safely and efficiently. These data are currently being used for planning and design, determination of sensitive areas such as wetlands boundaries, analyzing areas of differential settlement, and generation of land use alternatives. Multispectral and thermal imaging sensors deployed on the same platform are also being used for vegetation health analysis and gas wellhead temperature analysis, subsurface oxidation, and detection of gas releases.

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Quantifying Wind Turbine Noise

Ethan Brush and James Barnes

For renewable energy projects, wind turbine noise continues to be a contentious issue in the development and operation for a number of wind farms. Developers seeking to site a wind energy project rely on rigorous ambient sound measurements and extensive modeling to demonstrate regulatory compliance. Once operational, even with demonstrated project compliance per regulatory rules, wind farms may face heightened scrutiny as nearby community members begin to experience the noise emissions first-hand.

This paper will summarize the current regulations and research areas surrounding wind turbine noise. The many technical challenges in quantifying turbine noise apart from background sounds in the surrounding environment will also be discussed. Examples from wind projects throughout the northeastern United States will be covered.

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Generation of Bioenergy from Energetic Compounds-Contaminated Wastewater Streams Using Microalgae Scenedesmus obliquus

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Manufacturing facilities for energetic compounds generate large amounts of wastewaters that often require expensive and energy-intensive treatments in order to meet regulatory requirements for their release. The purpose of this study was to utilize the nutrient rich untreated wastewater streams from an industrial-base munitions facility for production of microalgae that can be used for bioenergy production. Ten different energetic-laden wastewater streams were collected and individually tested for their toxicity using *Scenedesmus obliquus* ATTC® 11477 as the target organism. Toxicity tests were performed using microplates for 6 days and the results showed that a majority of the untreated wastewater streams have the potential to promote microalgal growth, as they are not only non-toxic to the microalgal population but also can provide nutrient sources to sustain them. Laboratory scale batch incubation studies were performed to validate the findings of the toxicity tests using 250ml flasks with a working volume of 100ml. It was found that the mixing of certain wastewater streams well supported the growth of *S. obliquus* over a period of 25 days. A scaled-up study was performed using 100L open pond raceway reactor to grow *S. obliquus* using mixture of untreated wastewater streams as culture media. The raceway reactor was operated under 50 rpm agitator speed, 14:10 hours light:dark photoperiod, and 5000-7000 lux of light intensity for 30 days. Weekly harvesting of 10% volume was conducted from the raceway reactor and the samples were analyzed for their oil content. A continuous monitoring of pH and temperature of the media and periodic analysis of cell density and dry weight of microalgae and nutrient contents of the media were performed. The results of this study showed that the untreated energetic-laden industrial wastewater streams have the potential to support microalgae growth which can be further used to produce renewable bioenergy such as biofuel or biogas.

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Session 11: Per- and Polyfluoroalkyl Substances (PFAS) Hot Topics

Limitations of PFAS Data and Recommendations to Obtain Appropriate Data for Environmental Decision Making
Nancy Rothman and Susan Chapnick, NEH, Inc., Skillman, NJ

The Persistence of Fluorinated Chemicals in Food Wrappers and Consumer Products
David Andrews, Environmental Working Group, Washington, DC

Perfluorinated Compounds and Impacted Communities: Bridging the Knowledge Gap Between PFAS Contamination and Local Concerns
David Bond and Janet Foley, Bennington College, Bennington, VT

Potential for PFAS Cross-Contamination from Sampling Equipment, Clothing, and Personal Care Products
James Occhialini, Alpha Analytical, Westborough, MA; Greg Yogus, Alpha Analytical, Inc., Mansfield, MA; Elizabeth Denly, TRC, Lowell, MA

Per- and Polyfluoroalkyl Substances (PFAS) Remedial Options
Mike Marley, XDD Environmental, Stratham, NH

Wait, There's More? What's Next in the World of PFAS Toxicology
Janet Anderson, Integral Consulting, Inc., San Antonio, TX

Limitations of PFAS Data and Recommendations to Obtain Appropriate Data for Environmental Decision Making

Susan Chapnick and Nancy Rothman

Establishment of health advisory levels for per- and polyfluoroalkyl substances (PFAS) in drinking water requires that the site characterization and analytical methodologies are technically sound to generate appropriate data for environmental decision making. Unfortunately, we are limited to-date in that EPA Method 537 is the only published regulatory method for analysis of these substances and this method is only applicable to drinking water and not directly applicable to groundwater, soil, sediment, or biota. Additionally, there are currently no generally-accepted procedures or guidelines for field sampling of these other environmental media for PFAS. Therefore, the environmental community and regulatory decision makers face broad technical gaps and challenges to interpretation of PFAS contamination in environmental media important for evaluating exposure pathways.

The Interstate Technology & Regulatory Council (ITRC) has gathered a PFAS team of scientific experts to develop guidance and produce a series of six Fact Sheets on the following core PFAS topics:

1. History and Use of Environmental Sources
2. Nomenclature Overview and Physicochemical Properties
3. Fate and Transport
4. Site Characterization Tools, Sampling Techniques, and Laboratory Analytical Methods
5. Remediation Technologies and Methods
6. Regulatory Summary

This presentation will focus on Fact Sheet #4 based on the author's direct participation on the ITRC PFAS team and additional analytical experience. Specific issues, limitations, and interferences in PFAS data using EPA Method 537 will be discussed along with the major factors affecting analytical accuracy of PFAS compounds. Differences in quantitation approaches and their effect on data certainty will be presented as well as recommendations to obtain technically valid data for environmental decisions in various media.

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The Persistence of Fluorinated Chemicals in Food Wrappers and Consumer Products

David Andrews

Poly- and perfluoroalkyl substances (PFASs or PFCs) are common ingredients in consumer products due to their ability to add water- and oil-repellency. Fast food wrappers, textile and furniture treatments, outerwear clothing, and other products commonly incorporate PFAS chemicals. While the chemicals PFOA, PFOS and other long-chain PFAS chemicals are no longer directly used to make the coatings used on consumer products, the shorter-chain replacement chemicals are getting increased scientific, public, and regulatory scrutiny. A novel technique to measure the total fluorine content of food contact materials coupled with liquid chromatography/high resolution mass spectrometry was used to screen fast food wrappers across the country. Approximately 1/3 of fast food packaging, primarily treated paper wrappers, had levels of fluorine indicative of intentionally added PFASs. Public awareness and sustainability concerns along with these testing results are forcing a more in-depth analysis of persistent fluorinated chemicals and their use in food wrappers and presence in the waste stream. This fluorine testing technique is applicable to rapid marketplace screening of products in additional consumer product categories. This presentation will detail fast food wrapper testing results, consumer awareness of PFAS usage and recent policy developments.

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Perfluorinated Compounds and Impacted Communities: Bridging the Knowledge Gap Between PFAS Contamination and Local Concerns

David Bond and Janet Foley

This presentation outlines the ongoing work of Bennington College to respond to the discovery of PFAS contamination in our region. Our project, "Understanding PFOA," has worked to open the science classroom and science curriculum at Bennington College to community concerns regarding PFAS contamination. Working in Hoosick Falls, New York and Bennington, Vermont, and funded by the National Science Foundation (NSF), our project aims to bridge the knowledge gap between the questions raised by impacted communities and cutting-edge scientific research into PFAS contamination. This presentation will review our project, with special emphasis on unfolding investigations into the variance and distribution of perflourinated compounds, and describe how colleges and universities can be a useful partner in responding to PFAS contamination.

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Potential for PFAS Cross-Contamination from Sampling Equipment, Clothing, and Personal Care Products

James Occhialini, Elizabeth Denly, and Greg Yogus

Because of the potential presence of PFAS in common consumer products and in equipment typically used to collect soil, groundwater, surface water, sediment, and drinking water samples as well as the need for very low reporting limits, special handling and care is always advised when collecting samples for PFAS analysis to avoid sample contamination. In this paper, the authors investigate what the potential for cross-contamination is from a number of commonly used products, with the emphasis on evaluating what the possible worst-case scenario for cross-contamination could be. A series of experiments are performed utilizing leaching and vapor phase transport models. All data is presented along with experimental observations and recommendations.

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Per- and Polyfluoroalkyl Substances (PFAS) Remedial Options

Mike Marley

PFAS are contaminants of emerging concern that are increasingly being detected in ground, surface, and drinking water. PFAS are associated with a variety of products including firefighting foams, carpeting, non-stick cookware, and food wrappings, and are not naturally occurring in the environment.

This informative presentation will provide an overview of PFAS physical-chemical properties related to potential for remediation and discuss both ex- and in-situ remedial options for PFAS in soil and groundwater. An overview on the state of the knowledge on the treatment of PFAS using physical, chemical, and biological technologies for source and plume areas will be provided.

Commonly, characterization practices do not fully consider potential/probable remedial technology selection for a site. Integrating key data collection for the appropriate remedial options into the characterization phase of a project can reduce project costs and increase project execution efficiency. Appropriate key data for each promising PFAS remedial approach will be presented.

Case studies at the bench- and field-scale will be used to demonstrate both long and short-chain PFAS treatment effectiveness using adsorption and chemical technologies. For adsorption, a comparison of carbon and ion-exchange resin based systems will be presented. For chemical oxidation, bench and field pilot testing of PFAS intermixed with chlorinated solvents at an air force base will be discussed.

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Wait, There's More? What's Next in the World of PFAS Toxicology

Janet Anderson

As far as "emerging contaminants" go, one might think that per- and polyfluoroalkyl substances (PFASs) have already emerged. There are federal drinking water health advisories for the two most notorious PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), and over a dozen state regulatory agencies have developed their own drinking water guidance values or environmental screening levels, and the number of states with promulgated standards or guidance values continues to grow. Large public water supply systems nationwide have tested for a suite of PFAS in public drinking water, and where levels caused a health concern, actions are underway to mitigate human exposure and determine long-term remedies. Although absent a federal drinking water standard (i.e., a maximum contaminant level, MCL), large-scale and costly cleanup efforts are underway nationwide by industrial manufacturers and users, and by end-product users such as the U.S. Department of Defense whose use of products containing PFASs has resulted in extensive environmental contamination. However, the regulatory landscape for these chemicals remains inconsistent and disparate with regulatory decisions and threshold guidance values that span orders of magnitude. Despite the varying and still controversial and uncertain actions regarding PFOA and PFOS, scientific and regulatory attention is now shifting towards the vast number of "other" PFASs, including fluorotelomers (FTs) and shorter-chain PFASs, which are still in production and use today. Key factors impacting the controversy and uncertainty surrounding the entire class of PFAS will be highlighted in this presentation. Examples of emerging questions and new issues related to PFAS will be discussed. We will also present opinions regarding which of the emerging PFAS issues may be of importance to future public health and safety and/or current strategies employed to address PFOA and PFOS.

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Session 12: Sustainability Considerations in Remediation and Restoration

Life Cycle Inventory Data for Use in Assessing Environmental Footprints of Green Remediation Projects
Paul Randall, David Meyer, Wesley Ingwersen, Scott Unger, and Michael Gonzalez, US EPA, Cincinnati, OH; Karen Scheuermann, US EPA, San Francisco, CA

Geospatial Analysis for Optimization at Environmental Sites
Gail Lipfert, Maine Department of Environmental Protection, Augusta, ME; Ning-Wu Chang, California Department of Toxic Substances Control, Cypress, CA; Harold Templin, Indiana Department of Environmental Management, Indianapolis, IN

Buses, Brownfields & Bedrooms – A Case Study of the Former Bartlett Yard Bus Garage Remediation
Patrick Lyons and Paul Uzgiris, Weston & Sampson Engineers, Inc., Peabody, MA

Programmatic Integration and Management of Green and Sustainable Remediation
Lindsay Burton, ExxonMobil Environmental Services Company, Houston, TX; Frank Messina, ExxonMobil Environmental Services Company, Linden, NJ

Urban Background: The Development, Current Status, and Lessons Learned for the Southeast Regional Study
Sheri Adkins and Christoph Uhlenbruch, Kentucky Department for Environmental Protection, Frankfort, KY

Using Systems Thinking and Waste Materials to Improve the Sustainability Footprint of a Cleanup – The Drive for a Zero Footprint Cleanup Technology
Paul Favara, CH2M, Gainesville, FL; Jeff Gamlin, CH2M, Englewood, CO

Life Cycle Inventory Data for Use in Assessing Environmental Footprints for Green Remediation Projects

Paul Randall, David Meyer, Wesley Ingwersen, Scott Unger, Karen Scheuermann, and Michael Gonzalez

At contaminated site cleanups, activities use energy, water, and natural resources and create an environmental footprint. EPA is using life cycle modeling to develop emission factors associated with a contaminated site cleanup. The developed emission factors will be added to Spreadsheets for Environmental Footprint Analysis (SEFA). SEFA is a set of analytical workbooks used to quantify the environmental footprint of a site cleanup. EPA has developed emission factors for several aspects of environmental remediation sites that will be added to SEFA, including material production, transportation and onsite equipment, and analytical chemistry methods. The emission factors were derived from currently available life cycle inventory datasets developed for commercial databases, industry trade associations, and scholarly publications. The emission factors were based on the following metrics: NOX (kg NOX), SOX (kg SOX), Global Warming: GWP100 (Global Warming Potential) (kg CO2 eq), Water Use (m3 H2O), PM10 (kg PM), HAPs (kg HAPs), Fossil Depletion: FDP (Fossil Depletion Potential) (kg oil eq), and Energy Demand: CED (Cumulative Energy Demand) (MJ). Furthermore, the addition of vehicle and equipment emission factors constitutes a significant contribution towards improving the performance of SEFA. Numerous vehicle and equipment options were modeled using a consistent approach based on emission profile simulations provided by the US EPA's Motor Vehicle Emission Simulator (MOVES). The resulting emission factors provide adequate coverage for most vehicle and equipment options associated with remediation sites.

In addition, emission factors were developed for analytical chemistry services, specifically, EPA methods promulgated by the Clean Water Act section 304(h). The analyzed methods are used to measure chemical and biological pollutants in media, such as wastewater, ambient water, sediment, and biosolids (sewage sludge).

Although the datasets are suitable for current use, future work will focus on replacing emission factors based on European datasets with data more consistent with US conditions.

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Geospatial Analysis for Optimization at Environmental Sites

Gail Lipfert, Ning-Wu Chang, and Harold Templin

Optimization activities can improve performance, increase monitoring efficiency, and support contaminated site decisions to achieve green and sustainable remediation objective. Geospatial analysis can be used to help evaluate such optimization opportunities. Unlike traditional statistical analysis, geospatial methods incorporate the spatial and temporal dependence between nearby data points. This dependence is a central feature of almost all environmental data. Analysis of data within their location and time contexts often provides additional lines of evidence to support decision making and optimization across all project life cycle stages and in all media, and for different sizes and types of sites.

This presentation introduces the ITRC's Geospatial Analysis for Optimization at Environmental Sites (http://gro-1.itrcweb.org/) web-based guidance document, which provides the important fundamental concepts, requirements and approaches in geospatial analysis that are applicable to the environmental project, as well as geospatial analysis methods and useful tools to answer those optimization questions that may be asked during the project life cycle.

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Buses, Brownfields & Bedrooms - A Case Study of the Former Bartlett Yard Bus Garage Remediation

Patrick Lyons and Paul Uzgiris

Bartlett Yard took many forms in its one hundred plus year tenure serving Boston's Dudley Square neighborhood. It was born an elevated railcar station, turned bus terminal upon the "bustitution" of the rail car, and ultimately met its maker as an abandoned bus maintenance facility. Through its many faces and roles over the years, Bartlett Yard remained the linchpin connecting Roxbury to the rest of Boston's thriving community. Throughout the turn of the 21st century, Dudley Square saw a precipitous economic decline, and rampant business abandonment. Bartlett Yard was no exception, as it was vacant and vandalized for more than a decade. Nuestra Communidad, a local non-profit organization, headed up this project to redevelop the site for residential and commercial use.

The Brownfields site was riddled with weathered diesel fuel, heavy metals, LNAPL, and subsurface structures from its rail yard past. Cobblestones, rails, and historic cisterns were just a few of the discoveries on-site. Shallow bedrock and groundwater played a critical role in the spread of contamination through the 7 acre site. Bridging the gap between the developer's plans and the MCP regulations was a considerable collaborative effort. Part of the proposed redevelopment included a residential high-rise atop a 25 foot tall retaining wall that once was the foundation of the elevated tracks. Through metal hotspot removal and excavation and disposal of grossly contaminated material, the site was closed out without an AUL.

Crucial to the completion of the project were the funding through the EPA's Brownfields program and the support of the community. Nuestra Communidad and the community knew that the success of this project would further the revitalization of Dudley Square. Through the collaborative development efforts and multifaceted remediation of the site, the groundwork for Bartlett Yard's rebirth has begun.

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Programmatic Integration and Management of Green and Sustainable Remediation

Lindsay Burton and Frank Messina

Background/Objectives. Present the results of a Green and Sustainable Remediation (GSR) literature review and the steps taken toward integration and management on a programmatic level.

Approach/Activities. An initial comparative analysis was completed of Exxon Mobil Corporation principles and their degree of alignment with ASTM Standard Guide for Integrating Sustainable Objectives into Cleanup, ASTM Standard Guide for Greener Cleanups, EPA Green Cleanup Principles, ITRC Green and Sustainable Remediation: A Practical Framework, SURF Framework for Integrating Sustainability into Remediation Projects, and Navy Guidance on Green and Sustainable Remediation.

ExxonMobil Environmental Services Company subsequently performed a series of pilot studies to evaluate GSR metrics through the use of several sustainability tools to assess how to effectively incorporate best management practices (BMPs) into remediation decision making. From these studies it was concluded that a more structured and quantifiable approach was necessary to implement GSR BMPs on a global scale.

Using the analysis described above, a Best Management Practice (BMP) tool was created combining the spectrum of publicly available "Green" and "Sustainable" metrics and filtering to those which are relevant. A second pilot study using the tool will be implemented during the months of June to August (2017). Once pilot study is complete, the program will be internally peer reviewed to determine the best path forward.

Results/Lessons Learned. This presentation will demonstrate (1) the key metrics considered/ used to measure the success of a "Green" and "Sustainable" program, (2) challenges to implementation of the program, (3) key lessons learned that have shaped the evolution of the program, and (4) the results of GSR integration and management on a programmatic level.

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Urban Background: The Development, Current Status, and Lessons Learned for the Southeast Regional Study

Sheri Adkins and Christoph Uhlenbruch

Across the globe, regulators and environmental professionals struggle with making sound, science-based decisions at sites that are located in urban areas. These areas are often impacted by long-term anthropogenic deposition of common industrial and urban contaminants such as lead, arsenic and Polycyclic Aromatic Hydrocarbons (PAHs), accumulating over time to form a non-point source blanket of contamination.

Increasingly, studies are being conducted regarding the so-called "urban background" issue, and it is becoming widely recognized that anthropogenic sources can have a potential impact on the constituent levels at sites that are considered contaminated by regulatory standards, yet these sources are not related to a release or on-site activity. Too often the only way to address urban background at a site is to do a costly study which may be impractical. Regulators and environmental professionals are left with remediating or managing sites to standards that may be unwarranted.

In an attempt to address this issue, the Kentucky Department for Environmental Protection Superfund Branch has been working with EPA Region 4 and its member states. With funding and support from EPA's Office of Research and Development (ORD), EPA Region 4 offices, and EPA's Nevada and Georgia regional labs, a grant-funded project has been implemented to conduct a regional urban background study with sample sets from one to two cities from each Region 4 state.

This study was the topic of a workshop at the 2016 AEHS Foundation Amherst Conference; this session will give an overview of the study framework, discuss project updates, highlight recent sampling, and share innovative strategies utilized by the project team to continue the study despite funding and access issues.

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Using Systems Thinking and Waste Materials to Improve the Sustainability Footprint of a Cleanup – The Drive for a Zero Footprint Cleanup Technology

Paul Favara and Jeff Gamlin

The two most common approaches for implementing sustainability into cleanup projects are: 1) evaluating and selecting best management practices, and 2) performing a footprint analysis to compare cleanup options or identify opportunities to reduce the footprint of a specific remedy. These approaches are typically applied after a remedy has been developed, and miss some opportunities to develop a more sustainable remedy. Applying sustainability approaches after a remedy has been developed could be considered a "top-down" approach since sustainability is considered after the alternative is developed. The upside for implementing sustainable remedies is much higher when the remedy is developed with sustainability in mind. This can be considered a "bottom-up" approach, and allows for systems thinking to be included in the technology development and could result in new or different technologies being considered. By coupling systems thinking with an objective to maximize utilization of waste or non-refined materials, the sustainability profile for a cleanup can be improved.

By taking elements of industry experience, and leveraging the power of systems thinking to improve engineered outcomes, more sustainable remedies can be developed. The use of Life Cycle Assessment (LCA) can help identify many sustainability impacts for remediation projects and shine a light on the opportunity to reduce those impacts through material substitution and optimization while not compromising the effectiveness of the remedy. The design of an insitu solar powered biogeochemical reactor (SBGR) to treat chlorinated ethenes in groundwater is used as an example to demonstrate how systems thinking can be used to identify sustainability impacts and minimize their negative impacts. The SBGR technology is also compared to a recognized sustainable remediation technology, enhanced insitu bioremediation (EISB), to demonstrate the sustainability benefits of system thinking.

The approaches presented in this presentation indicate the promise of developing zero, or near zero, sustainability footprint treatment technologies.

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Session 13a: PFAS Fate and Transport

Occurrence of PFAS in Environmental Media Associated with AFFF Release Areas at Multiple Installations
Kerry Robert Tull and Nathan Hagelin, Amec Foster Wheeler, Portland, ME; Sean Gormley, Amec Foster Wheeler, Portland, OR

PFAS Fate and Transport – A Heuristic Model for Understanding PFAS in the Environment
Harrison Roakes, Sanborn, Head & Associates, Inc., Concord, NH; Stephen Zemba, Sanborn, Head & Associates, Inc., Randolph, VT

Evaluating Historical Industrial PFOA Emissions Through Air Deposition Modeling
Catherine Beahm, New Hampshire Department of Environmental Services, Concord, NH

Occurrence of PFAS in Environmental Media Associated with AFFF Release Areas at Multiple Installations

Nathan Hagelin, Sean Gormley, and Kerry Robert Tull

Background/Objectives. PFAS Site Investigations at 39 former installations has led to the discovery of multiple PFAS release areas, primarily from the use of aqueous film forming foam (AFFF) at fire training areas (FTAs). PFAS groundwater impacts have resulted in well-publicized closures of public water supplies. PFAS are persistent and migrate long distances in groundwater with little retardation or degradation rendering groundwater discharge areas vulnerable. Some surface water bodies downgradient from PFAS release areas have been contaminated with PFAS, but the relative contribution from groundwater transport versus surface flow related sources is unclear. PFAS has been found in fish tissue; fish advisories have been put in place to limit consumption of fish. The sediment and porewater interface between groundwater and surface water has been characterized. This presentation analyzes the occurrence of PFAS in media relative to environmental setting, source characteristics, fate and transport, and risk.

Approach/Activities. Preliminary Assessments and Site Investigations at 39 installations have confirmed PFAS releases and impacts to groundwater at multiple FTAs. A robust and growing data set is mined to glean initial findings about PFAS behavior in the environment. A comparative analysis of PFAS distribution in AFFF release areas, groundwater, storm water, surface water, sediment, and fish tissue is made focusing on the relative concentration of PFAS over various carbon chain lengths. An understanding of the dominant transport pathways, chemical fate, and contaminant sinks emerges. One installation is isolated from the data set as a case study.

Results/Lessons Learned. Patterns and trends in PFAS occurrence in sediment, porewater, surface water, groundwater and biota are useful in predicting impacts from AFFF release areas. PFAS are persistent and travel far from release areas, and the relative concentrations of PFAS in these media provide clues regarding relative contribution from various transport pathways.

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PFAS Fate and Transport – A Heuristic Model for Understanding PFAS in the Environment

Harrison Roakes and Stephen Zemba

Poly- and per-fluoroalkyl substances (PFAS) have been included on emerging contaminant lists for many years, but recently have drawn considerable attention because of: (1) their widespread discovery in drinking water wells in Hoosick Falls, NY, North Bennington, VT, Merrimack, NH, and other locations; and (2) the U.S. EPA's issuance of a stringent Lifetime Health Advisory (LHA) for drinking water. PFAS are widespread in the environment at low concentrations, are currently understood to be recalcitrant to degradation, and have been detected in drinking water supplies in the U.S. at concentrations near to or greater than the LHA. This presentation will explore the influences on PFAS fate-and-transport, focusing on the two most commonly used and studied PFAS, perfluorooctanoic acid (PFOA) and perfluorooctane sulfonic acid (PFOS), whose unique chemical properties are responsible for their more stable presence and apparently rapid transport in water systems. In addition, the potential importance of airborne transport and deposition will be discussed, including a general review of recent investigations that have identified PFAS in drinking water wells at locations that could not plausibly be affected by transport via groundwater and surface water flows alone. In these cases, deposition of PFAS released to the atmosphere is an important link to the contamination found in groundwater. We will present a heuristic model of PFAS fate and transport that considers atmospheric deposition, infiltration, and dissolution into groundwater. The model will be compared with published experimental and environmental data. In particular, we will discuss the potential role of soil as a reservoir for PFAS in environmental systems. The results provide an order-of-magnitude assessment of PFAS fate and transport that offers a basis for understanding the degree of PFAS presence in environmental media (i.e., air, soil, water).

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Evaluating Historical Industrial PFOA Emissions Through Air Deposition Modeling

Catherine Beahm

Per- and Polyfluoroalkyl Substances (PFAS) are an emerging class of chemicals garnering a lot of attention in recent years as PFAS contamination in groundwater, surface water, and soils near locations where the products were used, manufactured or disposed has been discovered. Beyond the typical release mechanisms associated with groundwater contamination, state regulators have begun reviewing the impact deposition of PFAS from industrial air emission sources has on surrounding PFAS concentrations found in other media.

Beginning with a brief overview of general PFAS usage and air modeling conducted for PFAS facilities in the U.S., this presentation will also outline the investigation NHDES has been involved with in identifying potential historical industrial uses of PFAS in New Hampshire. The presentation will also outline the current air deposition modeling effort undertaken by the Department for some specific PFOA air emission sources in NH and the inherent data gathering necessary to ensure the input information is as accurate as possible. The presentation will also address modeling methodology selection and techniques.

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Session 13b: Analyzing for PFAS

Advances in Poly- and Perfluoralkyl Substances (PFAS) Analytical Techniques – Assessing the Hidden Mass
Allan Horneman, Arcadis, Portland, ME; Jeff Burdick, Arcadis, Newtown, PA; Erika Houtz, Arcadis, San Francisco, CA; Jake Hurst, Arcadis, Leeds, United Kingdom; Ian Ross, Arcadis, Cheshire, United Kingdom

Perfluorinated Alkylated Substances Extraction and Analysis in Soils
Kavitha Dasu, Jonathan Thorn, Robert Lizotte, and Kevin McInerney, Battelle, Norwell, MA

Current Status for the Analysis of Polyfluoroalkyl Substances (PFAS) in Environmental Samples
Charles Neslund, Eurofins Lancaster Laboratories Environmental, LLC, Lancaster, PA

Advances in Poly- and Perfluoralkyl Substances (PFAS) Analytical Techniques – Assessing the Hidden Mass

Allan Horneman, Ian Ross, Jeff Burdick, Erika Houtz, and Jake Hurst

Poly- and perfluoroalkyl substances (PFAS), including perfluorooctane sulfonate and perfluorooctanoate, are commonly elevated in soil and groundwater at sites with industrial PFAS applications or past use of firefighting foams, including aqueous film-forming (AFFF), fluoroprotein (FP) and film foaming fluoroprotein (FFFP) foams. The products contain a complex mix of fluorinated compounds that include perfluorinated compounds, where all carbons are saturated with F atoms, and polyfluorinated compounds where some carbons have hydrogen bonds. The polyfluorinated compounds, termed precursors, are transformed in the environment to form perfluorinated compounds which are extremely persistent and not susceptible to further transformation. The precursors are not accounted for by the U.S. EPA analytical Method 537 (LC-MS/MS); however, precursors represent a "hidden" mass that should be considered in fate and transport assessments and conceptual site models, especially given that many PFAS are anionic and are not retarded significantly in the subsurface, whereas some precursors are cationic and bind to soils via ion exchange mechanisms and represent a less mobile source mass.

This presentation will discuss three new analytical methods developed to quantify the total concentration of precursors and PFAS in water and soil samples. The analytical methods include the total oxidizable precursor (TOP) method, particle induced gamma emission (PIGE) spectroscopy, and adsorbed organic fluorine (AOF). Soil and groundwater from PFAS contaminated sites as well as soil spiked with characterized AFFF were analyzed by the conventional, new and detailed analytical methods. The results demonstrate that PFOA and PFOS only account for only a small portion of the PFAS present in some impacted soil and groundwater.

This next generation of PFAS analytical techniques is generating more comprehensive analytical data that supports more robust conceptual site models and improving our understanding of PFAS fate and transport. Accounting for precursors is also key for the successful design of remedial systems.

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Perfluorinated Alkylated Substances Extraction and Analysis in Soils

Jonathan Thorn, Robert Lizotte, Kevin McInerney, and Kavitha Dasu

The emergence of poly- and perfluoroalkylated substances (PFAS) as an environmental contaminant of concern has necessitated the laboratories to develop methods for extraction and analysis in various matrices. Standard EPA drinking water method 537 is more commonly used for the extraction of PFAS from water samples. However, the solid matrix extraction and analysis methods are not as well defined. As the number of PFAS contaminated sites is rapidly increasing, the need for a quick and robust solid extraction and analysis method is important to investigate this emerging class of contaminant. Battelle has demonstrated an efficient and robust solid extraction method and comparable method detection limits (MDL), limits of detections (LOD), and limits of quantitation (LOQ), which are achieved between Ottawa sand, soil, sediment and biological (fish tissue) matrices using this method. The method has been successfully applied for multiple solid matrices and hence will be useful for PFAS contaminated site investigations. Further, the presentation will discuss the benefits and/or drawbacks of solid phase extraction compared to the direct injection method, and the comparison of quantitation methods – external standards, internal standards, standard addition and isotope dilution methods – used for routine PFAS analysis.

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Current Status for the Analysis of Polyfluoroalkyl Substances (PFAS) in Environmental Samples

Charles Neslund

The group of compounds referred to as PFAS are considered emerging contaminants. Even though PFAS compounds have been in use for many years, the label of "emerging" indicates that regulations, analytical methodologies, reporting limits and treatment technologies are still evolving. The rapidness with which compound lists, methods, matrices and limits are changing is a challenge for all of us in the environmental community. We will evaluate the current state of methodologies used for the analysis of PFAS compounds and what may lie ahead for this analysis venue.

Additionally, analysis and evaluation of the extent of groundwater contamination of PFAS compounds can be costly. The time and cost of transporting samples to a fixed lab and the time it takes for sample analysis and evaluation can add substantially to field investigation costs. Those costs may actually seem small, in a relative sense, when you consider the cost of personnel and equipment in the field waiting on sample analysis results.

An analytical technique has been developed that will allow for mobilization of the analytical instrumentation to the site and the generation of near real time data. This presentation will cover the development and validation of the method as well as the logistics of the field deployment.

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Session 14: Climate Change and Resiliency Within Sustainable Remediation

Establishing an Integrated Climate Change Strategy for Massachusetts Executive Order 569
Ann Lowery and Thomas Potter, MassDEP, Boston, MA

Massachusetts Climate Change Mitigation and Adaptation for Site Assessment and Remediation
Thomas Potter, MassDEP, Boston, MA

Overview of ASTM's Standard Guides on Climate Resiliency Planning and Strategy and Climate Resiliency in Water Resources
Stephanie Fiorenza, BP America, Houston, TX; Helen Waldorf, ASTM, Boston, MA

Impacts of Extreme Climate Events on Residual Contamination Under Sustainable Remediation
Haruko M. Wainwright, Bhavna Arora, and Boris Faybishenko, Lawrence Berkeley National Laboratory, Berkeley, CA; Konstantin Lipnikov and David Moulton, Los Alamos National Laboratory, Los Alamos, NM; Carol Eddy-Dilek and Miles Denham, Savannah River National Laboratory, Aiken, SC; Arianna Libera and Felipe de Barros, University of Southern California, Los Angeles, CA

Progress in SURF's Technical Initiative for Climate Change and Resilience Within Sustainable Remediation
Barbara Maco, Wactor & Wick LLP, Oakland, CA

Establishing an Integrated Climate Change Strategy for Massachusetts Executive Order 569

Thomas Potter and Ann Lowery

The Massachusetts Department of Environmental Protection will provide an overview of Governor Baker's 2016 Executive Order 569 and its implementation at the Secretariat level, the agency level, and at the Municipal level. The presentation will highlight efforts by MassDEP and others to mitigate and reduce greenhouse gas emissions, build resilience, and adapt to the impacts of climate change. Efforts required by the Order include:

- Implementation regulations for the Global Warming Solutions Act
- Efforts to strengthen resilience of communities
- Framework for each Executive Office to assess vulnerability
- Framework for each City or Town to assess vulnerability

The information will be presented using a combination of overview presentations and facilitated Q&A. This platform will help to connect the regulated community, municipalities, project developers, job seekers, students, and the interested public with Massachusetts's climate change goals and initiatives.

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Massachusetts Climate Change Mitigation and Adaptation for Site Assessment and Remediation

Thomas Potter

The Massachusetts Department of Environmental Protection (MassDEP) Bureau of Waste Site Cleanup (BWSC) will provide an overview of Governor Baker's 2016 Executive Order 569 as it relates to the assessment and remediation or oil and/or hazardous material release sites. The presentation will highlight efforts by MassDEP BWSC to mitigate and reduce greenhouse gas emissions, evaluate and build resilience, and adapt to the impacts of climate change.

The focus of this talk will be on the following points:

- Mitigation of greenhouse gas emissions through green and sustainable cleanups
- Regulatory considerations and nexus with assessment and remediation
- Vulnerability assessments for OHM sites
- Adaptation and resiliency measures for OHM sites

The information will be presented using a combination of overview presentations and facilitated Q&A. This platform will help to connect the regulated community, municipalities, project developers, job seekers, students, and the interested public with Massachusetts's climate change goals and initiatives.

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Overview of ASTM's Standard Guides on Climate Resiliency Planning and Strategy and Climate Resiliency in Water Resources

Stephanie Fiorenza and Helen Waldorf

ASTM International has two committees that focus on environmental (E50) and sustainability (E60) issues. The E50 Committee entered into the realm of sustainable remediation with its guide, Integrating Sustainable Objectives into Cleanup (E- 2876-13), which was published in 2013. The ISOC guide touched on the need for considering climate change effects in remediation systems, which led to the recognition of the need for a general climate resiliency guide.

The climate resiliency guide, ASTM E 3032-15, published in 2016, is a voluntary framework that was designed for individuals, local governments or businesses. It outlines risk management options and steps that may aid in the evaluation of climate resiliency solutions to extreme weather events and sea level rise. The guide presents a risk management approach that is organized by US regions and climate events, such as drought, fire, and flood. The planning process is then outlined and strategies are provided for identifying and selecting different levels of adaptation to climate events. Appendices provide further examples of adaptation activities.

The water resources resiliency guide is under development at this time. The intended audience is similar to the climate resiliency guide and it will also provide a voluntary framework to manage risks posed to water resources by extreme weather events.

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Impacts of Extreme Climate Events on Residual Contamination Under Sustainable Remediation

Haruko Wainwright, Arianna Libera, Felipe de Barros, Bhavna Arora, Boris Faybishenko, Konstantin Lipnikov, David Moulton, Carol Eddy-Dilek, and Miles Denham

"Sustainable remediation" has recently emerged as a key concept for better remediating contaminated soil and groundwater. The sustainable remediation considers not only contaminant removal but also cost effectiveness, greenhouse emission, waste production and energy usage. It highlights the use of passive remediation technologies to immobilize contaminants or natural attenuation with longer institutional control, both of which reduce remediation cost and waste significantly. However, recent increase in climate extreme events (e.g., flooding, droughts) poses a significant concern about the stability of residual plumes or immobilized contaminants.

In this study, we have developed a modeling approach to evaluate the effect of extreme events – in particular, flooding – on residual heavy metals and radionuclides. Although more water (i.e., increased water table and flow) may seem to mobilize heavy metals, the mobility is also controlled by geochemistry. Dilution of acidic plumes could, for example, decrease metal's mobility. We use a state-of-art flow and reactive transport modeling capabilities to assess this trade-off and to evaluate the impact of flooding. We demonstrate our approach at the uranium-contaminated Savannah River Site F-Area, which has been under passive remediation. This work intends to establish a framework for assessing climate resiliency of remediated sites as well as for exploring engineering solutions to enhance the resiliency.

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Progress in SURF's Technical Initiative for Climate Change and Resilience Within Sustainable Remediation

Barbara Maco

Contaminated site cleanup remedies (especially long term) should be designed, implemented, and monitored to withstand fires, floods, storms, rising sea levels, long-term stress on water availability, and dynamic groundwater levels. In other words, clean-up should be planned with climate change in mind.

In Spring 2016, the Sustainable Remediation Forum (SURF) organized a public/private sector team and began an technical initiative (TI) to evaluate the necessary planning, research, and activities to (1) ensure the long-term sustainability of site remediation and reuse from climate change impacts, and (2) examine the benefits of rehabilitated land to strengthen community and ecosystem resilience.

Our research team comes from both the private (global and small business) and public sectors, including regulators, non-governmental organizations, and academia.

As a non-profit, education-focused organization of volunteers, SURF has promoted 11 years of collaborative research and communications that "Advance Sustainable Remediation Science & Best Practices." Climate Change and Resilience builds on this history. The TI team is using SURF knowledge exchanges, along with a focus on resiliency provided in previous SURF white papers, such as "Groundwater Conservation and Reuse" and "Integrating the Social Dimension in Remediation Decision-Making: State of the Practice and Way Forward." Our report will be peer reviewed, nationally and internationally.

The talk will present TI progress including social equity and economic benefit. The information will be presented using a combination of overview presentations and facilitated Q&A.

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Session 15: Synergistic Remediation Technology Solutions

In Situ Chemical Reduction with ZVI and ZVI-Sulfide
Richard Raymond and Michael Lee, Terra Systems, Inc., Claymont, DE

Improving Remedial Actions Through Integrated Use of Direct-Push High-Resolution Site Characterization (HRSC) Technologies
Eric Garcia, ASC Tech Services, Rancho Cordova, CA

FROG-5000: The Next Generation of the World's Most Portable Gas Chromatograph
Patrick Lewis, Defiant Technologies, Inc., Albuquerque, NM

Successful Implementation of CHP Within a Sensitive and Active Brownfield Property
Jim Wilson, Geo-Cleanse International, Inc., Matawan, NJ; Will Moody, Provectus Environmental Products, Freeport, IL

Optimization and Performance of Aqueous Phase ZVI Remediation Amendments for In-Situ Chemical and Biological Reduction
John Freim and James Harvey, OnMaterials, Escondido, CA

Innovative Solution for Petroleum Releases in Eco-Sensitive Areas
Thomas Merski, Universal Remediation, Pittsburgh, PA

In Situ Chemical Reduction with ZVI and ZVI-Sulfide

Richard Raymond and Michael Lee

Background. Zero valent iron (ZVI) has been extensively used to treat chlorinated solvents. The combination of ZVI and sulfide can reduce the corrosion of iron with water and extend the reactivity of the ZVI. Most of the applications of ZVI have been for chlorinated ethenes (tetrachlorethene or PCE, and trichloroethene or TCE), chlorinated ethanes including 1,1,1-trichloroethane or 1,1,1-TCA and 1,1-dichloroethane or 1,1-DCA, and chlorinated methanes (carbon tetrachloride or CT, and chloroform or CF). 1,2-Dichloroethane or 1,2-DCA is generally resistant to attack by ZVI although the combination of ZVI with sulfide is more reactive against 1,2-DCA.

Approach. A batch treatability study was carried out with a mixture of solvents (PCE, CT, 1,2-DCA, 1,1,1-TCA, and BF); two zero valent iron (ZVI) products combined with Terra Systems emulsified vegetable oil product – SRS; with and without added sulfide. Many of the treatments were bioaugmented with a dechlorinating enrichment (TSI-DC).

Results. There was an immediate reduction of PCE, 1,1,1-TCA, 1,2-DCA, CT, and BF in the first day for most of the ZVI-amended microcosm treatments compared to the control. Over the 70-day study, the treatments with ZVI and sulfide showed more complete removal of the chlorinated ethenes (up to 91.8%) than the ZVI treatments without sulfide (54.7 to 73.2%). 1,1,1-TCA was consumed completely in the ZVI and sulfide treatments and was reduced by 91.1 to >99.97% in the ZVI treatments without sulfide. 1,2-DCA was more resistant to degradation with a maximum of 52.3% removed in the SRS + ZVI and bioaugmentation treatment. Complete removal of the CT and BF were observed in all ZVI-amended treatments, but the reaction rates were generally faster for the ZVI treatments with sulfide. The ZVI column amended with sulfide removed an average of 93.3% of the TCE and daughter products and 96.0% of the CF and daughter products, compared to 79.2% of the TCE and 78.6% of the CF in the ZVI column. More DCE, ethene, and acetylene were generated with the ZVI + sulfide column than the ZVI column without sulfide.

Lessons Learned. The addition of sulfide increased the reactivity of the ZVI against PCE and 1,1,1-TCA and increased the rates of reaction against CT and BF. In the column study, the ZVI + sulfide promoted more complete removal of the TCE and CF than ZVI alone.

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Improving Remedial Actions Through Integrated Use of Direct-Push High-Resolution Site Characterization (HRSC) Technologies

Eric Garcia

A key element to all successful remedial actions is an adequate Site Conceptual Model (SCM) which reflects both the macro and micro subsurface heterogeneities of a subject site. The principal failure in most remedial actions is a lack of a true understanding of these heterogeneities and their overall distribution. A field program, which follows the expedited site assessment process (TRIAD) and implements High-Resolution Site Characterization (HRSC) technologies, can be an effective approach to help obtain needed subsurface information. Direct push (DP) HRSC technologies are very effective tools to achieve subsurface investigation goals with high resolution data, which may then be used to support the design of remediation systems, guide removal actions or provide quality assurance for remedial actions.

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FROG-5000: The Next Generation of the World's Most Portable Gas Chromatograph

Patrick Lewis

The FROG-5000™ is the latest generation of portable gas chromatograph (GC) from Defiant Technologies. The FROG-4000™ was the world's first commercially available MEMS (micro electro-mechanical systems) based GC system. This second generation of the FROG improves upon the success of its predecessor by implementing key features requested by the end-users. In addition, recent advances in micro-GC have shown excellent performance for separation of polar compounds like ketones and alcohols. Defiant is also introducing a new way to provide multi-analyte state-of-health check samples so that users may confidently operate the system in the field.

We will present a brief background on the underlying technology, especially the micro preconcentrator and micro gas chromatographic column. We will show how the new instrument improves productivity in the field. We will show example chromatograms for the new stationary phase. Finally, we will show how the new technology is applied to solve real world analytical problems for analysis of VOCs in the field.

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Successful Implementation of CHP Within a Sensitive and Active Brownfield Property

Will Moody and Jim Wilson

Geo-Cleanse International, Inc. (Geo-Cleanse) recently completed the design and implementation of an in-situ chemical oxidation (ISCO) pilot test utilizing catalyzed hydrogen peroxide (CHP) at a former petroleum bulk storage and distribution facility in East Hartford, Connecticut. Soil and groundwater at the site were impacted with VOCs (primarily BTEX), SVOCs (primarily PAHs) and extractable total petroleum hydrocarbons (ETPH), including a light non-aqueous phase liquid (LNAPL), which has been identified throughout much of the 1.47 acre site.

The pilot test area is currently an active bituminous-paved faculty/staff parking lot for a college campus. Multiple utilities, including fiber optics, electrical and a storm water system, and existing PVC monitoring/recovery wells exist within the pilot test area, which posed additional implementation challenges. Geo-Cleanse developed a strategy to couple ISCO with CHP and enhanced product recovery (EPR) to remediate the heavily impacted pilot area. Benefits of coupling these systems extend beyond product recovery and contaminant destruction. The EPR system actively removes O2 and CO2 gases from the subsurface promoting a larger radius of influence and mitigating any potential damage to the bituminous-paved cap and utilities. The Geo-Cleanse® Process, combined with our constant process monitoring, ensured a safe and efficient injection and recovery program. Results demonstrated CHP can be effectively and safely implemented despite the many site challenges. Post-treatment sampling revealed total VOC and SVOC concentration reductions ranged from 84-97%, with saturated soil ETPH reductions averaging 93%. Furthermore, LNAPL was recovered and treated on-site during the pilot. This presentation will outline the site conditions, injection program activities and results of the pilot, focusing on how CHP can overcome significant site challenges through proper design and implementation.

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Optimization and Performance of Aqueous Phase ZVI Remediation Amendments for In-Situ Chemical and Biological Reduction

John Freim and James Harvey

Background/Objectives. Zero valent iron (ZVI) and reduced iron sulfides (FeS_x) can accomplish the rapid and complete abiotic electrochemical reduction of trichloroethylene and other chlorinated hydrocarbons. This work describes the development of aqueous phase ZVI products with iron sulfide modifications that have been shown to promote accelerated kinetics with chlorinated ethenes. Compared to ZVI, iron sulfide also reacts more slowly with water, potentially extending reactive capacity and amendment persistence.

Approach/Activities. OnMaterials has developed and commercialized AquaMetal ZVI, a remediation amendment with 40 weight percent 2-3 mm ZVI iron particles suspended in water. Experiments were undertaken to determine the effect of sulfide additions on reactivity with chlorinated ethenes. This involved adding 2 g/L AquaMetal ZVI to buffered tap water with 36 mg/L TCE and 3 mg/L PCE. The reactivity of commercially available ZVI powders (BASF OM carbonyl iron and Peerless 90D ZVI) was also evaluated at a higher dosing of 10 g/L. Experiments were also undertaken to determine the effect of sulfide reactions on reactivity with water with the objective of lessening wasteful reactions of ZVI with water that produce molecular hydrogen.

Results/Lessons Learned. Closed bottle treatability studies showed that small sulfide additions had a positive effect on reactivity with both TCE and PCE. Each material exhibited first order reaction kinetics with correlation coefficients greater than 0.995. Mass adjusted rate constants for TCE degradation were about 20 to 30 times greater than that provided by commercially available microscale ZVI powders. For example, the mass normalized first order rate constant of sulfidized AquaMetal ZVI with TCE was 0.337 L g^{-1} day^{-1}. This compared to only 0.0126 L g^{-1} day^{-1} for carbonyl iron. These experiments also showed that sulfide addition had the positive effect of inhibiting the production of hydrogen gas produced by the reaction of ZVI and water by more than 50%.

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Innovative Solution for Petroleum Releases in Eco-Sensitive Areas

Thomas Merski

Accidental releases of petroleum products into eco-sensitive areas such as coastal shorelines, mangrove forests, swamps, marshes, and wetlands present difficult challenges when managing an effective but constrained response effort. The prime question raised among these challenges is: How can we affect a comprehensive response without negatively impacting the natural resources of that eco-system? Unfortunately, intrusive response efforts can be much more damaging than the hydrocarbon release. The response question frequently asked is: Can the spill resolve itself by natural attenuation to prevent further physical damage that what would be inflicted by an aggressive response effort?

An effective solution is to deploy facultative methods to enhance Mother Nature's own response after a petroleum release. An innovative sorbent agent, Petroleum Remediation Product (PRP®), developed with the use of NASA spin-off technology, offers one such option. Using this oleophilic agent, the in-situ remediation of a release has been shown to reduce the impact to both flora and fauna of eco-sensitive areas. PRP® actually changes the sticky nature of oil and can reduce wildlife involvement. Formed from naturally-occurring waxes (beeswax and soy wax) using a proprietary process, PRP® actually changes the physical characteristics of the petroleum itself by encapsulating the release within hydrophobic, 50-micron, hollow microcapsules. This sorbent action isolates the petroleum away from these natural resources. Additionally, PRP® provides a platform for indigenous microbes to allow the petroleum release to naturally attenuate.

The unique flexibility of PRP® allows its deployment as a cost-effective control for petroleum hydrocarbons on water bodies, on/ in soil, or in the subsurface as well. It can be used on oil spills in eco-sensitive areas and be deployed by hand or with a hydroseeder. PRP® deployment is intended to help manage unique situations as part of response effort or as part of a treatment train. Since PRP® itself will also biodegrade, costs are greatly reduced for both follow-on labor for sorbent collection and sorbent disposal. Placed in booms, it can aid in sheen management.

This presentation will provide a series of successful case histories looking at the deployment of PRP®. Data will also be presented that will review this green and sustainable methodology to achieve the reduction of hazardous hydrocarbon residuals in eco-sensitive areas.

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Session 16: Remediation Geology: Focus on Geology to Improve Decision-Making and Outcomes

Environmental Sequence Stratigraphy: A Focus on Geology for Improved Remediation Decision-Making
Rick Cramer, Mike Shultz, and Colin Plank, Burns & McDonnell, Brea, CA; Herb Levine, US EPA, San Francisco, CA

Influence of Erosional Geologic Complexity on DNAPL Distribution and Plume Characteristics in Fractured Sedimentary Rocks
Jessica Meyer, Colby Steelman, Andrew Buckley, and Beth Parker, G360 Institute for Groundwater Research - University of Guelph, Guelph, ON, Canada

Managing Data for Dynamic Site Conceptual Models
Dave Rich, Geotech Computer Systems, Centennial, CO; James Cummings, US EPA, Washington, DC; Joseph Quinnan, Arcadis G&M of Michigan, LLC, Brighton, MI

Characterization of Crystalline Bedrock Sites to Enable Effective Remedial Decision Making
Larry Mastera, ERM, Boston, MA

Design Verification Program – Lessons Learned from Pre-Application Assessments at In Situ Remediation Sites
Craig Sandefur, Regenesis, San Clemente, CA

Make Your Hand Grenade a Laser: Lessons to Improve In-Situ Remediation Outcomes and Maximize Each Dollar Spent
Paul Dombrowski, ISOTEC Remediation Technologies, Lawrenceville, NJ; William Caldicott and Prasad Kakarla, In-Situ Oxidative Technologies, Inc., Lawrenceville, NJ

Environmental Sequence Stratigraphy: A Focus on Geology for Improved Remediation Decision-Making

Rick Cramer, Mike Shultz, Colin Plank, and Herb Levine

There is increased awareness that geology defines the "plumbing" (permeable pathways) that largely controls the subsurface heterogeneity responsible for groundwater flow and contaminant migration at complex sites. However, historically in the environmental industry, geology has been marginalized. The geology underlying contaminated sites is typically logged and described based on geotechnical engineering standards, and the focus of groundwater investigations is typically on the hydrology and to a lesser degree the geology. Examples of these are:

1. the standard in the industry for describing the subsurface is the Unified Soil Classification System (USCS), which is based on the classification of soils for engineering purposes with little to no emphasis on geologic features or depositional processes, and
2. the definition and depiction of groundwater flow and related contaminant migration is based primarily on groundwater elevation data with little to no emphasis on depositional environments and related permeability architecture controlled by the geology.

The science of sequence stratigraphy was developed in the petroleum industry and represents the current best practice for predicting and delineating reservoir geometry and continuity. Environmental Sequence Stratigraphy (or ESS) applies the concepts of sequence stratigraphy and facies models to the types of datasets collected for environmental groundwater investigation. This presentation emphasizes the importance of an advanced understanding of depositional environments and facies models, and shows how existing data (e.g., borehole logs) can be formatted to support a stratigraphic analysis that defines the subsurface permeability architecture which controls groundwater flow and contaminant migration.

This technology is being published as a best practice in the US EPA Ground Water Issue Paper "Best Practices for Environmental Site Management: Application of Environmental Sequence Stratigraphy to Contaminated Groundwater Sites." Case studies will be presented that show the application to a variety of geologic settings and groundwater remedies.

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Influence of Erosional Geologic Complexity on DNAPL Distribution and Plume Characteristics in Fractured Sedimentary Rocks

Jessica Meyer, Colby Steelman, Andrew Buckley, and Beth Parker

Studies have shown the impact of complex depositional processes on contaminant distribution and remediation. However, extreme heterogeneity in contaminant transport properties can also result from erosional processes. At a site in southern Wisconsin, dense non-aqueous phase liquids (DNAPL) migrated downward to depths of 45-56 m bgs and laterally about 80 m south of the surface release point through unconsolidated Pleistocene glacial deposits and a sequence of Cambrian/Ordovician aged sedimentary rocks. A high resolution transect approach was applied at five locations 70 m downgradient of the DNAPL source zone to better constrain conceptualizations of the stratigraphic, hydrogeologic unit, and contaminant distribution. The approach included detailed sedimentological and fracture logging of continuous cores, rock core contaminant sampling, and a comprehensive suite of borehole geophysical/hydrophysical logs at each location. Surface resistivity and seismic surveys were collected coincident with and perpendicular to the corehole transect. Integration of the data sets revealed an intensely fractured shallow bedrock terrain consisting of dolostone towers, with as much as 21 m of relief over a lateral distance of 57 m, embedded in a clay rich sandstone channelized by a clean sandstone. The extreme stratigraphic variability is the result of three overlapping unconformities. High resolution head profiles show little to no vertical gradient throughout the shallow rock units, indicating the fracture networks are reasonably well connected from a vertical groundwater flow perspective. However, detailed rock core contaminant profiles show large spatial variability in magnitude and composition of the contaminant mass reflective of the complex geologic conditions and the aged nature of the source zone. Understanding how these erosional features contribute to the complex DNAPL and dissolved phase plume distribution is still in progress. Developing this understanding was essential to understanding controls on DNAPL migration and retention, improving well designs to avoid cross-contamination, and evaluating remedial strategies for the site.

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Managing Data for Dynamic Site Conceptual Models

Dave Rich, James Cummings, and Joseph Quinnan

Some site remediation projects have been very successful, while many have not. While there are many reasons why these projects can fail, one of the biggest factors in remediation project success is effective use of site conceptual models. Better use of these models can significantly increase the chance of a positive outcome. In the past, for many projects the process has been very linear: investigation, feasibility study, remedy selection, and implementation. Then, if the remedy doesn't work, try another approach until something finally works. Often the investigation phase includes a site conceptual model. Many times, once the model has been created, it is used throughout the life of the project as it was originally defined.

Two changes can greatly improve the use of the site conceptual model, leading to a more positive outcome. The first is to more thoroughly involve input from geologists in creating the original model. The flow of groundwater, contaminants, and reactants is very complex, involving interactions between one or more liquid phases, various parts of the solid matrix, other constituents like organic matter and manmade materials, along with contaminants and reagents. Practitioners should gather enough geologic information to adequately characterize all of these materials.

Secondly, the site conceptual model should be a dynamic document, incorporating information about changes in subsurface conditions on an ongoing basis so that the best decisions can be made at all stages of the project. This is best done by creating and maintaining a comprehensive database of the data as it is gathered, and using that database to help understand the project as it proceeds.

By integrating these two changes into accepted best industry practices and government guidance documents, and managing projects this way, we can greatly increase the number of successfully completed projects.

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Characterization of Crystalline Bedrock Sites to Enable Effective Remedial Decision Making

Larry Mastera

A limited body of literature exists regarding the characterization of groundwater flow and contaminant transport in fractured crystalline bedrock using the Discrete Fractured Network (DFN) toolbox. Implementation of the DFN approach at crystalline bedrock sites is necessary to develop rigorous Conceptual Site Models (CSMs) that can be used to achieve regulatory compliance and design effective site management strategies.

Three fractured crystalline bedrock sites impacted with Chlorinated Volatile Organic Compounds (CVOCs) were characterized using a DFN toolbox approach. A targeted approach was developed for each of the three sites based on a number of factors including unique site conditions, regulatory drivers, and known or suspected contaminants. The targeted DFN approach employed at these sites included DFN investigation tools and techniques such as surface geophysical surveys, air rotary drilling, borehole geophysical logging, FLUTe™ transmissivity profiling, active line source temperature profiling, NAPL FLUTe™ employment, FLUTe™ FACT analyses, tracer tests, fracture connectivity testing, FLUTe™ Multilevel well system installations, hydraulic gauging and groundwater sampling.

The data generated using the targeted DFN approach were used to answer three important questions: 1) Since matrix porosity is negligible in most crystalline rocks, where does contaminant mass persist, resulting in the sustained presence of dissolved-phase plumes? 2) Is advective transport dominated by numerous highly interconnected fractures acting as an Equivalent Porous Medium ("EPM") or by a small number of interconnected transmissive fractures? 3) Is there a crystalline rock equivalent to hydrogeologic units (HGUs)?

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Design Verification Program – Lessons Learned from Pre-Application Assessments at In Situ Remediation Sites

Craig Sandefur

This presentation will focus on pre-application Design Verification steps that directly improve existing design assumptions prior to field application. The goal of this program is to determine which field based assessment methods might provide significant benefits (insight) into design and application method selection prior to in-situ application, thus, resulting in improved remedial performance outcomes. Over the past 20 years, application of remedial substrates has had an uneven track record in terms of performance. Generally speaking, remedial performance is the result of multiple factors which affect distribution and contact of the injectates in the aquifer. The primary focus of this presentation is on the identification of those meaningful aquifer characteristics that can be documented using traditional field methods and provide the most insight into the remedial design and application programs. Specifically, this presentation will focus on those Target Treatment Zone (TTZ) characteristics that directly affect application programs and ultimately remedial outcomes. On most remediation sites, two of the more important TTZ characteristics are A) soil type, and B) positional relationship between these soil types. The deposition process of sediments has a critical bearing on COC mass storage and distribution as well as remedial reagent selection and application methods. To assist design and application teams, a set of routine pre-application "Design Verification" steps were developed and performed on select project sites (N +50). These steps were used to identify the relationship between COC mass storage and distribution units within the TTZ. Identification of these variables has contributed to an overall improvement in application programs and is seen as a key element in higher remedial success rates. This presentation will discuss the use of "lower-cost" traditional field based logging techniques for remedial assessment that have been shown to provide valuable information that can be used to steer design and application.

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Make Your Hand Grenade a Laser: Lessons to Improve In-Situ Remediation Outcomes and Maximize Each Dollar Spent

Paul Dombrowski, William Caldicott, and Prasad Kakarla

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. Although costs for injection remedial approaches are generally lower than other treatment approaches (excavation, pump and treat, or other mechanical systems), the combined costs of design, implementation, and monitoring spur the requirement for successful outcomes.

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. Incorporating enhanced site characterization, bench-scale treatability study, and/or field pilot testing are important tools to optimize remedial design and field performance. This presentation will share lessons learned from hundreds of injections and in-situ remediation treatments, including projects inside and adjacent to buildings, in very low permeability soils (e.g., clay, tills), in very high contaminant concentrations, and/or where multiple amendments applied at a given site. Specific topics covered will be setting reasonable expectations for each injection event as a component of a large site-wide strategy, scaling up from pilot test results, and interpreting site contaminant and geologic data to develop more cost-effective strategies. The importance of injection volumes, injection methods, injection spacing, and vertical injection intervals will be elaborated on with demonstration through numerous case studies.

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Session 17: PFAS: State Case Studies, Policy Developments, and Lessons Learned Panel

Proposed New Regulations and Expectations for Notifications, Assessment, and Cleanup of PFAS in Massachusetts
Paul Locke, Massachusetts Department of Environmental Protection, Bureau of Waste Site Cleanup, Boston, MA

Per- and Polyfluoroalkyl Substances in New Hampshire: Update on NHDES Investigations and Next Steps
Lea Anne Atwell, New Hampshire Department of Environmental Services, Hazardous Waste Remediation Bureau, Concord, NH

Vermont's PFAS Experience
Richard Spiese, Vermont Department of Environmental Conservation, Waste Management and Prevention Division, Montpelier, VT

Rhode Island's Experience with PFAS in Drinking Water
Amy Parmenter, Rhode Island Department of Health, Center for Drinking Water Quality, Providence, RI

Proposed New Regulations and Expectations for Notifications, Assessment, and Cleanup of PFAS in Massachusetts

Paul Locke

MassDEP is preparing a Fact Sheet describing expectations for notifications, assessment and cleanup of PFAS under the current regulations as well as proposed revisions to the regulations to specifically address PFAS. The Fact Sheet and draft regulations will be available in the Fall 2017. PFAS meet the definition of a hazardous material under Chapter 21E, § 2 and 310 CMR 40.0006(12). Reportable Concentrations and Method 1 Cleanup Standards have not yet been established under the MCP for PFAS. However, a notifiable condition would exist under the MCP at 310 CMR 40.0311 for PFAS releases that pose an Imminent Hazard pursuant to 310 CMR 40.0311. A Method 2 and/or Method 3 Risk Characterization would apply to the characterization of risk at a disposal site with PFAS as COCs.

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Per- and Polyfluoroalkyl Substances in New Hampshire: Update on NHDES Investigations and Next Steps

Lea Anne Atwell

NHDES' PFAS investigations began in 2014 in response to PFAS-impacted drinking water related to former AFFF releases at the former Pease Air Force Base in Portsmouth. In 2016, two industrial facilities were identified as potentially responsible parties for PFAS-contaminated drinking water in six municipalities in southern New Hampshire related to air emissions. Two municipal supply wells serving over 25,000 people in one of these communities have been impacted and are currently off-line.

Since March 2016, NHDES has undertaken a statewide sampling effort to identify impacted drinking water sources. NHDES has collected over 2,200 samples from over 1,800 supply wells, primarily private drinking water supply wells. Samples from over 200 of these wells have concentrations of PFOA and PFOS greater than NHDES' Ambient Groundwater Quality Standard (AGQS) of 70 nanograms per liter (ng/L). Wells were selected for sampling based on their proximity to a variety of potential PFAS sources, including, but not limited to, industrial facilities where PFAS may have been used, landfills, and locations where Class B Foam / AFFF may have been used.

Recently, several programs across the agency are integrating PFAS as a contaminant of concern in their sampling programs.

Combined PFOA and PFAS groundwater concentrations reported to date have ranged up to 151,000 ng/L in monitoring wells, 2,850 ng/L in public drinking water supply wells, and 1,600 ng/L in private drinking water supply wells.

A summary and analysis of the findings from the various statewide sampling efforts will be provided, including the types and concentrations of PFAS detected; potential correlations with PFAS concentrations and source type and release mechanism; and size of the identified impacts.

Future considerations and additional PFAS information needs will also be discussed.

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Vermont's PFAS Experience

Richard Spiese

This talk with discuss the history of PFAS investigation within the State of Vermont. It will include a discussion of the findings at several specific PFAS sites as wells as a discussion of the approach and findings of Vermont's State wide PFAS investigations. Lastly, it will go over Vermont's work on assisting municipalities with our AFFF Plan as well as a discussion on the expansion of the Statewide PFAS Sampling Plan.

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Rhode Island's Experience with PFAS in Drinking Water

Amy Parmenter

Following the announcement of the EPA health advisory for PFOA and PFOS in May 2016, and the detection of these chemicals at two Rhode Island public water systems that were sampled under EPA's Unregulated Contaminant Monitoring Rule 3, the Rhode Island Department of Health Center for Drinking Water Quality used facilities data provided by EPA Region 1, the RI Department of Environmental Management, and the Brown University Superfund Research Program to evaluate drinking water wells at small water systems that could be susceptible to PFAS contamination. The resulting GIS model was used to implement a special surveillance monitoring study for PFAS in late summer 2017. The results of this study will be used to protect public health by limiting exposure to PFAS in drinking water, educating consumers about the health advisory, and better understanding the occurrence, distribution, and sources of PFAS contamination in RI's groundwater.

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Session 18: Vapor Intrusion

Use of Mass Loading Assessment to Characterize Vapor Intrusion Potential
Theresa Gabris and Helen Dawson, Geosyntec Consultants, Washington, DC; William Wertz, Geosyntec Consultants, Inc., Castleton, NY; Todd McAlary, Geosyntec Consultants, Inc., Toronto, ON, Canada; Darius Mali, Geosyntec Consultants, Inc., Guelph, ON, Canada; Daniel Carr, Sanborn, Head and Associates, Inc., Dayton, ME

Ensuring Long-Term Protectiveness of HVAC Engineering Controls for VI Mitigation of Large Buildings
David Shea and Bradley Green, Sanborn, Head & Associates, Inc., Concord, NH

Update on Vertical Screening Distances for Assessing Vapor Intrusion Risks at Petroluem UST Sites
Matthew Lahvis, Shell, Spring, TX

Multiple Lines of Evidence, Including CSIA, to Differentiate an Indoor Source from Vapor Intrusion
Safaa Dergham and Carol Serlin, Ramboll Environ, Irvine, CA; Devon Rowe, Ramboll Environ, Vancouver, WA; Blayne Hartman, Hartman Environmental Geoscience, Solana Beach, CA

The Fast and the Curious: Observations from an Expedited VI Investigation and Mitigation Effort
John Fitzgerald, MassDEP, Wilmington, MA

Use of Mass Loading Assessment to Characterize Vapor Intrusion Potential

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

The characterization of vapor phase VOC mass loading (VOC mass flux multiplied by building footprint area) offers a promising alternative to conventional indoor air and sub-slab sampling because mass loading results have been found to exhibit considerably less temporal variability than conventional indoor air samples. Three mass loading estimation techniques were employed as part of an ongoing ESTCP VI research project (ER-201503) to assess the VI potential at a former dry cleaning facility at Vandenberg Air Force Base. One technique used groundwater, soil and soil vapor data to characterize the mass loading potential associated with the presence of PCE, TCE and cis-1,2-DCE in the vadose zone beneath the building (MF_{soil}). Those loading estimates were compared with loadings determined through temporary operation of a sub-slab ventilation system (MF_{SSV}) that captured vapors below the building, and indoor loadings associated with sub-slab vapor entry induced during building pressure cycling (MF_{BPC}) via a blower door. In addition, the blower door fan was used to pressurize the building and inhibit sub-slab vapor entry in order to assess the mass loadings attributable to residual indoor sources of VOCs. Cross-slab and cross-building differential pressure measurements were used in conjunction with the MF_{BPC} results to develop building leakage and mass loading curves for use in estimating reasonable maximum exposure (RME) concentrations and calculating the building-specific magnitude of sub-slab vapor attenuation under natural and depressurized conditions. The results from each approach are presented and compared with historical VI characterization data from the building as well as the results of similar mass loading estimates from other buildings where these techniques have been used.

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Ensuring Long-Term Protectiveness of HVAC Engineering Controls for VI Mitigation of Large Buildings

David Shea and Bradley Green

For some commercial and industrial buildings, the use of heating, ventilating, and air conditioning (HVAC) systems to mitigate vapor intrusion (VI) may be preferable to other common mitigation methods, such as sub-slab depressurization (SSD). Such preference could arise when indoor air quality is acceptable under normal HVAC operations despite sub-slab VOC presence, or if HVAC adjustments are more feasible or cost-effective than SSD, even after considering long-term operational costs. HVAC systems can serve as active mechanical VI engineering controls, similar to an SSD system. For SSD systems, once effectiveness has been demonstrated through initial verification sampling, several regulatory VI guidance documents (e.g., New Jersey, New York) note that long-term protectiveness can be assured by periodic verification of system operating parameters without the need for on-going sampling. While the performance parameters for SSD systems are relatively simple (e.g., fan run status, sub-slab vacuum field), the appropriate monitoring parameters for HVAC systems are likely to be building-specific and system-specific. There are numerous ways to control and monitor the critical parameters such that HVAC may be as reliable as SSD. Recognizing the relative scarcity of guidance, reported data, and experience with regard to HVAC VI engineering controls compared to SSD, a demonstration project has been initiated at two large campuses of commercial/industrial buildings. The objective is to collect data and information to evaluate the long-term effectiveness of HVAC systems to maintain acceptable indoor air quality in buildings that might otherwise be affected by VI. Operational monitoring and observational checks are being coupled with various methods of indoor air sampling to evaluate the consistency of HVAC system performance and to assess the efficacy of routine operational monitoring to assure long-term protectiveness against VI.

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Update on Vertical Screening Distances for Assessing Vapor Intrusion Risks at Petroluem UST Sites

Matthew Lahvis

Vertical screening distances are not recommended for application at petroleum underground storage tank (UST) sites with historic releases of leaded gasoline because of a lack of empirical data on the fuel additives 1,2 dichloroethane (1,2 DCA) and ethylene dibromide (EDB). These compounds are a concern for petroleum vapor intrusion (PVI) because of their relative toxicity (i.e., low soil-gas RBSLs), volatility, and persistence in groundwater. Vertical screening distances have also not been rigorously evaluated for petroleum mixtures, such as Total Petroleum Hydrocarbon (TPH), C_5-C_8 Aliphatics, C_9–C_{12} Aliphatics, and C_9–C_{10} Aromatics, nor the common TPH fraction surrogates, n-hexane and naphthalene. These compounds are compounds of potential concern for PVI in some US states. This study will summarize the derivation of vertical screening distances for the lead scavengers, TPH mixtures, and TPH indicator compounds based on analyses of empirical soil-gas collected at numerous petroleum UST release sites located in US, Canada, and Australia.

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Multiple Lines of Evidence, Including CSIA, to Differentiate an Indoor Source from Vapor Intrusion

Safaa Dergham, Devon Rowe, Blayne Hartman, and Carol Serlin

A residential community sits downgradient from a former industrial site in southern California where active remediation to address TCE in groundwater is ongoing. As a precautionary measure to mitigate potential vapor intrusion, DTSC requested that homes overlying the plume be offered sub-slab depressurization systems (SSDSs). At one homeowner's request, an SSDS was installed shortly after purchasing the home. While historical IAQ sampling in that home did not indicate vapor intrusion, IAQ sampling after SSDS installation showed a sudden increase in TCE concentrations in indoor air.

The unhappy homeowner needed an answer – what was the source of the TCE – vapor intrusion, entrainment from the SSDS, and/or an indoor source? An indoor evaluation using portable monitoring equipment failed to provide an answer. Consequently, Ramboll Environ developed a multiple lines of evidence approach in conjunction with the regulatory agency and the homeowner that resulted in conclusive determination of the source. The approach involved multi-depth soil gas sampling around the perimeter of the home; continuous IAQ and sub-slab differential pressure monitoring in multiple rooms inside the home while changing SSDS operation; seven day passive IAQ sampling; continuous weather monitoring; and CSIA of groundwater, soil gas and indoor air. Using these multiple lines of evidence, Ramboll Environ concluded that the TCE in indoor air was not due to vapor intrusion.

This presentation presents a summary of the multiple lines of evidence investigation methods; the real-time implementation of the approved scope of work; the resulting IAQ, sub-slab differential pressure, weather, soil gas, and CSIA results; and the detailed analysis that resulted in the determination that the TCE in indoor air likely results from a consumer product located within the home.

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The Fast and the Curious: Observations from an Expedited VI Investigation and Mitigation Effort

John Fitzgerald

In the fall of 2014, elevated concentrations of Trichloroethylene (TCE) were detected at the water-table interface in an older, densely-settled residential neighborhood near Boston, Massachusetts. The presumed source – a former auto parts salvage facility – was now a residential condominium complex. With no viable responsible party, and new toxicological concerns over even short-term exposures to TCE, MassDEP needed to undertake a state-funded VI investigation and mitigation effort in an expedited timeframe.

Within a 5-month period, the area of impact was largely defined, via the headspace analysis of water samples from 39 ultra-low-cost direct-push groundwater monitoring wells and GC/MS analysis of 157 one-liter "grab" indoor air samples from 57 residential dwellings. Split-sample comparisons between the headspace groundwater samples and conventional EPA Method 8260 analyses showed good correlation for TCE and its breakdown products, as did the comparison of select "grab" indoor air sample data to conventional 24-hour EPA TO-15 canister data. TCE was detected in 19 homes, at concentrations up to 180 µg/m^3. "Off the shelf" air purifying units containing activated carbon were immediately deployed to 7 of these homes, with varying degrees of success, followed by the subsequent installation of sub-slab depressurization systems by a radon contractor, which were able to quickly achieve remedial objectives.

This presentation will provide details on the efficacy and cost-effectiveness of the various steps in this expedited and low-cost approach.

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Presenting Author: John Fitzgerald

Session 19: Site Investigation

Heavy Metal Detection Using Electrochemistry Coupled with Surface-Enhanced Raman Scattering (SERS)
Connor Sullivan, Guinevere Strack, and Pradeep Kurup, University of Massachusetts, Lowell, MA

Characterizing Reactive Iron Mineral Coatings in Redox Transition Zones Han Hua, Xin Yin, and Lisa Axe, New Jersey Institute of Technology, Newark, NJ

Scaling In Situ Geologic Data for Conceptual Site Modeling
David Carstens, WSP USA, Woburn, MA; Jessica Hinchliffe, WSP USA, Boston, MA; Allen Waldman, WSP USA, San Jose, CA

A Moving Target: Cleanup of a Former Firing Range on the Shore of Lake Erie
Amy Rosenstein, Lexington Environmental Risk Group, LLC, Lexington, MA; Michael Dorman, Earth Resources Technology, Inc., Laurel, MD

Vapor Intrusion Source Investigation Technique to Support Rapid Response Scenarios
David Jensen, Geosyntec Consultants, Acton, MA; Todd Creamer, Geosyntec Consultants, Portsmouth, NH

Heavy Metal Detection Using Electrochemistry Coupled with Surface-Enhanced Raman Scattering (SERS)

Guinevere Strack, Connor Sullivan, and Pradeep Kurup

The recent development of handheld Raman spectrometers has enabled the rapid onsite optical detection of a range of analytes. Unfortunately, only a small percentage of light undergoes Raman scattering, which renders the technique inadequate for trace detection. Amplification of the Raman signal, however, can be accomplished via the application of surface enhanced Raman scattering (SERS). Herein, we are using a combination of electrochemistry and SERS for the detection and quantification of aqueous heavy metal levels. The presence of heavy metals in drinking water can cause serious health problems, even at levels below 10 ppb; therefore, the rapid, sensitive detection of metals—such as mercury, arsenic, and lead—is imperative. To accomplish this, we designed a dual-purpose sensor that can be employed for the detection of mercury using square wave stripping voltammetry (SWSV), an electrochemical technique, and SERS, an optical technique. The sensor is comprised of indium tin oxide (ITO)-coated glass that is decorated with nanostructured gold. The ITO provides a conductive platform for the electrochemical reduction of mercury ions onto the surface of the electrode. The reduced mercury layer is detected via SWSV, which oxidizes the layer, thus generating a detectable current. The nanostructured gold serves two purposes: *i*) it provides conductive nucleation points for the electrochemical deposition of mercury; and *ii*) it enhances the Raman signal by providing "hot spots", i.e., an enhancement of the electric field. The Raman signal associated with the deposited mercury is relayed via a complexing agent that contains a pyridine moiety, which is highly Raman active. Combining electrochemical detection with SERS facilitates the detection of mercury in a wide range of concentrations. Therefore, this novel technique can be used to detect high concentrations of heavy metals, such as those found a superfund sites, and low concentrations found in drinking water.

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Characterizing Reactive Iron Mineral Coatings in Redox Transition Zones

Han Hua, Xin Yin, and Lisa Axe

The purpose of this research is to characterize reactive Fe mineral coatings in redox transition zones of contaminated sites. An anaerobic 60 foot core was collected from the Chambers Works Site in Deepwater, NJ. Two inch subsamples were used to evaluate redox transition zones using bulk composition, redox potential, pH, volatile organic carbon in the headspace, as well as microbial community. A suite of complementary analyses are being applied to characterize the surface chemistry in the transition zones. The analyses include sequential extraction (phases and speciation), x-ray diffraction (mineralogy), x-ray fluorescence (composition), field-emission scanning electron microscopy (surface morphology down to the nm scale) with energy dispersive analysis (surface composition), and bench-scale experiments. Evidence from multiple lines suggests a clear trend in reactive iron (II)/(III) mineral coatings throughout transition zones. Bulk minerals observed included quartz, muscovite, clinochlore, and zeolite. Other zones have also included albite and anorthite. Using the suite of tools, reactive iron mineral coatings involve the iron (II) minerals pyrite, mackinawite, pyrrhotite, and siderite in the first transition zone between depths from 21' to 22.8'. Ferrihydrite, goethite, and lepidocrocite were the dominant iron (III) minerals in two transitions, while magnetite iron (II)/(III) was the most abundant mineral coating in this first transition zone. The presence of reactive mineral coatings through the redox transition zones is a strong indicator of Fe^{2+}/Fe^{3+} cycling. Therefore, further studies on abiotic degradation of the halogenated solvents present will be investigated.

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Scaling In Situ Geologic Data for Conceptual Site Modeling

David Carstens, Jessica Hinchliffe, and Allen Waldman

Hydrogeologic investigations at contaminated sites rely heavily on manual descriptions of soil samples by onsite geologists, and the collection of bulk samples for geotechnical analysis. Increasingly, environmental professionals are incorporating the use of in-situ, direct sensing tools to improve site investigations. Direct sensing tooling, such as the Geoprobe® hydraulic profiling tools (HPT) and Waterloo Profiler® (WP) can provide corollaries for hydrogeologic properties such as grain size and hydraulic conductivity that are integral to the understanding of contaminant fate and transport. Direct sensing data generates a high frequency of data (typically 20 measurements per foot) within a borehole. These data can be scaled for lateral correlation using software-based interpolation methods to build accurate high resolution three-dimensional (3D) subsurface models. The subsurface models, honoring both direct measurements and interpolated data, can then be incorporated into detailed conceptual site models (CSMs) that allow users to visualize trends between boreholes for the creation of complex and highly detailed models of subsurface structures and contaminant extents.

Case studies will be presented for conceptual modeling of hydrogeologic properties at two sites. The first site, located in Quebec, Canada, incorporates data collected using HPT tooling in shallow glacial materials. Flow data were used to estimate material properties (e.g., grain size), and were compared to geotechnical sampling results to generate a site-scale 3D geologic model. The second site, located in the eastern United States, incorporates index of hydraulic conductivity (iK) collected with the Waterloo Profiler® tooling to estimate low flow zones within unconsolidated sediments.

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A Moving Target: Cleanup of a Former Firing Range on the Shore of Lake Erie

Amy Rosenstein and Michael Dorman

A Remedial Investigation was completed (2012-2014) for eight miles of the Lake Erie shoreline near Port Clinton, Ohio, a former impact area for munitions testing for the U.S. Army where both munitions constituents (MC) contamination and munitions and explosives of concern (MEC) hazards existed. Planning a site investigation at this location posed numerous challenges due to the dynamic nature of the shoreline, which is subject to tides, wave action, and varying water depths. The shoreline is intermittently covered with water at varying depths or is dry for days, weeks, or months at a time. The site investigation and risk assessment team worked with the stakeholders (U.S. Army National Guard Directorate, Ohio EPA, and the U.S. Army Corps of Engineers) to come up with a feasible and representative sampling plan. The analyte list was determined based on munitions known to have been used at the site, and the metals identified in MIDAS associated with these munitions. However, many metals also exist at high levels in background soil and sediment along these shores due to industrial activities and the outflow of the Detroit River. An additional complication was the active, current use of the Lake Impact Area operational range for live firing from Camp Perry Training Site and for testing by a munitions manufacturer. We designed and conducted sampling, human health risk assessments, and ecological risk assessments for this complex lake environment. Random, biased, and incremental sampling of surface and subsurface sediment was performed, depending on the goals of the sampling. The human health risk assessment was conducted for workers, residents, recreational beach users, fishers, and hunters, and the ecological risk assessment was conducted for both terrestrial and aquatic receptors.

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Vapor Intrusion Source Investigation Technique to Support Rapid Response Scenarios

David Jensen and Todd Creamer

Some vapor intrusion (VI) pathway investigations require results on short timelines, including commercial property transactions and exposure scenarios related to trichloroethylene (TCE). Evaluating large buildings under these conditions can be challenging using traditional discrete sub-slab soil gas sampling. High Volume Sampling (HVS) is an innovative investigation technique, which can rapidly and more cost-effectively increase confidence in identifying contamination sources beneath a building slab than by traditional methods. Traditional sub-slab sampling may only involve screening 5 to 10 liters of soil gas. To increase confidence that all significant sources have been identified can require using very large numbers of such discrete sampling locations. In contrast, one HVS test is typically used to screen between 10,000 and 100,000 liters of soil gas covering an area of several thousand square feet. By screening soil gas during an hour-long test, spatial trends of common soil gas parameters are generated. Analysis of these trends can discern information about the presence, magnitude, and geometry of sources beneath the building slab. Additionally, the HVS testing facilitates collection of pneumatic data, which can be used to identify and test preferential pathways, to estimate slab leakage, and to collect design criteria for targeted mitigation system design.

A case study will be presented for a 1,000,000 square foot active manufacturing facility where HVS was used to dramatically reduce investigation time, cost and disruption to active manufacturing.

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Session 20: Advances in In-Situ Remediation

Evaluation of Extensive Groundwater Remedial Actions for Chlorinated Ethanes/Ethenes and Selection of In-Situ Chemical Oxidation for Chloroethane Polishing
Yasemin Kunukcu and Nidal Rabah, TRC Environmental Corporation, New Providence, NJ

Development of Klozur SP with a Built-in Activator: Overcoming the Challenges of Storage and Mixing While Maintaining Treatment Effectiveness
Brant Smith and Ravi Srirangam, PeroxyChem, Philadelphia, PA; Ian Horner and Brianna Desjardins, PeroxyChem, Tonawanda, NY

Karst Bedrock Remediation of PCE in Kentucky
Duane Guilfoil, AST Environmental, Inc., Midway, KY

Zero Valent Iron Reactivity Testing and Project Design
Patrick Randall, Hepure, Claymont, DE

A Comparison Study of the Delivery and Performance of Injected Powdered and Liquid Activated Carbon
Richard McGregor, InSitu Remediation Services Ltd., St George, ON, Canada

Evaluation of Extensive Groundwater Remedial Actions for Chlorinated Ethanes/Ethenes and Selection of In-Situ Chemical Oxidation for Chloroethane Polishing

Yasemin Kunukcu and Nidal Rabah

Extensive groundwater remedial actions including pump & treat, dual-phase extraction, and in situ bioremediation (ISB) were conducted at a former industrial site in northern New Jersey since 1994 to remediate 1,1,1-trichloroethane (1,1,1-TCA) and tetrachloroethene (PCE) impacts in on-site soil and groundwater to prevent contaminant migration off-site and into surface water. Although these prior efforts resulted in significant source zone mass removal, high residual levels (>3,500 µg/L) of chlorinated ethanes, which primarily consisted of chloroethane (CA), persisted in the shallow zone of the source area monitoring wells. The shallow zone underlies a layer of peat and organic silt and extends to depths ranging from approximately 15 to 23 feet below ground surface (ft. bgs) consisting of primarily silty sand.

The treatment of chlorinated ethenes, such as PCE or trichloroethylene (TCE), has become somewhat commonplace as such contaminants are known to be reactive with a wide variety of in-situ treatment technologies including in-situ chemical oxidation (ISCO), in-situ chemical reduction (ISCR) and ISB. However, the treatment of chlorinated ethanes has proven to be more difficult and recalcitrant.

Based on a comprehensive technology review and a laboratory study, ISCO using alkaline-activated persulfate was selected as a supplemental, polishing remedy to address the residual contamination in the groundwater. The laboratory study consisted of a persulfate demand test (PDT) and a base buffering capacity (BBC) test. The resulting PDT values were used as a guide to develop appropriate persulfate dosing for the field application. Choice of the activation method is dependent on the contaminant of concern and site geochemical characteristics.

The presentation will review and evaluate the previous remedial actions and discuss the persistence of residual contamination of CA. The presentation will also provide details for the laboratory results from both PDT and BBC tests and the selection of the polishing remedy compared to other alternatives.

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Development of Klozur SP with a Built-in Activator: Overcoming the Challenges of Storage and Mixing While Maintaining Treatment Effectiveness

Brant Smith, Ravi Srirangam, Brianna Desjardins, and Ian Horner

Background: Activated Klozur® persulfate has been implemented for over 10 years to successfully remediate sites impacted with a wide assortment of contaminants of concern ranging from petroleum hydrocarbons, oxidizable chlorinated solvents, and reducible organics such as carbon tetrachloride and 1,1,1-trichloroethane. The ability to treat different contaminants has been attributed to the activation method and the formation of the sulfate, hydroxyl, and superoxide radicals. Conventional methods of activating persulfate include iron chelates, alkalinity, heat, zero valent iron, and hydrogen peroxide. As these chemistries react with persulfate, it has required that the activator reagents be stored and mixed separately from the persulfate.

Certain sites can benefit from having the persulfate and activator delivered as a single bag and mixed into a single solution. However, activators can promote the decomposition of persulfate. This is the intended result in the subsurface needed to generate the oxidative and reductive radicals but should be eliminated or minimized when stored or once mixed into solution.

Objectives: The objective of this work was to identify a blended activator-persulfate system that could be safely stored, transported, and batched together while still effectively treating the different contaminants of concern.

Summary: This presentation will discuss the existing methods of activating persulfate, conditions used to generate oxidative and reductive pathways, and then review key stability data and treatment efficacy of an all-in-one blend containing Klozur SP and a novel activation system. The stability data will show that the blend can be safely stored and transported. Stability and losses measured over time upon mixing will be compared to that of different organic activators. Finally, the treatment efficacy of different activation systems in treating common contaminants of concern such as 1,4-dioxane, TCE, carbon tetrachloride, and benzene will be presented.

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Karst Bedrock Remediation of PCE in Kentucky

Duane Guilfoil

The site is located within the Kentucky Inner Bluegrass physiographic region. Bedrock is 10 to 20 feet below ground surface and overburden is mainly clay to a silty clay residuum. The site is a former dry cleaner facility within a cluster of retail shops, banks, retail gas stations and restaurants. The cleaners operated dry cleaning equipment onsite for several years. The parking lot and service driveway near the facility is crisscrossed with multiple utilities including gas, water, sewer and electric. PCE is found in overburden and epi-karst where concentrations initially ranged from 0.4 mg/L to 87 mg/L in the groundwater, and soil ranged from <1 mg/kg to 500 mg/kg. A down-hole camera and borehole geophysics (temperature, electrical conductivity, caliper, and optical borehole imaging) was used to determine the specific fracture intervals to target for hydraulic tests. Targeted intervals were isolated using a straddle packer equipped with pressure transducers within the sample zone, and below and above the sample zone to confirm the discreteness of the sample. The final designs for the injections, targeting individual fractures, were based on the iron demand required to dechlorinate PCE within the fracture volume. Using the packer system to isolate individual fracture zones, the injections were customized, reducing the chances of under dosing or overdosing an interval. Material was injected discreetly into fractures under pressure forcing it into the bedrock fractures instead of remaining in a minimal zone of influence. Monitoring indicates the injection was successful in reaching and treating the bedrock groundwater. The success at the site was directly attributed to the characterization effort which quantified zones yielding contaminant mass, frequency and intensity of secondary porosity features, occurrence of groundwater, and conductivity (both vertical and horizontal) between monitoring points within the treatment area.

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Zero Valent Iron Reactivity Testing and Project Design

Patrick Randall

Zero Valent Iron (ZVI) is being used for remediation of chlorinated ethenes on many projects. Laboratory reactivity testing and data interpretation is an important part of designing a successful remediation project. In addition to an introduction of ZVI, its properties, and its applications, this paper will provide detailed information on the design and implementation of laboratory reactivity testing and how to utilize the laboratory results in project design.

Laboratory tests are used to determine site specific and iron-specific reactivity constants for ZVI. Proper planning, design, and implementation of the tests are critical to obtaining meaningful results that can be used in design of remedial systems. Reactivity constants can be determined via batch or column tests. The preferred method depends upon the intended application method of the ZVI. Each test type will be examined in detail to provide project managers with a better understanding of their options and enable them to communicate with their laboratories to develop and conduct a successful test.

Laboratory generated reactivity data has been used to aid design of permeable reactive barriers. Innovative ZVI applications now involve injection into the plume, source area and application in the bottom of excavations. Combining reactivity data with simple groundwater flow models can help determine design parameters such as the required reactivity of the ZVI, mass loading, and how geochemistry will affect ZVI performance.

Combining simple groundwater models with laboratory generated reactivity data can help remedial managers design applications which are cost effective and meet remedial goals.

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A Comparison Study of the Delivery and Performance of Injected Powdered and Liquid Activated Carbon

Richard McGregor

The use of injected activated carbon has grown for the management of impacted groundwater. Until recently, injection of activated carbon was problematic with distribution and consumption of the adsorption sites being the main challenges. To overcome the adsorption issue, the injectable activated carbon is usually enhanced with an electron donor or acceptor depending on the compounds of concern.

A comparison study was completed at a petroleum hydrocarbon-impacted site where injections of powdered (PAC) and liquid activated carbon (LAC) were conducted. Monitoring of the groundwater over an 18-month period post injection indicated that over the short-term, both versions of the activated carbon were effective at removing the dissolved compounds of concern. Long-term monitoring, however, indicated that the adsorption sites on the PAC were consumed and biodegradation reactions were not occurring at a rate high enough to overcome the mass loading onto the activated carbon. The LAC was effective over both the short and long-term.

Analyses of soil cores taken in the area of injection suggested that the distribution of the LAC was more uniform both vertically and laterally. Examination of the cores within the PAC-injected area indicated that the PAC was observed 4.5 m away from the point of injection with PAC being detected in less than 1% of the target injection zone. The LAC distribution was observed to be more uniform compared to the PAC distribution profile with LAC being observed in up to 64% of the target zone at a distance of 2.5 m from the point of injection.

The results of this comparison study indicated that both forms were effective for the short-term removal of the compounds of concern; however, at the site evaluated, LAC appeared to have better lateral and vertical distribution and a longer period of effectiveness.

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POSTER PRESENTATIONS

(in alphabetical order by presenting author)

Biochar Soil Amendment for Sustainable Rhizosphere Nutrient Management

Kamran Abdollahi and Zhu Ning

The purpose of this study was to contribute to the knowledge of bio-char utilization and soil amendment management. This knowledge will allow more efficient and economic use of co-products of bioenergy production from wood-waste. The experiment was conducted using a randomized complete design, with 20 replications. One experimental unit consisted of the soil and one tree sapling in one 2 gallon plastic container in the greenhouse environment. Treatments consisted of 0%, 10%, 20%, and 30% bio-char and one commercial fertilizer (Peters General Purpose 20-20-20) soil amendments. Repeated measures of soil nutrient concentrations, foliar nutrients, tree height, and leaf chlorophyll concentration were conducted for the containerized Nuttall Oak and White Oak saplings subjected to the above treatments. This poster will present the results of the assessment of the impact of four, bio-char, application rates (0%, 10%, 20%, and 30%) and one fertilizer (20-20-20) on soil nutrient dynamics and pH levels in the rhizosphere of the containerized Nuttall Oak and White Oak tree saplings for one growing season. In addition, this poster will present the results for the assessment of the effect of four bio-char application rates and one fertilizer on the foliar nutrient dynamics of containerized Nuttall Oak and White Oak tree saplings, assessment of the effect of four bio-char application rates on leaf length, and foliar chlorophyll concentration of the containerized Nuttall Oak and White Oak tree saplings.

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Engineering *Camelina sativa* for Improved Seed and Oil Yields via Manipulating Triacylglycerol Synthesis Pathway and the Associated Molecular and Biochemical Consequences

Hesham Abdullah, Om Parkash Dhankher, and Danny Schnell

Since the crude oil production is subjected to decrease worldwide, and as consequences for the limited production of crude oil, the current prices of the crude oil and its derivatives are rapidly rising. The less availability and the growing demand for the oils have crucially increased the demand for vegetable oils as alternative renewable resources for food, biofuel, biodiesel, and many other oil-based products. Among the seed oil-producing crops, *Camelina sativa* has attracted much interest in the last few decades as an emerging oilseed crop dedicated for biofuel and biodiesel applications as well as a source for edible oils. Its unique seed and oil qualities attract the researchers to engineer new varieties exhibiting improved oil quantity and quality. The overexpression of enzymes that catalyze the synthesis of the glycerol backbone and the sequential conjugation of fatty acids into this backbone appear to be far more promising targets for increasing the triacylglycerols (TAG, the main lipids in seeds). In our previous study, we combined the overexpression of two genes involved in TAG metabolism under the control of seed-specific promoters. The transgenic plants exhibited a higher percentage seed oil content, a greater seed mass, and overall improved seed and oil yields, on a per plant basis, than either the non-transgenic wildtype (WT) or manipulation of each gene individually. However, in order to further increase seed oil content in *Camelina*, we utilize metabolites profiling, in conjugation with transcriptome profiling during seed development in order to reveal the rate-limiting step(s) in the production of building blocks for TAG biosynthesis. The whole seed-specific transcriptome of transgenic lines revealed the identification of approximately 1,566 and 2,102 transcripts were differentially regulated (fold change ≥1.5 or ≤-1.5, p-value ≤0.05) in *Camelina transgenics.* Many of these transcripts were found to be involved in various functional categories, with many of them controlling alternative metabolic routes in fatty acid synthesis, TAG assembly, and TAG degradation. Further, we quantified the relative contents of over 240 metabolites by using GC/MS and LC/MS/MS platforms. The results indicate major metabolic switches in transgenic seeds, which are associated with significant changes in the levels of glycerolipids, phospholipids, most amino acids, sugars and organic acids, especially the ones involved in TCA cycle and glycolysis. Collectively, the integration of transcriptome and metabolome can be highly useful to understanding the regulation of TAG biosynthesis and identifying the bottlenecks in TAG pathways, providing a precise selection of candidate genes for generating *Camelina* varieties with improved seed and oil yields.

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The Potential Utilization of Grey Water for Irrigation: A Case Study on KNUST Campus

Victoria Adjei

The problems of shortages and quality deterioration of water have led to an increased interest in the reuse of treated grey water in many parts of the world. This study examined the suitability of locally available materials (beach sand, oyster shells, and charcoal) to treat grey water samples collected weekly from three halls of residence (Unity Hall, Africa Hall, and Independence Hall) on Kwame Nkrumah University of Science and Technology (KNUST) campus for irrigation. Beach sand, oyster shells, and charcoal were employed in the construction of three vertical flow-through filter systems, each consisting of PVC pipes of height 100 cm and internal diameter 5.08 cm. The grey water samples were filtered and the levels of physicochemical parameters (pH, conductivity, TDS and salinity), nutrient and microbial counts determined over a three-week period. Results indicate that the measured physico-chemical parameters of the treated grey water were within the permissible limits for irrigation water. Also filtration process is effective in reducing phosphate, the total and faecal coliform levels in grey water from the halls of residence. These observations suggest that treated grey water from KNUST campus would support production when used as irrigation water.

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Environmental Restoration Wiki – Tech Transfer in the 21st Century

Ed Alperin, Allison Stenger, and Robert Borden

With support from ESTCP, Solutions-IES, a division of Draper Aden Associates, has developed an Environmental Restoration (ER) Wiki (http://www.environmentalrestoration.wiki) to provide a readily accessible, easily updated platform for communicating research results to users. The overall format is similar to Wikipedia with short 'encyclopedia'-type summaries of current information, technical challenges, and extensive links to reports and project summaries of research funded by SERDP, ESTCP, and other organizations. Each page is prepared by internationally recognized experts from academia and industry and is subject to an extensive review for accuracy and completeness. Major sections of the ER Wiki focus on common and emerging contaminants, fluid flow and transport, characterization methods, degradation processes, remediation technologies, performance evaluation, environmental impacts and risks, and management approaches.

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Sulfate Enhanced Bioremediation of Non-Chlorinated Hydrocarbons: Full Scale Application

Brad Elkins, Ed Alperin, and Mike Branson

Dissolved petroleum hydrocarbons in groundwater can be degraded by both aerobic and anaerboic oxidative metabolic processes – How do practitioners choose? A consulting firm was responsible for addressing a benzene, toluene, ethylbenzene, and xylenes (BTEX) plume from a former gas station site in North Carolina. The site is now located within the median of a 4-lane highway, with the BTEX plume migrating approximately 150 ft under the eastbound lanes toward a neighboring water supply well (WSW). The site remains "high-risk" because the downgradient WSW could not be closed and suitably replaced elsewhere with sufficient yield from the shallow, underlying fractured bedrock.

The remedial design for removing dissolved hydrocarbons required an *in situ* technology in order to minimize disruption to the site. In the Corrective Action Plan, the consultant recommended *in situ* sulfate-mediated anaerobic oxidation. Of the electron acceptors considered, EAS® (commercial sulfate-based amendment) was selected to enhance anaerobic biodegradation of BTEX under established sulfate-reducing conditions. A pilot study performed in June 2012 provided evidence that sulfate enhancement was a viable remedial approach. With approval from local regulatory agency full-scale application began in May 2015. One drum of EAS® was gravity-fed into each of the 21 wells constructed in a grid pattern covering the plume. The performance monitoring network included 13 shallow and one deep monitoring wells, but only three shallow wells within the plume had dissolved petroleum hydrocarbons above the groundwater standards.

The first of three proposed injection events has been completed. The 3-month post-injection sampling showed 2- to 13-fold increases in sulfate in the treatment zone, average pH 6.1, and a change to more reducing oxidation-reduction potentials, which is required for anaerobic sulfate-mediated transformations. The BTEX has seen a 58% decrease in concentrations within the first 3 months of monitoring. Results of additonal monitoring data and follow-up injection events will be presented.

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Fast Track Remediation Case Studies

Imtiyaz Khan, Matthew Wenrick, Angelo Falabella, Omer Uppal, Matthew Ambrusch, and Stewart Abrams

Contrary to popular belief, complete site closure is achievable with minimally invasive solutions that result in cost savings and short remedial timeframes, as demonstrated by the systems in both of the case studies discussed herein.

Air Sparge (AS) and Soil Vapor Extraction (SVE) System Implementation

The contaminants of concern (COCs) at the site include tetrachloroethene and trichloroethene. The original cleanup strategy favored remediation by excavation, application of a chemical oxidant, implementation of an SVE system, and installation of an engineered cap. The proposed alternative strategy called for installation of an AS/SVE system, a less invasive and less expensive approach.

Data gathered from an AS/SVE pilot test was used to design a full-scale AS/SVE system, which was installed, activated and is currently operational. By the first quarterly groundwater sampling event, notable reductions in the total chlorinated volatile organic compound (CVOC) concentrations were observed. As of the most recent round of on-site groundwater sampling, more significant reductions in concentrations were observed, the majority of which were below the regulatory criteria.

SVE System Implementation

A vapor intrusion (VI) Immediate Environmental Concern (IEC) was identified inside an active warehouse and distribution facility. A subsurface depressurization system was previously installed to mitigate the VI IEC. The investigation identified VOCs in soil at concentrations exceeding the New Jersey Department of Environmental Protection (NJDEP) Soil Cleanup Criteria (SCC).

An SVE system was implemented to remediate the VOC impacts in the soil. The system was activated and operated continuously for 18 months until it was shut down to perform a soil gas rebound evaluation. Performance soil sampling was completed at the site to assess the performance of the system. The system was then adjusted to optimize system performance. Two rounds of confirmatory soil sampling were performed and the results indicated that COC concentrations were below the NJDEP SCC.

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Review of PAH Bioaccumulation Factors Used by USEPA in Derivation of Human Health Water Quality Criteria

Paul Anderson, Jacqueline Iannuzzi, and Michele Buonanduci

In July 2015 EPA released updated human health ambient water quality criteria (HHWQC). As part of that update EPA revised its approach to estimating bioaccumulation of substances into fish employing bioaccumulation factors (BAFs) in place of bioconcentration factors (BCFs) when supported by existing data and methodology. In January 2016 EPA released additional guidance providing more detail on the process followed to update bioaccumulation factors. This presentation has two goals: first, a review of that process to determine if it was applied correctly by EPA when developing HHWQC for PAHs and other highly metabolized compounds; and second, to the extent the process was not followed and alternative BAFs (or BCFs) should or could have been derived, the paper presents those alternative BAFs (or BCFs) and associated revised HHWQC for PAHs. This presentation also provides a general overview of the process developed by EPA, evaluates its application on a national basis, and as necessary, recommends modifications that would improve the process.

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The Use of a Model to Determine Soil Organic Carbon Sequestration in Soils of Southwestern Nigeria

Joseph Aruleba

The need to study factors influencing carbon sequestration is important for the enhancement of soils to act as a natural sinks to mitigate the climate change challenges. The objective of this study is to determine the influence of ecological variables on the stock of carbon using a stepwise regression model. The study was carried out at Itapaji, a farming community in the derived savanna zone in Ekiti North Senatorial District. The site covered about 10 ha which was divided into two locations of 5 ha each. At each location, two distinct topo sequences were identified and delineated into upper slope, middle slope and valley bottom. A profile pit was dug at each topographical land type, 12 profiles were dug in the site, their locations and coordinates were determined using Global Positioning System (GPS). Soil samples were collected from the identified horizons and the profiles were described following standard method. Data obtained were analyzed using stepwise multiple regression analysis with the aid of SPSS 17.0 software package. A model that identifies the significant ecological variables that explained increased variability in the SOC sequestration of the study area was developed as: Y=8.60 + 2.25LUT-0.20 LT -0.81BD + 5.69 N + 0.55Fe + 0.23Al (for location A) and Y=0.69 + 0.38 LUT + 2.11 LT -0.92BD + 11.01N + 0.89Fe – 0.23Al (for location B). The model results are expected to be a guide for predicting SOC storage in different soil types with similar land types, ecological conditions and vegetation types. It is recommended that management practices such as cover crop, residue retention, zero tillage, appropriate use of fertilizer, long fallow period, controlled bush burning, and appropriate management technique suitable for different topographic land type will enhance SOC sequestration in the study area.

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A Review of Historic and Current Site Closure at Disposal Sites with Vapor Intrusion

Dean Bebis

Prior to the 2014 310 CMR 40.0000 Massachusetts Contingency Plan (MCP) revisions, vapor intrusion of volatile organic compounds (VOCs) into indoor air and soil gas was not considered a vital component of risk assessments, and modeling of potential indoor air impacts of VOCs was an acceptable method of eliminating or addressing the risk of exposure to humans. Rather, these closure documents or Response Action Outcomes (RAOs) focused on the risks associated with the potential exposure to humans from impacted groundwater and soil. However, recent toxicology studies conducted by the Massachusetts Department of Environmental Protection (MassDEP) and others have highlighted the risk associated with the vapor intrusion of harmful VOCs such as trichloroethylene, tetrachloroethylene, and their degradation daughter products. As a result, the MassDEP has increased the importance of vapor intrusion assessment as well as determining the risks associated with exposure of VOCs in indoor air. The MassDEP is currently in the process of auditing historic closures relating to disposal sites where VOCs were their primary contaminants of concern (COCs) in order to determine if the historic site closure documents have accurately addressed the potential for vapor intrusion. This study reviews the assessment of indoor air in the historic RAO closure assessment process under the pre-2014 revision of the MCP, how the MassDEP is approaching the auditing of these historic site closures, and what these audits mean for the Licensed Site Professionals (LSPs) and business owners. Additionally, this study will address the importance of the vapor intrusion assessment process in achieving/maintaining a Permanent Solution at disposal sites with indoor air impacts in accordance with MassDEP Vapor Intrusion Guidance: Site Assessment, Mitigation and Closure Policy #WSC-16-435 and how MassDEP's recent emphasis of vapor intrusion affects these current disposal site closures.

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Multi-Faceted Remediation Strategy for Tetrachloroethene in a Complex Urban Environment

Alice Blayney, Douglas Larson, Erin Kirby, Julianna Connolly, Carl Elder, and Christopher Arsenault

Historical operations at a dry cleaning facility in a mixed-use urban setting introduced tetrachloroethene (PCE) to the subsurface beneath the dry cleaner building and an adjacent four-lane roadway. PCE containing wastewater was discharged from the building into a leaky sewer lateral that extended from the dry cleaner to a storm drain under the adjacent four-lane roadway. Remediation was complicated by the high-traffic urban environment and multiple utilities beneath the roadway. Construction of a nearby building with a deep slurry wall foundation divided the source area from a large section of the downgradient plume, providing an opportunity to treat the two areas separately using multiple sustainable remediation strategies.

The source area was treated using enhanced in situ biodegradation (EISB) and targeted soil excavation. EISB amendments were distributed to the subsurface using multiple methods including injections in the four-lane roadway, recirculation of amendments beneath the dry cleaner foundation slab, and injection of amendments through the leaky sewer lateral, after the connect to the main sewer was plugged. Additionally, a temporary groundwater capture and treatment system (GCTS) was installed adjacent to the downgradient slurry wall to establish hydraulic control of source area groundwater while source area treatment was ongoing. Treated groundwater was supplemented with an electron donor to remove nitrate and reinjected downgradient of the slurry wall, resulting in enhanced flushing of the plume's toe.

Tailoring a variety of remediation strategies to this complex urban site resulted in an effective remedy with a small carbon footprint. Installation of the temporary GCTS and implementation of EISB were concurrent with planned capital improvements, resulting in reduced marginal cost for remedial construction. The combination of EISB, hydraulic control, enhanced natural attenuation, and targeted soil removal have reduced the mass of chlorinate ethenes to concentrations where active systems will not be necessary to achieve regulatory closure.

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Development of a Cost-Effective LNAPL Site Closure Strategy

Todd Bridgeo, Rick McCullough, and Prasanta Bhunia

Persistent light non-aqueous phase liquid (LNAPL) is present at thousands of sites across the country. Historically, the presence of LNAPL prevented many of these sites from achieving permanent regulatory closure; however, many states have recently shifted away from LNAPL management based on its occurrence and adopted a risk-based management approach. This shift means many legacy LNAPL sites, where soil and groundwater contamination have otherwise been addressed but small amounts of LNAPL persists, may be eligible for closure. The challenge is how to implement an effective LNAPL closure strategy.

Numerous guidance documents have been published that outline the development of lines of evidence to comply with new risk-based regulatory performance standards. An effective LNAPL closure strategy must cost-effectively balance generating sufficient lines of evidence to meet the new performance standards while adequately consider site-specific conditions that control risk and project budgets. This presentation will seek to identify the critical components of an effective LNAPL closure strategy. Building on LNAPL conceptual site model (LCSM) principals and recognized lines of evidence regarding LNAPL mobility, we will demonstrate a method to analyze site conditions affecting LNAPL risk and how to select appropriate lines of evidence. Special attention will be given to evaluating existing data sources as a guide for the efficient development of a comprehensive LCSM and cost-effective lines of evidence investigation. Topics will be presented in the context of a case study that included evaluation of a decades-old No. 6 fuel oil release near a large diameter storm drain along a major public right-of-way, assessment activities to evaluate preferential pathway for LNAPL migration, emergency response actions to mitigate LNAPL discharge to surface water, performance of a LNAPL mobility and recoverability evaluation, and permanent closure under the Massachusetts Contingency Plan.

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Bioremediation Treatment of Overburden and Bedrock in a Heavily Wooded Wetland

Dustin Bytautas, Michelle Snyder, A. Curtis Weeden, Jr., and Paul Dombrowski

Bioremediation pilot testing using enhanced reductive dechlorination (ERD) was implemented at a heavily wooded Site located in a Massachusetts wetland. The purpose of the ERD treatment was to reduce groundwater concentrations of CVOCs (predominately PCE) found in both overburden and shallow bedrock. Two simultaneous pilot tests were conducted; one focused on the overburden and the other focused on bedrock. Pre-injection PCE concentrations ranged up to 25 mg/L within the overburden and 17 mg/L in the bedrock.

The overburden pilot test treatment area was a 3,450 ft^2 area located near the former discharge source; the vertical extent ranged from 6 to 20 ft bgs. The bedrock treatment area was 500 ft^2 located approximately 50 ft downgradient of the overburden zone. The vertical extent of the bedrock treatment ranged from 25 to 35 ft bgs. Pre-injection depth to water was as shallow as 0.5 ft bgs within the overburden treatment area.

The pilot tests included separate injections of both water soluble lactate and emulsified vegetable oil (EVO) electron donors. Lactate injections were conducted first and consisted of 3,800 gallons of 10% lactate injected over 23 permanent injection wells in the overburden and 550 gallons of 10% lactate injected over 6 injection wells in the bedrock. EVO was injected within the same treatment area nine months following the lactate injections. During the EVO injections, 2,800 gallons containing 8% EVO was injected amongst the existing injection wells and 15 direct push points in the overburden and 670 gallons of 10% EVO was injected in the bedrock. Performance monitoring indicated positive trends in geochemical parameters (creation of reducing conditions) and daughter compound concentrations (degradation) in both treatment areas. Analytical results collected five months following completion of injections showed decreases in PCE concentration of up to 99% in monitoring wells located in both the overburden and bedrock treatment areas.

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Tracking a Petrogenic Source with Pyrogenic Compounds: PAH Apportionment for Severely Weathered Crude Oil

Deborah Chiavelli, Peter Simon, Mike Rury, and Philip Simon

Forensic investigation was conducted to assess residual spilled crude oil contribution to PAH contamination in soil several years post cleanup at an undisclosed site. Pre-existing hydrocarbon contamination from other sources presented a challenge to correctly apportioning PAHs to spilled crude oil. A second challenge was advanced environmental weathering of the oil from years of exposure in surface soils. We present a mathematical apportionment model robust to a wide range of oil weathering stages and sensitive to small concentrations of oil (petrogenic) PAH mixed with larger amounts of background (pyrogenic) PAH sources.

Spill area soil samples, "background" soil: immediately upgradient, and oil were analyzed for PAHs and petroleum biomarkers. Crude oil samples were available in a range of weathering states – the most weathered were petroleum tar/surface soil aggregations collected several years post spill.

Conventionally, weathered petroleum is fingerprinted using petroleum biomarkers, which are highly resistant to weathering, or ratios of alkylated PAHs with similar weathering rates. The 5- and 6-ring PAH (5+PAH), more associated with pyrogenic PAH sources, are rarely used for petrogenic fingerprinting due to low abundance and lack of alkylated results. However, the biomarker fingerprints and alkylated PAH ratios were too altered by weathering in the petroleum tar samples to be used for fingerprinting, whereas 5+PAH in the petroleum tar were relatively unweathered and had a fingerprint distinct from background. We developed a mixing model series; pairing background with a range of oil weathering stages and using 5+ PAHs. To increase sensitivity to small amounts of oil, the models included one biomarker and several 4-ring alkylated PAH that were most resistant to weathering in the tar samples. The models provided an excellent fit to soil samples from the spill area and quantified benzo(a)pyrene concentration attributable to background versus oil, demonstrating that most benzo(a)pyrene at the site originated from background.

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Bioremediation of Diesel-Polluted Soil

Olivia Chitayat and Rachel Thietq

Conventional soil remediation strategies are often energy intensive and destructive to beneficial soil properties that persist through human pollution. Bioremediation – the use of bacteria, plants, and fungi to degrade, remove, or contain pollution – is an alternative strategy that promotes environmental stewardship, community aesthetics, and ecosystem functioning. In this study, I will explore the effects of biochar, compost and the planting of Canada wildrye (*elymus canadensis*) on diesel degradation and soil carbon sequestration in a New Hampshire agricultural soil. Eight treatment groups will be established, each with three replicates for analysis. It is anticipated that the combination treatment will have a significantly greater degree of pollutant degradation, aggregation, microbial biomass and a beneficial pH for most plants.Through my research, I hope to emphasize bioremediation as a practice that may be accessible to communities. (Experiment results will be ready in Fall 2017).

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Adjusting Analyte Concentrations in Groundwater Samples Using Potassium Bromide to Account for Drilling Water Dilution

Dariusz Chlebica, David Adilman, Christopher Arsenault, Carl Elder, Bruce Thompson, and John Hunt

Many drilling methods add water to lubricate and cool the drilling bit, remove cuttings and/or maintain hydraulic pressure on the formation to prevent influx of "heaving" sands. Typically, some water used during drilling is lost to the formation which can be problematic when groundwater profiling is used to assess contaminant concentrations during drilling. To ensure samples representative of only groundwater are collected, it is common to pump from the sampling point 1 to 5 times the volume of water lost to the formation before collecting samples. Alternatively, tracers can be mixed into the drilling water and the boreholes are pumped until the tracer concentrations are sufficiently low. A novel method using potassium bromide as a tracer was developed for the PushAhead™ profiler designed by Cascade Drilling, LP. For this approach, drilling water with a known concentration of potassium bromide is used, and the concentration of the potassium bromide is measured in each groundwater sample. The ratio of bromide in the sample relative to bromide in the drilling water is used to calculate a "dilution factor" that is used to adjust analyte concentrations in the sample to account for dilution from drilling water. The method provides more reliable analytical data for decision-making (e.g., ensuring monitoring well screens are in the intervals with most significant contamination). This approach also eliminates purging prior to sampling, minimizing waste generation and decreasing drilling time. The potassium bromide is recovered during well development following monitoring well installation. The method was approved by EPA and MassDEP for use in a wellhead protection zone. Using this approach, the vertical and horizontal extent of overburden 1,4-dioxane and VOCs plumes were delineated allowing optimal screen placement for 15 monitoring wells within a 90 foot-thick stratified drift aquifer at a Massachusetts CERCLA site.

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Combined Surfactants and Hydrogen Peroxide Application for NAPL Removal

Geeta Dahal, Dan Socci, and Jennifer Holcomb

Removal of non-aqueous phase liquid (NAPL) from the subsurface can be a costly and time consuming process. Most chemical approaches result in multiple treatments while traditional pump and treat systems produce modest progress over the course of years and often decades. Compared to traditional pump and treat contaminant removal approaches, in-situ injections of low doses of optimized plant based, surfactant blends and hydrogen peroxide to enhance NAPL removal using SEPR™ (Surfactant Enhanced Product Recovery) technology can greatly improve treatment economics and performance effectiveness while greatly reducing treatment duration. Surfactants used in the SEPR process lower interfacial tension and decrease the capillary forces which keep NAPL in place, resulting in greater mobility of the NAPL phase. Additionally, the simultaneously injected hydrogen peroxide helps loosen the NAPL and provides buoyancy, facilitating NAPL transport towards recovery wells. A SEPR alone treatment typically will meet treatment objectives if the endpoint criteria is NAPL mass removal or NAPL removal to no measureable free product in the monitoring wells. If achieving low soil and groundwater criteria are the site objectives, SEPR can be followed by a S-ISCO® (Surfactant enhanced In-Situ Chemical Oxidation) treatment. Bulk NAPL removal in the preceding SEPR phase provides improved cost/performance of subsequent surfactant enhanced oxidation of the residual soil contamination. Background on the benefit of surfactants in NAPL remediation will be presented, along with field case studies demonstrating significant advantages of surfactant use for in-situ remediation, particularly for heavy hydrocarbons and NAPL.

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Use of Modern Characterization Tools to Optimize Thermal Treatment System Designs

Rob Danckert and Amber Bonarrigo

Advances in subsurface characterization technologies over the past two decades have yielded tools which allow rapid characterization of data gaps at sites where thermal treatment have been proposed. The following tools were applied to obtain the best possible understanding of the contaminant location and geology to ensure accurate cost estimation and project success. Furthermore, understanding the heterogeneity of the subsurface and removing uncertainties further improves extraction strategies and lowers implementation costs.

This abstract summarizes a brief description of several tools and how they were applied to uniquely support successful design of thermal remediation treatment systems.

- Sonic drilling at a site in Southington, CT allowed a dynamic method of well installation for simultaneous vertical characterization and thermal borehole construction. Heater cans were modified on site to match the extent of vertical impacts observed during drilling;
- Hydraulic profiling with the Waterloo APS TM tool was utilized at a site in Schenectady, NY to further delineate the boundaries of a low permeability silty clay layer, and optimize the screened intervals of vapor extraction and air injection wells; and
- Core DFN TM and installation of Flute TM FACT liners have been proposed as alternatives to conventional packer testing at a site to further characterize bedrock contamination and transmissivity in anticipation of thermal treatment. Proper planning of the borehole locations will allow for later re-use of the boreholes as heating points assuming full-scale implementation proceeds.

The site delineation tools described all lead to an improved definition of the thermal treatment area, and promote successful and cost-effective thermal remedies.

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Heavy Metal Attenuation Using Hemp (*Cannabis sativa L.*)

Gautham Das, Katherine Asciutto, and Audrey Iodice

A sorption study of heavy metals using hemp seeds was performed. Water dosed with part per million range concentrations of chromium and cadmium were passed through columns of hemp seed and effluent concentrations were collected and analyzed by both flame and graphite furnace atomic absorption. Results indicate sorption of these heavy metals did occur.

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Bacterial Degradation of Tetracycline: Metabolic Profiling and Biochemical Pathway Analysis

Aparupa Sengupta, Saumik Panja, Susan Bagley, Dibyendu Sarkar, and Rupali Datta

The excessive use, improper handling and disposal of antibiotics have created negative impacts on environmental and human health. Biological remediation systems using plants and/or microbes could be used to degrade antibiotics in the environment. Two bacterial species associated with vetiver grass roots were recovered during an in-vitro remediation study and identified as *Serratia marcescens* and *Burkholderia cepacia*. These two species were found to be highly tolerant to tetracycline (TC) and could utilize TC as a single carbon source in a minimal media (SCS). To understand the biochemical/metabolic pathways impacted during TC breakdown by these bacteria, glutathione S transferase (GST) activity analysis and metabolomic profiling were conducted. The results show GST activity was significantly induced in both bacterial species in enriched media during their exponential phase of growth. However, in SCS media, induction in GST was only seen in *B. cepacia*, and not in *S. marcescens*. Metabolomic analysis also indicated a differential response in the two species when treated with TC. *S. marcescens* showed a significant increase in pyrimidine and purine nucleotides and key amino acids indicating upregulation of nitrogen metabolism. Certain common metabolic pathways were induced in both species, such as alanine, aspartate and glutamate metabolism, and nitrogen metabolism. In contrast, in *B. cepacia* aminoacyl-tRNA metabolism was upregulated, which plays a critical role in protein synthesis, peptidoglycan biosynthesis and membrane lipid modification, likely to reduce the permeability of cell membrane. These results strongly suggest involvement of metabolic pathways, in these bacteria, in TC degradation hence in future can be used as a potential bioremediation tool.

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Optimization of Bioethanol Production from Lignocellulosic Biomass Using Vetiver Grass (Chrysopogon zizanioides) Grown on Metal-Contaminated Stamp Sands in Upper Peninsula, Michigan

Emily Geiger, Virinder Sidhu, Dibyendu Sarkar, and Rupali Datta

Depletion of fossil fuel reserves and increasing emission of greenhouse gases have generated world-wide interest in producing biofuels from renewable sources, such as lignocellulosic materials. However, lignocellulosic material is highly recalcitrant. Hence, optimization of three sequential steps that convert lignocellulose to ethanol, i.e., pretreatment, enzymatic saccharification and fermentation, are important. We found that vetiver grass (*Chrysopogon zizanioides*) is an excellent candidate lignocellulosic species for ethanol production, due to its rich fermentable hemicellulose and cellulose content and high biomass productivity. Vetiver can grow on nutrient-poor, marginal and contaminated soils, and tolerate heavy metals such as lead and copper. In the current study, vetiver grass was grown in copper-contaminated stamp sands in the Upper Peninsula of Michigan, where mining operations in the late 1800s and early 1900s left vast areas devoid of vegetation. Our goal was to (1) provide a vegetative cover on exposed stamp sands to reduce erosion of contaminated soil into the adjoining Torch Lake, which is an offshoot of Lake Superior, and (2) optimize bioethanol production using the vetiver biomass. Dilute acid pretreatment, enzymatic hydrolysis, and fermentation parameters were optimized sequentially for vetiver grass using response surface methodology (RSM). Following optimization, the effect of copper uptake in the vetiver biomass on ethanol production was investigated. At 23.5 hours 15.41 ± 1.81g/L ethanol (110% of theoretical) was achieved for the stamp sand grown vetiver and 8.71 ± 1.08g/L ethanol was achieved at 35 hours (62.3% of theoretical) for the control. Hydrolysates produced from copper exposed biomass achieved a significantly greater ethanol yield and volumetric productivity than hydrolysate from the control biomass.

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Implementation of a Hybrid Poplar Phytoremediation Program for Trichloroethene at an Arid Fractured Bedrock Site

Devon Rowe, Seema Turner, Erik Pearson, Carol Serlin, John Freeman, Christopher Cohu, and Safaa Dergham

Several areas within a former industrial facility in Southern California are being remediated for volatile organic compounds (VOCs), predominantly trichloroethene (TCE) in groundwater. In one area, recent concentrations range from approximately 1,400 micrograms per liter (µg/L) to 18,000 µg/L, exceeding cleanup levels. In this area, the plume is well-defined, bounded to the north, east and west. Groundwater flows slowly to the south towards an ephemeral stream. Geochemical indicators (e.g., dissolved oxygen, oxidation-reduction potential, presence of methane, and elevated cis-1,2-dichloroethene and vinyl chloride concentrations) suggest that natural attenuation processes are occurring in the vicinity of the ephemeral stream. Due to the subsurface conditions in this area (low permeability alluvium/degraded bedrock overlying fractured bedrock), remedial technologies used elsewhere at the site were not feasible, and phytoremediation was identified as the remedial alternative. Pilot studies (field and bench-scale) were conducted to assist in development of a full-scale phytoremediation design.

A field study was conducted to evaluate the presence of TCE in tree tissue, and qualitative relationships, if any, with nearby groundwater. The study included collection of 20 tree core samples, and analysis of headspace concentrations of VOCs from the tree tissue. Groundwater from monitoring wells near the cored trees was also analyzed for VOCs. The results of the field study confirmed that TCE was present in most of the trees sampled at the site, and correlated well with observed groundwater concentrations.

A bench-scale study was conducted to evaluate growth rates of candidate tree species, and assess tolerance to high salinity soils at the site. Two hybrid poplars were selected, and trees were installed in March 2016. This presentation summarizes the installation methods and irrigation design, and provides the results of the first year of growth, including tree tissue and groundwater sampling results to evaluate changes in groundwater geochemistry, VOC concentrations, and biodegradation conditions.

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Low Temperature Evaporative Desorption Technology As a Remedial Measure for On-Site Soil Treatment

Joseph Muzzio and Brian Desmarais

Advantages of on-site ex-situ thermal soil remediation are well documented, but development of approaches that provide these advantages and comply with stringent air emission regulations have been limited. Low temperature thermal treatment using the proven Evaporative Desorption Technology (EDT) offers a fast, cost-effective, and guaranteed remedial alternative to remove contaminants from soil, including petroleum hydrocarbons and chlorinated and semi-volatile organic compounds. EDT is a mobile, all-electric, ex-situ vapor extraction system designed for high throughput. EDT is a static process using electrically heated air to evaporate contaminants from soil with no particulate or vapor emissions. The cleaned soil can be reused on site, removing the long-term generator liability that is otherwise left in place at the site or moved to a disposal facility. Diesel emissions, traffic safety and other risks associated with trucking for off-site soil disposal are eliminated.

This presentation will describe the EDT process and operating parameters, permitting requirements, and the use of multiple lines of evidence to confirm contaminant removal. Discussion will include a Life Cycle Analysis comparing EDT to "Truck and Disposal" for key sustainability indices of Global Warming Potential, Primary Non-Renewable Energy Demand, and Particulate Emission. Multiple case studies demonstrating large- and small-scale EDT applications to mitigate identified exposure routes and expedite site redevelopment will be presented.

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Characterization of Urban Surficial Soils Using Particle Size Distribution and Metals Analysis

John Duggan, Dan Alix, and Phillip Curtsmith

A study of soil samples collected in the South End of Boston is being performed to compare the composition of different grain sizes in the sample to lead (Pb) levels. Grain size distribution (ranging from ½ inch to less than #200 sieve (0.0029 inches)) of three surficial soil samples was performed to qualitatively identify the soil and non-soil (i.e., glass, metal, brick, ash, etc.) components of different sized particles in the samples. Representative samples from different particle sizes were analyzed by atomic absorption – graphite furnace to measure lead levels present. Preliminary results indicate that lead concentrations increase as grain size decreases. While there is not an apparent association between non-soil particles and lead levels, this study is ongoing and includes developing methods to quantify non-soil particles in the fine-grained fractions of the samples.

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Temporal Variation of Aromatic and Aliphatic Hydrocarbons in Fresh Gasoline from Volatilization

John Duggan, Sofjola Bala, Maggie Cameron, Thomas Redznak, Benjamin Lutz, Ryan Ferriter, and Phillip Curtsmith

A twenty-day study of the change in composition in gasoline due to volatilization was performed. A fresh sample of gasoline over water was allowed to volatilize in a controlled setting. BTEX and aliphatic hydrocarbons in a gasoline sample were measured over time by gas chromatography using both flame ionization and photo-ionization detectors. As expected, results show that higher vapor pressure components volatilized more quickly from the sample, and over time the percentage of relatively lower vapor pressure hydrocarbons in the sample increased. A comparison of the relative amount of individual BTEX compounds and non-BTEX compounds in the sample over time was also determined.

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Jet Injection Emplaced mZVI Treatment of TCE in Clay Till: Two Years of Performance Monitoring

Dylan Eberle, Chapman Ross, Neal Durant, William Slack, Peder Johansen, Torben Højbjerg Jørgensen, and Eline Begtrup Weeth

Direct-Push Technology Jet Injection (DPT-JI) is a treatment strategy that can overcome the challenges of treating chlorinated solvents in low-permeability formations. This patent-pending injection method combines high pressure jetting (10,000 psi) and controlled hydraulic fracturing for emplacement of amendments into geologic matrices where remediation is limited by contact between reagents and solvents trapped in the matrix. In this study DPT-JI was used to emplace zero valent iron (mZVI) into a clay till source zone in Nivå, Denmark (the Site) for in-situ chemical reduction of chlorinated solvents. The target treatment area (TTA) at the Site is approximately 750 m^2 and 6 to 12 meters below ground surface (mbgs). Trichloroethene (TCE) is the primary contaminant of concern, with concentrations as high as 83 mg/kg observed during the baseline soil characterization.

In November 2014, 49 tonnes of mZVI was injected into the TTA. Results indicate that this new injection method can consistently create subhorizontal mZVI zones with a radius of influence of at least 3 m and depth spacings of 0.5 and 1 m. During the first two years of performance monitoring, strongly reducing conditions have been observed within the TTA. After 18 months, the estimated mass of TCE in TTA soils decreased approximately 85% from 29.3 kg to 4.5 kg. Reductions of TCE in post-injection soil cores are typically coincident with observed mZVI filled fractures. Groundwater data indicate that the TCE mass discharge from the source area has decreased by over 70% two years post-injection. Significant ethene and ethane production, up to 3.6 mg/L ethane, has been measured in the TTA demonstrating complete TCE degradation. Although three more years of performance monitoring are planned, the findings to date show that DPT-JI emplaced remedies can achieve significant degradation of chlorinated solvents in low-permeability soils that are largely inaccessible to conventional injection technologies.

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Full-Scale Enhanced Anaerobic Bioremediation of Two Low Permeability Source Areas

Heather Fariello, Mark Harkness, Damian Foti, and Thomas Antonoff

Enhanced anaerobic bioremediation through electron donor amendments in and directly downgradient of suspected source areas was used to treat trichloroethylene (TCE) found in two source areas at a manufacturing site. The treatment system included the design and installation of a biobarrier in highly permeable channel fill surrounding the source areas and direct injections into lower permeability flood plain deposits containing the source material. Two electron donors, emulsified vegetable oil (EVO) and EHC®, were employed to promote reductive dechlorination of TCE. EVO was selected for the channel fill biobarrier because the low viscosity emulsion could be readily distributed in the permeable deposits and is slowly depleted. A total of 21,120 pounds of 60% EVO solution was delivered to the aquifer through a series of 55 injection wells screened across the zone of highest dissolved phase VOC concentrations to ensure a uniform distribution of amendment. The biobarriers were emplaced prior to source treatment to allow for time for bioreactive zones to develop around the source areas to minimize the transport of contaminants liberated by the source treatment.

EHC® was selected for the flood plain deposits because it could be injected into the low permeability formation. EHC®, a solid material composed of a plant-based carbon source and zero-valent iron (ZVI), is designed to combine both short- and long-term availability of soluble carbon and ZVI. At total of 28,897 pounds of EHC® was injected into the two source areas under high (100-400 psia) pressure through 87 injection points. The distribution of EHC® in the subsurface was directly and quantitatively measured using confirmation soil cores and magnetic susceptibility measurements.

Groundwater sampling completed three months post injection demonstrates that extensive reductive dechlorination is occurring in both source areas and at downgradient locations. In several cases downgradient monitoring wells now contain predominantly ethene and ethane.

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PCE and TCE Source Identification: A Multiple-Parameter Approach

Stephen Emsbo-Mattingly, Katherine Flanders, Eric Litman, James Occhialini, and Andy Rezendes

Chlorinated volatile organic compounds (CVOCs) are regulated at very low concentrations, especially in groundwater and drinking water. Environmental forensic strategies must be equally flexible and adept at determining the source of these constituents in a variety of situations. Recent work with tetrachloroethylene (PCE), trichloroethylene (TCE), dichloroethylenes (DCE), vinyl chloride (VC), and others demonstrate the benefits of a multiple parameter approach at sites potentially impacted by degreasing, dry cleaning, and electrical equipment operations.

The first level of forensic analysis focuses on the existing historical data. The composition of CVOCs and co-contaminants can be screened through the detailed inspection of traditional volatile organic compound analyses using EPA 8260. The compositional features help characterize the Cl isotopic composition of one or more sources which may be in various stages of degradation. The spatial distribution of the field samples helps confirm the point of release and the extent of contamination. In combination with the groundwater flow and direction, these data can also help constrain the age of release.

Advanced confirmation methods can more precisely determine the chlorine isotopic composition of CVOC contaminants. The use of GC/MS SIM methodology provides a sensitive analytical technique to characterize the source specific composition of CVOCs and allocate contributions from different source materials. Chlorine isotope methods prove especially helpful for distinguishing the origin of solvents that are also reductive dechlorination byproducts, such as TCE. Co-occurring contaminants, like cutting oils, plasticizers, polymers, and polychlorinated biphenyls (PCBs) help further distinguish mixed solvent plumes. Case studies illustrate the value of the multiple parameter approach.

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Data-Driven Decision Management: A Values-Focused Approach to Enable Traceable Decision Analytics for Adaptive Climate Resilience

Aharon Fleury

The rapid pace of large-scale environmental changes around the globe underscores the value of long-term data sets for understanding the context of scientific observations, forecasting future conditions, and making informed decisions on how to adapt to these large-scale challenges. However, data and models that provide status and trend information are only as good as the human-mediated processes that utilize these information products for decisions. How do we derive a stakeholder-driven set of climate resilience solutions that combines stakeholder values, data, and models to guide decisions that are technically defensible? How do we facilitate adaptive management by creating "decision management products," akin to scientific data products, where decision processes are reproducible and traceable? What are the best practices informed by decision science that lend structure to the co-creation of resilience solutions by stakeholders and subject matter experts? This poster presents an interdisciplinary framework that synthesizes accomplishments and approaches from informatics, socio-ecological science, decision science, and global change research. The framework demonstrates how our respective roles in the climate solutions enterprise relate to the larger goals of values-focused and data-driven decision management for climate resilience.

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Use of Permeable Reactive Barrier to Bioremediate a Petroleum Hydrocarbon Groundwater Plume

Mike Mazzarese and Duane Guilfoil

Circa 1980s release of gasoline at a large throughput fueling facility at an Interstate Rest Area produced a groundwater plume which impacted a downgradient wetland area. Previous remediation efforts at the facility sufficiently addressed petroleum impact to the vadose zone but the groundwater plume persisted. Dissolved volatile petroleum hydrocarbons (VPH) were detected in monitoring wells located at a wetland area approximately 200 feet from the sources (underground storage tank systems). The natural reducing conditions at the wetland were exacerbated by the petroleum hydrocarbon groundwater plume resulted in the concentration of arsenic and beryllium in shallow soils. Remediation of the groundwater plume was complicated due to the active fueling operation and presence of approximately 25 feet of fill material [boulders, blast rock, and concrete from the circa 1960s construction of the Interstate highway] overlying the saturated zone. A permeable reactive barrier (PRB) was installed orthogonal to groundwater flow approximately 100 feet up-gradient of the affected wetland to bioremediate the groundwater plume. A mixture of granular activated carbon product (BOS 200®), calcium sulfate, and water was injected throughout the saturated zone to establish the PRB. Post-installation monitoring data indicate that the remedy is performing as designed. The conceptual site model, PRB design and installation data, and approximately 18 months of post-PRB installation performance monitoring will be presented.

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Application of the Biotic Ligand Model to Derive Acute and Chronic Site-Specific Water Quality Criteria for Copper in the Little Androscoggin River

Patrick Gwinn

The U.S. Environmental Protection Agency (EPA) national ambient water quality criteria (AWQC) are derived from bioassays conducted in laboratory waters, and are meant to be protective of waters nationally. However, EPA and many states provide for modification of national recommended criteria to reflect site-specific conditions. As part of the 2007 freshwater AWQC update for copper, EPA promulgated the use of a biotic ligand model (BLM) as a tool for developing state- and/or site-specific criteria (SSC). This predictive tool accounts for site-specific influences on copper's aquatic toxicity by estimating the bioavailability of copper based on relatively simple and inexpensive water quality measurements. This presentation provides an overview for the successful development of acute and chronic site-specific copper criteria on the Little Androscoggin River in Maine. The biotic ligand modeling project, conducted on behalf of a rural municipal water district, accounts for site-specific chemical influences on copper's aquatic toxicity. The end product of this successfult project is two-fold: 1) the development of site-specific acute and chronic copper criteria that are both protective of human health and the environment, and 2) NPDES discharge license limits that are attainable.

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Use of a Novel Biomarker, Botryococcane, to Monitor Biodegradation of Lacustrine-Sourced Crude Oils

Jeff Hardenstine, Gregg Douglas, Sara McMillen, Robert E. Hoffmann, Roopa Kamath, and Deyuan Kong

Bioremediation has been a proven alternative for remediating petroleum-impacted soils at Exploration and Production (E&P) sites since the early 1990s. The relative enrichment of stable refractory compounds such as $C_{30}17\alpha(H),21\beta(H)$-hopane (hopane) is used to measure the efficacy of the bioremediation process. Because of the low concentration of hopane within the complex petroleum matrix, gas chromatography with mass spectrometry (GC/MS) is required for the reliable identification and quantification of this compound. Unfortunately, GC/MS analysis is not always available at remote E&P sites, and the development of a bioremediation monitoring tool based on the more available gas chromatography with flame ionization (GC/FID) would allow a cost effect way to monitor how well bioremediation is progressing.

Lacustrine oils derived from ancient inland fresh or brackish lakes in Sumatra, South Australia, and the Maoming Shale, China, contain a relatively high concentration of a C_{34} isoprenoid – botryococcane. Botryococane is more abundant in these oils than hopane and can be measured using GC/FID which is more commonly available. This study evaluates the use of the botryococcane to monitor the biodegradation of two lacustrine-sourced oils from Sumatra. Results indicate that after 3 weeks of biodegradation in laboratory experiments, botryococcane and hopane exhibited similar ranges of stability ratios with respect to the more recalcitrant biomarker C28, 20S-triaromatic steroid. Continued biodegradation of the oils between 7 to 15 weeks resulted in severe biodegradation of the oils. Under these conditions, which are more likely to be observed under laboratory optimized system, results indicate that although hopane and botryococcane can biodegrade, botryococcane was almost twice as stable as hopane (T_{7wk}). These results provide a novel application of the GC/FID-measureable concentrations of botryococcane in lacustrine crude oils to more accurately monitor bioremediation effectiveness at remote E&P locations.

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Injectable Activated Carbon Reactive Barriers: Remedial Progress and Lessons Learned

Karen Kinsella, Sara Haupt, Erik M. Beloff, Richard A. Carlone, Bernard G. Fenelon, John C. Osborne, and Edward A. Summerly

PlumeStop® (Regenesis) is a colloidal injectable activated carbon (AC), with the viscosity of water. The colloidal coating biodegrades within a few weeks following injection, leaving AC dispersed throughout the soil matrix to form a sorbent reactive biobarrier. PlumeStop was injected at three sites in 2016, and will be injected at two sites in 2017.

Chlorobenzenes in fractured bedrock groundwater underneath a Rhode Island landfill are managed by groundwater extraction and treatment. A former source area extraction well was used to inject PlumeStop. Chlorobenzene concentrations decreased initially at the injection site, but returned to baseline at three months, suggesting that AC infiltrated the downgradient bedrock fractures as anticipated, rather than remaining in the source area. Downgradient chlorobenzene concentrations three months after the injection were 54 to 87% less than pre-injection concentrations.

Degreasing operations at a site in Wisconsin created a tetrachloroethene (PCE) plume that extends offsite. Site stratigraphy is complex, with glacial clay layers underlain by a sand aquifer and dolomitic bedrock. The source area remedy is in-situ thermal treatment. PlumeStop was injected into the downgradient sand aquifer to address potential enhanced PCE migration during heating of contaminated soil.

A former jewelry plating facility in Rhode Island is contaminated with PCE, trichloroethene (TCE) and their breakdown products. Enhanced reductive dechlorination is ongoing in the source area. A PlumeStop barrier was injected at the downgradient property boundary to address downgradient migration.

Injectable AC promotes contaminant diffusion out of tight soils and bedrock fractures, minimizing groundwater impact while enhancing natural attenuation and reducing downgradient contaminant migration. We will present remedial progress and lessons learned at these sites and two others, one where PlumeStop will be used to manage a petroleum plume, and another where a PlumeStop barrier will be injected to manage migration and back-diffusion of chlorinated ethenes in clay.

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Influence of Suspended Sediments on Electrochemical Remediation of Karst Groundwater

Kimberly Hetrick, Ljiljana Rajic, Akram Alshawabkeh, Dorothy Vesper, Mohammad Shokri, and Ingrid Padilla

Electrochemical remediation is an innovative, sustainable, and promising approach for treatment of complex groundwater terrains such as karst. Electroremediation offers high flexibility in generation and control of conditions needed for the contaminants' transformation to harmless byproducts. However, performance of the treatment can be affected by the presence of suspended sediments, which appear in karst groundwater due to direct recharge through sink holes and other areas. In this study, we evaluated the impacts of suspended sediments originating from three locations (denoted MC, DLC, and CTS, which respectively leach 32, 37, and 33 ppb Fe, and 4, 2, and 48 ppb Mn in simulated groundwater) on electrochemical processes supporting the electro-Fenton reaction. We tested the production rates of in situ electro-generated hydrogen peroxide in the absence and presence of 2 grams per liter of each sediment sample (particle size <2 mm). The tests were conducted in a flow-through electrochemical reactor under current intensity of 90 mA and flow rate of 5 mL/min. Compared to the control experiment, the hydrogen peroxide production decreased by 53% in presence of MC, 49% in presence of DLC and 71% in presence of CTS. Tests confirmed some sorption of sediment particles on the electrodes, which lowers their active area and limits the production of chemical species involved in hydrogen peroxide formation. Tests have shown that at a pH of 10 in the cathode vicinity, as opposed to a pH of 4, results in a greater effect of suspended sediments on reducing hydrogen peroxide production, most likely due to hydrogen peroxide degradation into water, which is greater at higher pH values in the presence of particulates. Further investigations involve exploring other inhibition pathways, as well as the influence of additional redox-species such as Fe and Mn from sediments on hydrogen peroxide activation to hydroxyl radicals: a favorable pathway that supports creation of oxidizing conditions.

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Evaluating the Shutdown of Sub-Slab Depressurization Systems Downgradient of a Former Drum Burial Site

Shahen Huda, Joseph Jeray, Chapman Ross, and Julianna Connolly

After completion of groundwater remediation, Geosyntec conducted shutdown tests to demonstrate that active sub-slab depressurization (SSD) systems were no longer needed to mitigate vapor intrusion at three buildings downgradient of a Former Drum Disposal Site. Concentrations of volatile organic compounds (VOCs) in shallow groundwater near each building have decreased due to groundwater remediation activities at the Site, and we hypothesized that VOCs migrating from shallow groundwater to indoor air may no longer pose an unacceptable risk. SSD systems are installed in a commercial office building and two residential buildings, including a duplex with separate SSD systems in each unit's basement.

Shutdown tests were conducted to evaluate indoor air VOC concentrations when the SSD systems were not operating. Multiple tests were completed for each SSD system in accordance with MassDEP guidance. The shutdown tests involved shutting down each SSD system for at least one week to allow conditions to equilibrate. Indoor air samples were then collected. For selected tests, sub-slab soil gas samples and groundwater samples were also collected. Groundwater samples were collected periodically throughout the SSD operational period.

Indoor air and sub-slab soil gas results from the shutdown tests were compared to regulatory threshold values and risk management criteria. Results were also compared to concentrations in samples collected before the installation of each SSD system. Trends in indoor air and soil gas concentrations, and their relationships to groundwater concentrations, were also evaluated.

The SSD system shutdown tests were an effective application of the MassDEP Vapor Intrusion Guidance to limit the duration of active SSD operation. This project is a case study for using SSD systems as an interim measure rather than a permanent engineered control requiring long-term operation and maintenance. The data evaluated here can be used to inform decision-making at similar sites about the effects of source remediation on downgradient receptors.

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Drinking Water Guidelines for PFOS and PFOA – Toxicological Basis and Decision-Making Implications

Julie Kabel, Usha Vedagiri, and Betsy Ruffle

There is increasing concern in the U.S. and world-wide about the potential health effects of perfluoroalkyl substances, including perfluorooctane sulfonate (PFOS) and perfluorooctanooic acid (PFOA). PFOS and PFOA have been detected in numerous groundwater and drinking water systems. In response, several countries and agencies have published health advisories and/or screening levels for drinking water that are protective of human health. However, there are wide variations in the recommended advisory levels. For example, the U.S. Environmental Protection Agency (2016) recommends 0.07 µg/L for both PFOS and PFOA as drinking water health advisories. In contrast, Australia Department of Health (2017) recommends health-based drinking water guidance values of 0.07 µg/L for PFOS and 0.56 µg/L for PFOA. The state of New Jersey (2017) recommends a health-based maximum contaminant level (MCL) of 0.014 µg/L for PFOA. The variations are a result of differences in interpretation of and level of confidence in toxicity data, exposure assumptions and agency priorities. The expected response actions associated with exceedances of these guidelines are also variable and are of particular interest to institutions and responsible parties that have a multi-state or multi-county presence. This presentation examines the toxicological basis of drinking water guidelines from several states and countries, the association between water concentration and serum concentrations and the implications of using these guidelines in the context of decision-making about water supply and for contaminated sites.

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Using 'Big Data' Techniques to Optimize Soil Remediation

Tomasz Kalinowski, Cameron Dixon, Christopher Brownfield, Scott Mikaelian, Mark Terril, Jody Overmyer, and Richard Feinberg

Executive Summary: Results from a data-intensive study to characterize the capillary rise and water table elevations as part of a large remediation effort are presented. In total, over 5 million sensor measurements of 18 different kinds were recorded and analyzed as part of a year-long field study. The analysis included development of novel data visualizations, including animated graphics and web-based interactive data visualizations.

Extended Summary: Concerns of contaminated groundwater impacting clean soils through capillary rise prompted a year-long high-resolution field study with ~200 soil and groundwater sensors collecting hourly measurements. Data was paired with an on-site meteorological station recording weather conditions in 15-minute intervals. The study focused on understanding the range of elevations where contamination from groundwater may be present in the future.

Findings from the high-resolution year-long field study were then integrated with a complementary analysis of the relatively sparser historic site dataset going back 14 years, as wells as meteorological data over the past century.

'Big Data' is a term commonly used to describe datasets, such as this one, that are too large to analyze using conventional techniques and that require the development of advanced custom analytics software.

The large volume of data on this project required the development of a custom R data-analysis pipeline, which featured novel visualizations and statistical workflows, and heavy use of automation and report reproducibility. Additionally, custom interactive data visualization and reporting tools were built, allowing the project team to interactively explore visualizations of up-to-date data through a web-browser-based "dashboard."

The results of the study were used in remedial design to determine the final ground surface elevation and to identify site areas where construction of a "capillary break" was appropriate. The outcome of the study was a highly data-driven, optimized, and efficient site remedy.

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ERH Remediation of Shale Bedrock – Central New Jersey

Chris Blundy, Emily Crownover, and Mark Kluger

Electrical resistance heating (ERH) is being implemented at a site in central New Jersey in which the treatment volume consists entirely of weathered shale bedrock. Past bedrock remediations have combined treating overburden soils with the underlying bedrock matrix. Due to the lithology of this site and the depth of contamination, the ERH treatment interval extends as deep as 30 feet into the shale bedrock and does not entail treating the overburden. Tetrachloroethylene (PCE) is the contaminant of concern at the highest groundwater concentrations with baseline concentrations exceeding the water solubility limits for PCE.

Active utilities exist within and surrounding the ERH treatment area including sewer, electrical, natural gas, and multiple fiber optic lines. Utility vaults are also present within the ERH treatment area. Sensors were installed to implement continuous temperature monitoring of the subsurface vaults and utilities to ensure that temperatures remain below each of the utility specific limits. A portion of the treatment volume is beneath a building that remained active during the installation of the ERH system. Angled electrodes were installed to enable heating beneath the building which has continued to remain active throughout operations.

Due in part to the weathered nature of the shale bedrock at this site, subsurface heating achieved with ERH has been highly effective, resulting in steaming conditions at the deepest bedrock treatment depths. The remediation is ongoing and groundwater concentrations from upcoming sampling events will be reported.

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Influence of Soil Characteristics on the Bioluminescence Activity of a Bioreporter Strain Used for Monitoring Toluene Analog Pollutants

In Chul Kong, Eun Jin Lee, Hyeun Jin Jang, Xin Yang, Moon Hee Lee, and Kyung-Seok Ko

This study evaluated the influence of soil properties, including metal content, on the bioluminescence of a bioreporter strain (*Pseudomonas putida* mt-2 KG1206) used for monitoring soil pollution by toluene analogs. In control experiments, bioluminescence activity was induced by such analogs to varying extents, in the following order: toluene > m-toluate > m-xylene > p-xylene > o-xylene. The extent of bioluminescence triggered by each inducer in different soil extracts was influenced by a wide range of factors; bioluminescence activity ranged from 53% to 156%, relative to the control values. Neither the total nor weak acid-extracted metal content of the soil samples correlated with the sum of the total bioluminescence activities over all inducers (R2 < 0.2671). However, considerable correlations were observed between the weak acid-extracted metal content and the bioluminescence activity of specific inducers; toluene and m-toluate produced R2 values of 0.6133 and 0.7677, respectively. Our results suggest that, among the soil characteristics examined, the weak acid-extracted metal content and cation exchange capacity are slightly more correlated with the bioluminescence activity of the bioreporter strain KG1206 at biomonitoring sites.

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Legionnaires' Disease Prevention: A Novel Approach to Analyzing Data and the Risk of Amplification

Megan Canright, Shaiasia Itwaru-Womack, Alexis Jones, and David Krause

The confluence of regulatory pressures to reduce energy and water consumption, limit exposures to carcinogenic disinfectant by-products, and an aging potable water distribution infrastructure has accompanied record rates of Legionnaires' disease (LD) across the United States. In the past, public health authorities only recommended environmental testing for Legionella sources after an outbreak. In 2015 a series of standards and guidelines were published that recommended a proactive preventive approach. By implementing a water management plan that periodically measures water temperatures, disinfectant or biocide levels, in addition to other parameters known to control Legionella, building operators can proactively reduce the risk of exposure, and by extension, risk of contracting Legionnaires' disease. An unavoidable outcome of implementing such a program is the generation of large volumes of data, and the need for analysis and interpretation. There is currently no consensus for how to compile, evaluate, and communicate the risks posed by various factors contributing to Legionella amplification. Our novel approach to data compilation, interpretation, and its representation described here enables the simultaneous analysis and representation of multiple factors that contribute to the amplification of Legionella in building water systems. Polar plots represent the increased risk of Legionella amplification for each sampled area and the resulting concentration of Legionella bacteria detected. Data plotted closer to the center (origin) of the circular graph indicates higher risk of amplification while data plotted near the outer boundary indicates lower risk of amplification. The importance of this novel approach to analyzing and communicating multi-factorial risk factors in a single comprehensive graph is that existing methods of data representation are complex, cumbersome, and difficult to understand and communicate. As data for a building's water system accumulates and trends are observed, predictive indicators may be identified that may aid in preventing Legionella amplification.

Keywords: Legionnaires' Disease, risk communication, data presentation

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PFAS Analytical Data: Potential Data Quality Issues

Lisa Krowitz

As of January 2017, the only promulgated method for the analysis of poly- and perfluoroalkyl substances (PFASs) is US EPA Method 537 Rev. 1.1 (Method 537) which uses liquid chromatography with tandem mass spectrometry (LC/MS/MS). The method is specific to drinking water samples, but most laboratories are using their own modified version of Method 537 for analyzing other matrices, such as groundwater, surface water, soil, and sediment. The modifications vary by laboratories with some using internal standards and surrogates along with external calibration and others using isotopically labelled surrogates and isotope dilution quantitation. Thus, comparison of PFAS data from different laboratories through data validation is an important step to ensure the quality, comparability, and usability of the data for specific project objectives. Since there are currently no data validation guidelines specific to PFAS data, the US EPA *National Functional Guidelines for Superfund Organic Methods Data Review*, EPA-540-R-2016-002, September 2016 can be used as a general data validation reference along with the analytical method and quality assurance project plan (QAPP) requirements, when available. As a result of varying versions of Method 537, issues have been noted during data validation, especially with regards to quantitation of linear and branched isomers. Even though Method 537 specifically addresses including the branched isomers when quantitating for PFOS, PFHxS, NEtFOSAA, and NMeFOSAA, and EPA issued a Technical Advisory recommending that laboratories quantify linear and branched isomers for PFOA, not all laboratories are following these guidelines. This presentation provides some of the data quality issues and differences between PFAS data from different laboratories that have been discovered during data validation.

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Advancing Urban Site Remediation Using Aerobic Bioaugmentation and Strategic Direct Push Application

Keri Lauer and Jarrod Yoder

Remediating recalcitrant chlorinated volatile organic compounds (CVOC) in soils in developed urban areas requires the use of innovative technologies. Challenges presented by utilities, buried structures, and nearby buildings involve access limitations to areas requiring treatment. As a result, conventional remediation via excavation, mechanical/electromechanical equipment, or other invasive methods are often infeasible, disrupt neighbors, and are cost prohibitive. In addition to the variety of subsurface challenges, selection of an effective remedial technology can be limited further by contaminant type, aquifer characteristics, and difficult soil types that are common in densely populated areas.

At two urban sites, direct push technologies were used to deliver low volumes of aerobic, pathogen-free *Pseudomonas* to the subsurface to facilitate rapid bioremediation of chlorinated solvents. By capitalizing on the aerobic aquifer characteristics, the microbial consortium was injected to produce enzymes capable of degrading PCE and associated daughter products. The injected microbial consortium has a wide metabolic diversity that has the ability to transfer plasmid encoded enzymes between strains, allowing them to thrive in many subsurface environments under variable geochemical conditions. This aerobic process will deplete dissolved oxygen in groundwater over time, thereby slowing microbial population growth and activity. To counteract the depletion of dissolved oxygen, an oxygen supplement was used to support the cometabolic process.

Results of the bioaugmentation injections at these two sites demonstrated that these "green remediation technologies" achieved remedial goals faster, and with fewer risks (e.g., chemical exposure, engineered lateral earth supports for buildings, safety) than if other remedial technologies had been used. Data will be presented that illustrates: 1) CVOC concentrations were initially reduced by 50%; 2) the resulting injections assisted with the desorption of CVOCs from soil; and 3) post-injection monitoring indicated that CVOC concentrations were reduced between 90 and 99% within 6 to 12 months with limited rebound.

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Use of PIANO Data for Differentiation of Gasolines Based on Source and Regionality

Jonathan Thorn, Kevin McInerney, and Robert Lizotte

Gasoline releases to the environment are a common source of environmental contamination and can lead to punitive damages for a responsible party. In many cases, identification of one or more responsible parties relies on site history and a complete forensic investigation, including chemical analysis of source material as well as impacted water and soil/sediment samples.

Standard methods approved by the United States Environmental Protection Agency (EPA), specifically method 8260C, are designed to provide quick, quantitative, and inexpensive information needed for regulatory decisions. This method, for volatile organic compounds (VOC), has limitations with regards to gasoline range organics. Specifically, 8260C only includes only selected compounds found in gasoline. To fully characterize gasoline releases for site characterizations, forensic applications, and toxicity tests, more robust analysis is required. A complete suite of paraffin, iso-paraffin, aromatic, naphthenic, and olefinic (PIANO) analytes, plus oxygenates and other gasoline additives (totaling 170 individual constituents with a few coeluting compounds) is required. Battelle has conducted extensive PIANO analysis on gasolines collected from various regions and sources as well as artificially weathered gasolines. Differences in chemical fingerprints from source to source, regional differences, and artificial weathering are prevalent in the extended PIANO suite of analyses. A discussion of these differences as well as differences in methodology from standard EPA methods will be presented.

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Development of Approach for Removing Highly Viscous DNAPL from a Well at a Former MGP Site

James Marolda

Environmental forensic results from samples of non-aqueous phased liquid (NAPL) collected from a former Manufactured Gas Plant (MGP) site in New York State indicated that coal carbonization was likely the process used at the former MGP. As with other MGP Sites where the coal carbonization process was used, one of the waste byproducts is a dense NAPL (DNAPL) with a density slightly greater than water, and which typically occurs as a viscous material ("tar") in the subsurface.

Removal of tar that accumulated in one monitoring well proved to be challenging due to the highly viscous nature of the material. To provide a better understanding of its characteristics important for evaluating its recoverability, an analysis of the physical properties of the tar was performed. The viscosity data obtained corroborated the characteristics observed in the field and provided a result that is comparable to the viscosity of chocolate syrup.

Through trial and error, several methods were employed to remove the tar before an effective approach was developed. The removal process, which is currently being conducted, involves bailing using a small diameter (1.25-inch) bailer constructed with a cap on the bottom end of a PVC pipe and attaching this short section of pipe to a longer section of PVC pipe using a steel bar, leaving an approximate six-inch open space between the sections of pipe to allow the tar to enter the short section of pipe at the bottom of the device.

Over the course of seven months since the tar removal efforts were initiated, over three gallons of this highly viscous DNAPL have been removed from this well location. The tar continues to accumulate in the well and monthly removal activities will continue until the rate of recovery decreases such that a reduction in the frequency of the removal efforts would be warranted.

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Denitrifying Permeable Reactive Barriers: Bench-Scale Studies and Implementation of the First In-Situ EVO PRB on Cape Cod

Paul Dombrowski, Michael Temple, Thomas Parece, Julianne Marrion, Betsy Shreve-Gibb, Mark Owen, James Begley, Michael Lee, and Richard Raymond

Septic systems are used for approximately 85 percent of the wastewater on Cape Cod, Massachusetts. Nitrogen from leach fields sinks to groundwater, where bacterial reactions transform organic nitrogen to ammonia and eventually to nitrate under aerobic conditions. Nitrate-laden plumes travel without significant attenuation to Cape Cod's coastal waters. The cost to bring Cape Cod communities in compliance with the Clean Water Act has been estimated to be at least $4 billion. To meet the estuary Total Maximum Daily Load and minimize sewering, sustainable technologies like permeable reactive barriers (PRBs) are being evaluated as non-traditional alternatives to remove nitrate from groundwater via denitrification.

Fast groundwater flow (1-2 feet per day) and high fluxes of nitrate and oxygen are design challenges. Column studies were performed to evaluate the nitrate treatment capability of emulsified vegetable oil (EVO) PRBs and determine critical design parameters using soil and groundwater from a representative site in Cape Cod. Different EVO formulations and loadings were tested at groundwater flow rates expected. Based on public concerns of EVO migration, modifications were made to surfactant properties to make the amendment stickier to soil to minimize migration of oil. In parallel, sites in one Cape Cod community were evaluated for a denitrification PRB considering site suitability, depth to groundwater, ownership, groundwater nitrogen profile, and ease of monitoring.

The first EVO PRB demonstration test on Cape Cod, a 100-foot barrier, was completed in November 2016. Post-injection monitoring has demonstrated reductions in dissolved oxygen and nitrate, indicating the EVO PRB is enhancing native denitrifying bacteria. The presentation will highlight lessons learned from the bench-scale and field-scale demonstration test, evaluation of nitrate flux reduction, and design considerations for full-scale PRBs. A key conclusion will be the cost per kilogram of nitrogen removed using PRBs as compared to nitrogen removed using traditional sewering.

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Comparison of Dry Oxygen Scavengers for Preparing Anaerobic Injection Waters for EISB

Brendan McShane and William Newman

Background – Using anaerobic injection water to distribute electron donors and bioaugmentation cultures enables workers to inject into aerobic groundwater that is typically toxic to *Dehalococcoides* and other obligate anaerobes. Anaerobic injection water can be drawn from local groundwater sources (often with above-ground treatment) or produced on site through a variety of techniques. Dry powder oxygen scavenging blends were produced and tested for their dissolved oxygen (DO) removal and ORP reducing rates on highly oxidized municipal water. Testing was conducted at the bench- and tote-scale in Minnesota, and the field-scale in Washington, California and Georgia. Field-scale treatment projects focused on treating chlorinated ethenes and ethanes in moderate to highly oxidized potable water, while bench- and tote-scale testing focused on clean potable water. A brief conceptual comparison of various deoxygenation methods will be used in order to compare dry powder oxygen scavenging blends to other possible techniques (e.g., N2 stripping, applying a vacuum, prior injection of electron donors). Anaerobic water can be prepared quickly and affordably if a quality oxygen scavenging blend is used.

Approach – Antioxidants remove DO and free chlorine from water, buffering agents maintain adequate pH, and chelated metal catalysts significantly increase reaction rates in many water chemistries. Monitoring probes were used for semi-continuous monitoring of DO removal and ORP reduction at bench- and tote-scales for a wide variety of oxygen scavengers including sulfites, ascorbates, erythorbates, amino acids, enzymes and reduced metals.

Results – The most successful oxygen scavenging blends tested include three major classes of ingredients: antioxidants, buffers and chelated catalysts. Anticipated data and analyses will compare the advantages and disadvantages between amino acids, antioxidants, enzymes, metals and sulfites when used with or without pH buffers and/or chelated catalysts.

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PAH Mobilization from Coal Tar-Based Asphalt Rejuvenators

Caroline Meyer, Seth MacDonald, and John Bergendahl

Coal tar-based pavement products, including sealcoats and rejuvenators, have been under scrutiny due to the presence of high concentrations of polycyclic aromatic hydrocarbons (PAHs) in the coat tar base. Researchers have found that PAHs mobilize from coal tar sealcoats, primarily through the formation of PAH-laden dust particles. Coal tar-based sealcoats have been banned in many locations in the U.S. due to the concerns over carcinogenic and mutagenic effects of the PAHs they contain. In this research, the environmental impacts of a coal tar-based pavement rejuvenator were investigated. The purpose of this project was to quantify PAHs mobilized from a coal tar-based rejuvenator by collecting street dust samples and catch basin sediment samples, and analyzing for PAH compounds. Samples were taken from a neighborhood in New England where the coal tar-based product was applied in 2016. These samples were tested for PAH concentrations using gas chromatography. The concentration of PAHs mobilized from the application site to the surrounding environment gave a snapshot of the possible environmental and health risks of coal tar-based products. Recommendations for alternative products were explored.

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Control of Methane During ERD and ISCR to Lower Greenhouse Gases for a Sustainable Remediation

Jim Mueller and Will Moody

At some sites, excessive production of methane has been observed following the addition of organic hydrogen donors such as (emulsified) oils, lecithin, sugars and conventional ISCR reagents. This is because methanogens are commonly the most ubiquitous indigenous microbes in anoxic aquifer settings. And given that methanogens replicate in 1 to 2 hours they often bloom and dominate following the addition of organic hydrogen donors, thereby liberating large amounts of methane gas. There are at least three important consequences of this response:

1. By utilizing hydrogen, the methanogens compete with dechlorinating microbes thus making inefficient use of the remedial amendment
2. Rapid growth of methanogens consumes alkalinity while generating acids thereby having the potential for aquifer acidification (which may liberate heavy metals causing secondary contaminant issues); and
3. Elevated methane concentrations can exceed current and pending regulations.

Case studies will be reviewed where methane production was problematic and a quantitative analysis of the reduction in carbon footprint will be presented:

1. Generation of up to 23% methane in soil gas immediately adjacent to a public church in North Carolina (with sustained methane production for 8 to 9 months) from an excavated area treated with, a non-anti-methanogenic conventional ISCR reagent;
2. Sustainability analysis of a 10 site remediation program for chlorinated solvents.
3. Analysis of a large ISCR site that would benefit from a 33% reduction in the production of methane.

It is clearly important to prevent excessive methanogenesis during a successful remedial action, from a regulatory perspective and a sustainability perspective. The use of Provect anti-methanogenic reagents uniquely utilizes a source of natural statins as inhibitors of protein biosynthesis and activity of enzyme systems unique to Archaea (*i.e.,* methanogens). Data from laboratory and field studies will be presented to demonstrate rapid contaminant removal coupled with controlled methanogenesis for safer, more sustainable remediation.

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Temporal and Spatial Evaluation of Two PCB Groundwater Plumes Based on Homolog Distributions

Jeffrey Holden and Wendy Moore

A former electronics manufacturing facility in the Northeast historically used polychlorinated biphenyls (PCBs) in the production of capacitors. Records indicate that the facility primarily used PCB Aroclors 1242 and 1016 prior to the phase-out of PCBs in 1977. During this use period, PCBs were released inside the facility as a result of operational practices, causing PCB impacts beneath the buildings. Investigations performed following building demolition indicated PCB concentrations in soil up to 140,000 mg/kg and in groundwater up to 85.5 ug/L. The site's operational history also included a state-permitted landfill area where manufacturing wastes – including drummed spent solvents and discarded capacitors – were disposed in unlined trenches.

As a result of the former facility operations and waste management practices, two zones of PCB-affected groundwater have been identified. One is within and downgradient from the former facility area. The other is beneath the former landfill area. Since 2006, PCB concentrations in groundwater have been investigated and monitored using US EPA Methods 1668 and 680 with reporting of individual homolog groups. The resulting dataset, in combination with typical homolog signatures for the types of Aroclor mixtures historically used at the site, facilitates a comparative evaluation of the two PCB-affected groundwater areas. This includes changes in PCB homolog signatures over time and with distance along the flow paths. The evaluation is confounded by various remediation activities that have been performed over time to address PCB and non-PCB impacts to soil and groundwater. It is further complicated by ancillary PCB release areas downgradient of the former facility, which change the PCB homolog signature beyond simple weathering effects from a single release source. However, this process can also provide valuable insights regarding the need for and scope of ongoing monitoring and remediation activities for the site.

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Design and Implementation of Air Sparge Systems – Innovative Approaches to Overcome Area-Specific Contstraints

Nadira Najib, Andrew Quinn, Kale Novalis, Angelo Falabella, Omer Uppal, and Matthew Ambrusch

Two air sparge systems were innovatively designed to remediate groundwater impacts consisting of volatile organic compounds (VOCs) in two complex geological settings. Each system was uniquely designed to address the specific constraints presented in its respective area of concern (AOC). Essential to accomplishing this was the completion of extensive pre-design pilot testing activities, in-situ air stripping mass-transfer modeling, and subsurface pneumatic modeling. The results of the pilot testing activities demonstrated that the air sparging technology would be effective at addressing the target contaminants of concern. State-of-the-art design and implementation techniques were applied to optimize the system performance.

The AOC-1 air sparge system was designed as a source area treatment system. Based on the results of the pilot test and subsequent pneumatic modeling, a unique operational pulsing scheme was incorporated into the design. The results of the pneumatic modeling also identified the need for installation of a 3-foot-thick artificial vadose zone to enhance the performance of the vapor collection system. Significant reductions in benzene groundwater concentrations were observed following only the first five months of system operation.

The AOC-2 air sparge system was designed as a barrier treatment system to prevent the downgradient migration of the contaminant plume into a nearby brook onsite. AOC-2 demanded a different air sparge conceptual design than that for AOC-1. Various site constraints were taken into consideration during the design process to uniquely tailor the design. Analytical data from the groundwater sampling events conducted prior to and following the pilot test showed promising results, as significant reductions in benzene concentrations were observed.

A review of these two air sparge system implementation case studies is intended to demonstrate the importance of pre-design pilot testing and modeling activities to ensure the effectiveness of the system and to assess how design features can be tailored to site-specific conditions.

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Diagnostics and Retrofit of Non-Functional Remediation Systems

Imtiyaz Khan, Matthew Wenrick, Angelo Falabella, Omer Uppal, Stewart Abrams, Matthew Ambrusch, and Nadira Najib

Whether due to improper design, incorrect equipment selection, or simply inadequate construction and operational practices, remediation systems can often fail to meet their remedial goals. Rather than completely replacing or redesigning such systems, the existing systems can be altered and rehabilitated to achieve remedial goals. Two case studies are discussed herein that highlight methods to inspect, assess, and upgrade failing remediation systems to improve operational up-times and remedial effectiveness.

Sub-Slab Methane Gas Venting System Upgrade

This sub-slab venting system was intended to mitigate intrusion of landfill gases into a facility. The system had experienced operational issues resulting in significant downtime. Following a recent assessment of the existing system, it was concluded that repairs would be insufficient and a less complicated system design could achieve the required performance needs. This retrofit resulted in a cost savings of approximately $120,000. The system has been fully operational and methane has not been detected within the building since the completion of the system retrofit.

Sub-Slab Soil Vapor Venting System Upgrade

A sub-slab soil vapor venting system designed to mitigate the intrusion of volatile organic compound vapors had experienced operational issues, resulting in significant system downtime. A recent inspection of the system detected notable quantities of grit and water in the system influent vapor stream to the blower. This grit and water had ultimately led to blower failure. As a result of assessment and redesign, key system components will be replaced and additional fail-safes will be installed. The proposed repairs are anticipated to restore the effective operation of the vapor intrusion mitigation system.

In conclusion, non-functional remedial systems can be retrofitted to effectively operate and achieve their intended remedial goals. The methods used to perform remedial system diagnostics, retrofitting, and upgrades will be demonstrated through the presentation of the two case studies discussed above.

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Degradation of 4-Chlorophenol in Aqueous Solution Using Sono-Electro-Fenton Reaction

Roya Nazari, Ljiljana Rajic, and Akram Alshawabkeh

Electro-Fenton (EF) and ultrasound radiation (sonolysis) are known to produce strong oxidative agents such as hydroxyl radicals and have drawn great interest for removal of chlorinated compounds from water. The main objective of this study was to investigate the performance of sono-electro-Fenton (SEF), a coupled Pd-catalyzed EF and sonolysis, for degradation of 4-chlorophenol (4-CP) in an aqueous solution and to evaluate the effects of different parameters on contaminant removal efficiency. SEF ability to degrade 4-CP was compared with individual application of EF process and sonolysis. Initial pH, current intensity, background electrolyte, ferrous iron concentration, Pd/Al2O3 catalyst dosage, pulsed ultrasound frequencies and sonifier amplitude were optimized in a two electrode (Ti/mixed metal oxide or Ti/MMO) batch system. EF tests were conducted with a 200 mg L-1 4-CP initial concentration where more than 90% of 4-CP was removed within 300 minutes in the presence of 80 mg L-1 Fe(II), 200 mA of current, 1 g L-1 Pd/Al2O3 catalyst (10 mg Pd) and initial pH of 3. With application of ultrasound radiation with 70% amplitude and 1:10 ON/OFF ratio the removal rate of 4-CP degradation increased to 98% (comparing to 62% under EF) within the first 120 min. However, the degradation rate decreased after 120 min of treatment and complete 4-CP removal was observed after 300 minutes. 4-CP degradation efficiency was increased in the order: Electro-Fenton < Ultrasound < Sono-electro-Fenton processes by 83%, 90%, and 100%, respectively.

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A Technique for Determining Total Oxidizable Precursors (TOP) of Perfluroalkyl Compounds

Charles Neslund

PFAS compounds have been manufactured and in use for many years. Over that time and due to variables in the production processes like electrofluorination, many different chemistries of PFAS compounds have been produced and used. Many of these compounds have not yet been fully characterized and, therefore, analytical standards are typically not available. This presents a challenge for the accurate assessment of PFAS contamination at environmental sites.

A new method, developed by Houtz and co-workers, can be set up and commercialized such that it converts polyfluorinated precursor compounds to more studied and analyzable perfluorinated chemistries such as PFOA and PFOS, and therefore allows for a way to determine the total PFAS content of an environmental sample. This presentation will discuss the set-up and application of this technique and its utility for risk assessment.

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Economic and Technical Analysis of Electron Donors for Anaerobic Bioremediation Applications

William Newman

Effective delivery of electron donors will be discussed in detail with a focus on the key electron donor properties including the hydrogen release potential and rates of various electron donors, mobility of electron donors during and after injection, and electron donor longevity. A brief discussion of bioaugmentation strategies and pH control will also be presented.

Electron donor dosage and hydrogen release rates have large effects on the microbial community. Optimal hydrogen concentrations favor desired processes such as reductive dechlorination by *Dehalococcoides mcartyi*, while excessive hydrogen may produce unwanted methane, acidity and competition by other microbes. Electron donor mobility and longevity determine the necessary injection frequency as well as which injection methods can be used for effective distribution in the subsurface. Electron donor costs are rarely the largest cost of bioremediation and the electron donor properties can greatly affect other project costs including well installation and maintenance, injection labor, well sampling and analytical costs. Both laboratory microcosm data and brief project case histories will be presented to illustrate how electron donor selection and delivery methods can be optimized for cost effective treatment.

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Green and Sustainable Campus – The i-Tree Eco Modeling Project at Southern University

Zhu Ning and Michaela Gleason

Air pollution is a persistent environmental problem in most major cities across the world. An important focus of research has been the role of urban vegetation in mitigating air pollutants. Studying the ecological function of urban trees is important because of their geographic extent, their impact on local economies, and their proximity to people. Using i-Tree Eco model along with its sampling and data collection protocol, an assessment of the ecological function of trees on the campus of Southern University in Baton Rouge, Louisiana was conducted. Modeling results indicated that there are total 6,950 trees on campus which provide ecosystem services through air pollution removal of 3 tons/year, carbon storage of 4,060 tons, carbon sequestration of 144 tons/year, oxygen production of 336 tons/year, and avoided runoff of 98,800 cubic feet/year. These ecosystem services are valued at $300,000 per year, in addition to the campus trees' structural values of $8.74 million. The i-Tree Eco modeling project on campus not just yielded research results that can be used to improve campus urban forest management, but also was a teaching tool and a learning laboratory for urban forestry students to obtain hands-on experience in green and sustainable campus assessment.

Key Words: Urban Trees, Air quality, Air pollution, i-Tree Model, Carbon sequestration

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A Comparison of the New MassDEP VPH by GC/MS Method with the Original VPH Procedure by GC-FID

James Occhialini, Richard Rago, Mitchell Ostrowski, and Joseph Watkins

In January 1998, the Massachusetts Department of Environmental Protection (MassDEP) issued a Volatile Petroleum Hydrocarbon (VPH) analytical testing method for water and soil samples, which involved the use of a gas chromatograph and in-series PID and FID detectors (GC/PID/FID). In February 2012, MassDEP released a draft of a new VPH test method that utilizes a mass spectrometer (MS) in lieu of the PID/FID. Both methods were designed to provide moderately conservative/health-protective data to support risk characterization efforts conducted under the Massachusetts Contingency Plan. A "single blind" Round Robin study was conducted in June 2012 to evaluate the performance of both methods, focusing on the draft GC/MS procedure. The VPH GC/MS procedure was finalized in January 2016, and the DEP conducted training on the new method for the laboratory community in February 2017. In this paper, the authors analyze replicate environmental samples by both procedures, evaluate comparibility and investigate how each procedure accounts for the presence of non-petroleum hydrocarbon compounds in the samples.

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Computational Fluid Dynamics Modeling of Vapor Intrusion Mitigation Using Sub-Slab Depressurization with Multiple Collection Points

Ana Oliveira and Eric Suuberg

Vapor intrusion is defined as the migration of volatile contaminants from the subsurface into indoor air spaces of overlying buildings. Where source remediation is not possible, mitigation is a preferred technique for limiting occupant exposure to potentially harmful vapors. It is generally understood that an important factor determining vapor entry into structures overlying source zones is a pressure gradient (due to the "stack effect") that drives advective flow into the building. The entry flow into the building can be diverted by installing sub-slab pipes to extract soil gas from the sub-slab and vent it to the atmosphere. Normally, these systems are driven by a fan, creating a negative pressure in the sub-slab and are hence called sub-slab depressurization systems. In this study, we assumed trichloroethylene is present in a groundwater source beneath the building. A steady state analysis was performed, in which the influence of various parameters was examined. We will present results demonstrating the effects of the location and number of collection points on predicted indoor air contaminant concentrations while examining the influence of different soil permeabilities (including the presence or absence of a gravel sub-base) and the distance to the groundwater source.

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Removal of Ciprofloxacin and Tetracycline by Vetiver Grass from Nutrient Amended Secondary Wastewater Matrix

Saumik Panja, Dibyendu Sarkar, Rupali Datta, and Abhishek RoyChowdhury

Antibiotics have played a major role in improving human health and have been widely used since the 1940s. After ingestion, only a minor fraction of antibiotic compounds is retained in the physiological system; the rest is excreted. These excreted antibiotics enter the environment through animal husbandry, municipal and hospital sewage, increasing the risk of developing antimicrobial resistance in microorganisms. Prolonged residence time of these emerging contaminants in the environment has instigated the search for environment-friendly and innovative remediation techniques. In this study, we investigated the potential of vetiver (*Chrysopogon zizanioides*), a fast-growing, high biomass perennial grass to remove two extensively used antibiotics (ciprofloxacin and tetracycline) from secondary wastewater effluent with high nitrogen (N) and phosphorus (P) concentrations. Our previous studies demonstrated the efficiency of vetiver in removing the above antibiotics both from nutrient media and secondary wastewater effluent. Although sunlight-mediated photodegradation of ciprofloxacin (CIP) and tetracycline (TTC) has been reported in some studies, due to certain physico-chemical properties of wastewater, such as the abundance of organic matter and complex matrix chemistry, photodegradation may not occur. In recent years, vetiver system (VS) has been implemented in several parts of the world as a sustainable, green remediation technology due to its ability to uptake and hyperaccumulate many chemical pollutants from both soil and water. Major objectives of this study were to: i) evaluate the potential of vetiver grass to selectively phytoextract nutrients (N, P) and antibiotics (ciprofloxacin and tetracycline), and ii) determine the combined effects of nutrients and antibiotics on plant physiological system. Vetiver plants were grown hydroponically in wastewater matrix spiked with nutrients and antibiotics. Periodic samples were collected to determine removal kinetics of nutrients and antibiotics for two months. Significant ($p<0.0001$) removal (>90%) of antibiotics (CIP & TTC) was observed in all experiments. Antibiotic removal declined with increasing concentrations of nutrients.

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Step-Wise Approach to In-Situ Thermal Remediation of Trichloroethene in Granitic Bedrock

Erik Pearson, Carol Serlin, and Gorm Heron

Following the completion of a remedial investigation/feasibility study (RI/FS), a several hundred acre former industrial facility in Southern California was divided into several distinct treatment areas for remediation of groundwater impacted by volatile organic compounds (VOCs). The predominant constituent of concern at the site is trichloroethene (TCE). Historical groundwater concentrations in one area were as high as 100,000 micrograms per liter (μg/L), exceeding the site-specific risk-based target concentrations and potentially indicating the presence of dense non-aqueous phase liquid (DNAPL). In this treatment area, impacted groundwater was identified within the fractured granitic bedrock located at a groundwater divide and bounded to the east and west by bedrock hills. Given the complexity of fractured rock, elevated TCE concentrations that may indicate DNAPL, and lack of significant groundwater recharge, In-situ Thermal Remediation (ISTR) was the selected remedial alternative.

The targeted treatment zone (TTZ), approximately 18,333 cubic yards, was defined using a combination of groundwater, soil vapor and passive soil vapor sampling results. Typically ISTD "success" is based on post-remediation soil sampling results. In this case, because it is difficult to sample bedrock while retaining VOCs, remediation success was to be based on baseline and post-remediation soil gas and ground water sampling results.

This presentation will summarize Ramboll Environ's step-wise approach to remediate TCE in granitic bedrock covering development of the TTZ, design considerations, including electrical power required, installation, an overview of the equipment and treatment process, the five-month operational period, and lessons learned.

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Emerging Contaminant 1,4-Dioxane in Our Drinking Water

Michael Pierdinock and Kevin Paradise

The latest emerging contaminant that is threatening our drinking water in Massachusetts and elsewhere that is yet to be regulated throughout the United States is 1,4-dioxane. The source of this contaminant impacting our groundwater is from landfills and septic systems and the associated chemicals and products, resulting in the discharge of 1,4-dioxane into our drinking water. Many old and dated cesspools and septic systems with private wells less than 150 feet from these sources are encountering evidence of 1,4-dioxane in private wells and in some cases exceeding Massachusetts Contingency Plan ("MCP"), reportable concentrations and drinking water standards. This is further exacerbated in areas such as Cape Cod where the tourist season results in a significant increase or pulsed discharge of sewerage from cesspools and septic systems to groundwater.

The purpose of this paper is to provide an overview of the multiple sources of 1,4-dioxane being released to our waters, MCP regulatory history and details associated with the present reportable concentrations and cleanup standards, limitations of analytical methods to detect 1,4-dioxane in groundwater, examples of locations where 1,4-dioxane has been detected on Cape Cod, and subsequent difficulty treating 1,4-dioxane impacted groundwater.

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Laboratory Study of Metals Treatment by Permeable Reactive Barrier and Engineered Wetland

Ryan Thomas, Christa Bucior, Sophia Dore, Donald Pope, and Alan Weston

Contamination by metals can be a persistent issue at numerous sites. Generally, metals in their solid or insoluble form are not toxic and do not present a risk to human health or the environment. Once metals become soluble they can be highly toxic. The chemical nature of metals depends on the source of the metals contamination and the soil, groundwater, and surface water chemistry at the site. The solubility of metals can be lowered in an effort to precipitate them from groundwater. Redox conditions and pH will often determine the solubility of the metals.

Laboratory treatability studies were performed to establish design parameters for permeable reactive barriers (PRB) and engineered wetlands to treat metals from groundwater and surface water at two sites. For Site 1, a column study was performed to test potential PRB media such as emulsified vegetable oil, gypsum, and activated sludge for the removal of nickel from groundwater. Once optimum hydraulic retention times were established, the dissolved nickel in the effluent was reduced to non-detect levels. For Site 2, zinc levels in the surface water were in exceedance and a white floc material was present. In a two-step treatment process, the surface water was first filtered to remove the white floc and then the zinc was treated. Zinc forms insoluble compounds with both sulfide and carbonate resulting in the precipitation of a metallic complex from the surface water. Limestone and gypsum were tested to induce zinc precipitation. Biological mechanisms were also tested and were successful in reducing zinc concentrations below surface water criteria.

Design considerations explored in the studies include the length of contact time required in order for adequate metals treatment to occur. This presentation will include the laboratory studies design, performance, and results for both Sites.

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Orthogonal Functions and Hybrid Functions for Problems in Environmental Modeling and Remote Sensing

Mohsen Razzaghi

The available sets of orthogonal functions can be divided into three classes. The first includes a set of piecewise constant basis functions (PCBFs) (e.g., Walsh, block-pulse, etc.). The second consists of a set of orthogonal polynomials (e.g., Laguerre, Legendre, Chebyshev, etc.). The third is the widely used set of sine-cosine functions in Fourier series. While orthogonal polynomials and sine-cosine functions together form a class of continuous basis functions, PCBFs have inherent discontinuities or jumps.

For problems in environmental modelling and remote sensing, images often have properties that vary continuously in some regions and discontinuously in others. Thus, in order to properly approximate these spatially varying properties, it is necessary to use approximating functions that can accurately model both continuous and discontinuous phenomena. Therefore, neither continuous basis functions nor PCBFs taken alone can accurately model these spatially varying properties. For these situations, hybrid functions, which are the combinations of piecewise and continuous functions, will be more effective.

The solution of radiative transfer equation (RTE) has been of considerable concern. This equation has wide applications in environmental modelling and in remote sensing. In this work we present a new approach to the solution of RTE. Our approach is based upon hybrid functions, which are combinations of block-pulse functions and Legendre polynomials. Numerical examples are included to demonstrate the applicability and the accuracy of the proposed method and comparisons are made with the existing results.

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Green Remediation Technology for Prevention of Erosion and Metal Leaching from Acid Mine Drainage-Impacted Soil

Abhishek RoyChowdhury, Dibyendu Sarkar, and Rupali Datta

Generation of acid mine drainage (AMD) and acid sulfate soils are the most concerning environmental problems associated with mining activities. Acid sulfate soils are structurally unstable soils that are extremely erosion prone. Exceedingly acidic environment and presence of high concentration of metals in AMD-impacted soil is detrimental for local biodiversity. Implementation of proper post-mining measures is very important to protect the environment. The objective of this study was to develop a cost-effective and environment-friendly "green" technology for treatment of AMD-impacted soils utilizing the metal binding and acid-neutralizing capacity of an industrial by-product, namely drinking water treatment residuals (WTRs), and the extensive root system of a metal hyper-accumulating, non-invasive, fast-growing, perennial grass, vetiver (*Chrysopogon zizanioides L.*) to prevent soil erosion. Locally-generated aluminum (Al) and calcium (Ca)-based WTRs were used to treat AMD-impacted soil collected from an abandoned coal mine, Tab-Simco in Carbondale, Illinois. The soil was highly acidic (pH 2.6) and contained high concentrations of metals such as Fe, Ni, Zn, Pb, and As. Initially, a 60-day soil incubation study was performed using 7 different rates of Al- and Ca-WTR amendments. Results showed a significant decrease in exchangeable fractions of all metals present in soil with increasing WTR rates. Next, a four-month long greenhouse column study using 5% and 10% w/w WTR application rates was performed. Vetiver grass was grown on soil-WTR matrix. Turbidity and total suspended solids (TSS) analysis of leachates showed that soil erosion potential decreased significantly in the soil-WTR-Vetiver system over time. A scaled up simulated field study in 4 feet x 3 feet x 1 foot wood panels was performed using 5% WTR application rate and Vetiver. Soil pH increased (2.6 to 7.7) and soil erosion decreased significantly. Results from the study showed that this "green" remediation technique has the potential to effectively treat AMD–impacted soils.

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A Green BMP for Mitigation of Nutrients and Metals in Stormwater: Greenhouse Column Study

Dibyendu Sarkar, Virinder Sidhu, Kirk Barrett, and Rupali Datta

Stormwater runoff is a major source of nutrients and metals in surface waters. Excess nutrients in stormwater runoff can cause eutrophication. Contamination of surface waters by metals is a major problem due to their accumulation, non-degradability and toxicity; the problem is more acute in urban coastal waters. The goal of the project is to develop "green" and inexpensive stormwater Best Management Practice (BMP) to reduce stormwater-induced nutrients and metal loads in surface waters. To achieve the goal, a greenhouse column study was conducted with the objective of designing a buffer strip utilizing a locally-generated waste material (aluminum-based drinking water treatment residuals, or Al-WTR) and a high biomass hyperaccmulator grass, vetiver (*Chrysopogon zizanioides*), two native non-accumulator grasses, switchgrass (*Panicum virgatum*), and big bluestem (*Andropogon gerardi*) for removal of nutrients (N, P) and metals (Cu, Zn, Pb and As) in stormwater. Soil from the field site was amended with Al-WTR in columns (45 cm long and 15 cm wide PVC pipes) at rates of 0 (control), 5% and 10%. Columns were leached bi-monthly for 5 months with stormwater spiked with exaggerated levels of As (16.85 mg/L), Cu (6.36 mg/L), Pb (8.16 mg/L), Zn (11.70 mg/L), and P (100 mg/L). Leachates were analyzed for As, Cu, Pb, Zn, P, NO^-_2, NO_3^- by ICP-MS and IC. After the first simulated storm event, big bluestem showed acute toxicity symptoms and subsequently died. Concentration of metals (Cu, Zn, As and Pb) and nutrients (P, NO^-_2, NO_3^-) in leachates decreased with increasing Al-WTR amendment rate (5%, 10%) in soils with plant cover (vetiver, switch grass) as compared to control (no Al-WTR/plants). Data obtained in this study provides the basis for subsequent field demonstrations where buffer strips with Al-WTR-amended soils and plant cover will be emplaced for removal of nutrients and metals from urban stormwater entering coastal systems.

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Ecological Risk Assessment of an Abandoned Shoreline Landfill in the Intertidal Marine Environment

John Schaffer

Historical disposal activities on occupied islands within urban estuaries often included burning to reduce the mass of discarded debris/garbage generated based on limited access for off-island disposal. The resulting ash is disposed of either in on-island landfills or in near shore line areas as fill as part of island enhanced expansion. The occurrence of historical debris within intertidal and shallow sub-tidal zone from such an on-island landfill was investigated in the eastern end of Long Island Sound. Land use surrounding the formerly occupied island consists of residential and commercial properties. An ecological risk assessment was performed to assess ecological risks to benthic communities in the intertidal and shallow sub-tidal sediments where historical debris and ash and cinder deposits have accumulated. Principal contaminants of concern associated with the ash and debris were PAHs and metals from the ash and corroded metallic scaling from metallic debris. A triad approach incorporated whole sediment chemistries, 10-day toxicity tests with the amphipod *Ampelisca abdita,* and qualitative benthic community characterization for benthic community assessment. Whole sediment toxicity testing with the amphipod *Ampelisca abdita* included survival and growth endpoints. Benthic community measurements included species richness and diversity and metrics of the index of biotic integrity for marine benthic communities. The triad integrated these three lines of evidence to assess the significance of observable waste as related to aesthetic issues versus measured impacts from contaminants associated with the physical debris present.

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Advanced Petroleum Biomarker Analysis for Use in Source Identification

Jonathan Thorn, Kevin McInerney, Robert Lizotte, and Stephanie Schultz

Crude oil and refined product releases are common sources of contamination to the environment on a domestic and global scale. Whether through a catastrophic release or through chronic pipeline leaks, the potential ramifications of an accidental release and its environmental injury could result in legal action and, ultimately, punitive damages.

Crude oil and petroleum distillates are complex mixtures of hydrocarbons across a broad boiling point range. Differentiation of crude oil sources, as well as selected petroleum distillates, can be performed using petroleum biomarker analytical data. Selected petroleum biomarkers, including cyclic terpanes, steranes, diateranes, adamantanes, diamantanes, sesquiterpanes, aromatic steranes, and alkylcyclohexanes, can potentially be used to differentiate sources of releases. A review of recent data, collected from sources including crude oils, motor oils, heavy fuel oils, lubricating oils, diesel fuels, kerosenes, and selected source rock materials, indicates selected biomarkers useful in source identification from several of these distillates. Battelle has identified several classes of biomarkers in crude oil, as well as across a range of petroleum distillates, that may be useful in source identification and attribution.

In the unfortunate event of an accidental release of crude oil or petroleum product, site characterization using advanced hydrocarbon fingerprinting methodology is of the utmost importance. Precise, accurate, and defensible analytical data is required to identify additional possible sources of contamination and potentially define liability.

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Horizontal Wells: Avoiding Obstructions and Minimizing Site Disruptions

Seth Croy and Michael Sequino

On many cleanup sites, the property owners' requirement to minimize site disruption can be a deciding factor for assessment or remedial technology selection. Several case studies will be presented to overview the ability of Horizontal Wells to remediate contaminated sites with minimal site disruption.

Horizontal Air Sparge (HAS) and Soil Vapor Extraction (HSVE), Retail Gas Station

Impacts from a retail gas station had migrated across a busy road and were affecting a nearby restaurant. A horizontal well installation, consisting of one HSVE and two HAS wells, stretched from a retail gas station to below the restaurant across the street.

Horizontal Biosparge Wells (HBWs), Bulk Petroleum Terminal

Twenty-one HBWs, totaling 13,000+ linear feet, were installed to remediate impacts. On-site wells remediated underneath roadways, fueling racks, storage tanks. Off-site wells stretched across busy 4-lane roads and under an operating gas station and warehouse.

Horizontal Soil Vapor Extraction (HSVE), Former Petroleum Storage Facility

Petroleum impacts under apartment building from former crude oil storage facility. A successful pilot test was performed with Horizontal SVE Well showing a Radius of Influence (ROI) of up to 87 ft. The full scale implementation of the horizontal SVE system is expected to be a total of 6 wells. A comparable vertical system would require 24-32 wells, plus the trenching and restoration necessary for connective piping.

Horizontal Soil Sampling, Former Power Plant

Soil samples were required in residential areas not accessible with vertical drilling methods to delineate the extent of impacts at a former power plant. The horizontal drilling rig was set up at three locations on the power plant's property and the bores were advanced 30 to 50 feet to collect discrete and undisturbed soil samples under the neighboring residences.

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Performance of Reductant Amended Backfill for Groundwater Remediation at a Former Chromate Ore Processing Facility

Lucas Hellerich and Sachin Sharma

Background. Soils containing COPR have been excavated and the excavations have been backfilled with fill amended (mixed) with FerroBlack-H reductant (a reductant mixture of insoluble ferrous sulfide and soluble hydrogen sulfide) at a former chromate ore processing residue (COPR) facility located in New Jersey. The soluble hydrogen sulfide reacts rapidly with residual hexavalent chromium (Cr^{6+}) present in the groundwater, reducing it to trivalent chromium, which forms an immobile and relatively insoluble hydroxide precipitate. The insoluble ferrous sulfide provides a longer term source of reductants that will continue to reduce Cr^{6+} over many years.

The application of the amended backfill is also remediating shallow groundwater, as well as serving as a safeguard against recontamination from contaminated groundwater entering the site from adjacent residual sources. The longevity of the reductant in the amended backfill is a function of the dosing of the reductant, amount of chromium in the subsurface, site geochemistry, and rate of exposure of the reductant to rainfall-induced infiltration and groundwater flow.

Approach. The dosage and placement of the amended backfill was selected depending on the concentration of Cr^{6+} in groundwater. The performance assessment of the amended backfill included quarterly groundwater sampling of chromium species and geochemical parameters. The data were evaluated and geochemical/concentration trends were analyzed; reductive capacity calculations of the amended backfill were performed.

Results. Evaluation of groundwater data indicates that negative oxidation-reduction potential conditions have been sustained following placement of the amended backfill. Groundwater pH has also moderated in areas where amended backfill was placed. Concentrations of Cr^{6+} and total chromium have reduced and continue to reduce over time. FerroBlack-H activity and longevity is a function of the dosing of the reductant, and site-specific geochemical and contaminant/geochemical loading conditions. An assessment of the longevity and reducing capacity of the reductant amended backfill will be presented.

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Effect of Compost and Plant Cover on Sustainable Restoration of Soils Contaminated by Copper Mining Activities

Virinder Sidhu, Dibyendu Sarkar, Emily Geiger, and Rupali Datta

Several million tons of residuals (called stamp sands) were generated in the Upper Peninsula of Michigan during extensive copper (Cu) mining activities in the late nineteenth and early twentieth century. These stamp sands were discharged into various offshoots of Lake Superior. Due to increasing aquatic toxicity with time, the sediments were eventually dredged and dumped on the lake shorelines, subsequently converting these areas into vast, fallow lands that are not conducive to plant growth because of high toxicity and very low water holding capacity; some were listed as Superfund sites. Erosion of these Cu-contaminated sands back to the lakes is again severely affecting the benthic community. In this study to investigate a potential sustainable restoration plan, we grew cold-tolerant oil-seed crops camelina (*Camelina sativa*) and field pennycress (*Thlaspi arvense*) to serve the dual purpose of providing a vegetative cap to reduce erosion of stamp sands back to the lake, as well as utilizing the biomass as feedstocks for the biofuel industry. First, a greenhouse column study was performed to optimize the rate of wood compost addition (instead of chemical fertilizers) for maximum nutrient and water holding capacity of stamp sands collected from Hubbell/Tamarack site in Torch Lake, Michigan. Compost was added at rates of 0, 2.5%, 5%, 10% and 20% of stamp sand. Soil samples and leachates were collected at monthly intervals for a period of six months. Concentration of Cu was highest in roots closely followed by leaves and then pods, seeds and stem in both camelina and field pennycress. However, pennycress did not seed adequately, hence, was eliminated from the follow-up simulated field-scale study performed in wooden panels in the greenhouse. Camelina growth in panels was excellent, which significantly reduced stamp sand erosion compared to control (no plant cover) and produced seeds with high oil content and quality.

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Analytical Advancements in the Analysis of Alkylated PAH and Petroleum Biomarkers for Hydrocarbon Fingerprinting at Petroleum Release Sites

Peter Simon, Philip Simon, Sarah Stubblefied, Edward Paulson, and Deborah Chiavelli

Petroleum crude oil is a complex mixture of hydrocarbons and related heteromolecules comprised of more than 17,000 discrete compounds. Among the constituents of crude oil is a group of substances called polycyclic aromatic hydrocarbons (PAHs). PAHs refer to a ubiquitous group of several hundred chemically-related, neutral, nonpolar molecules that are environmentally persistent. To further understand sources of PAHs, they may be generally classified as Petrogenic (petroleum inputs and generally associated with fossil fuels), Pyrogenic (combustion sources) and Biogenic (natural biological processes).

In environmental testing, PAHs were included as target analytes in some of the earliest analytical methods developed by US EPA. These early US EPA methods focused on 16 common "Priority Pollutant" PAHs, with analysis performed by GC/FID, HPLC/UV or GC/MS. Although PP PAH analysis is still used for environmental monitoring and cleanup, more comprehensive analysis of PAH compounds is needed for forensic/fingerprinting investigations and damage assessments from petroleum spills.

Many laboratories have established specialized methods based on the use of GC/MS–Selected Ion Monitoring (GC/MS-SIM) techniques for parent and alkylated PAHs along with a related class of petroleum biomarkers. GC/MS-SIM methods can provide detection and quantitation limits much lower than common "full scan" GC/MS analysis. Inherent with low-level GC/MS–SIM analysis comes the propensity for false positives and overstatement of actual concentrations. Most regulators do not typically view this as a problem, but when tasked with apportioning responsibility at petroleum release sites with multiple historical releases, the overstatement of actual values frequently miss-apportions responsibility and associated costs.

Advances in analytical instrumentation and the use of multi-ion SIM/ion ratioing, high sensitivity full scan GC/MS, and GC/MS/MS has resulted in detection and quantitation levels for many analytes comparable to single ion GC/MS-SIM methods, while eliminating false positives and overstatement of concentrations for parent and alkylated PAHs and petroleum biomarkers.

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Reconsideration of 1,4-Dioxane As an Emerging Contaminant of Interest

Peter Simon, Philip Simon, Edward Paulson, and Sarah Stubblefied

For more than two decades now, the presence of 1,4-dioxane in the environment has had increasing focus by many regulatory agencies across the United States, based on its designation by US EPA as "likely to be a carcinogenic to humans" by all routes of exposure.

The physical and chemical properties of 1,4-dioxane create unique challenges for its characterization and treatment. 1,4-Dioxane is a relatively volatile, colorless liquid with a mildly pleasant odor. It is very soluble in water, does not adsorb to soil particles, and does not readily biodegrade. It is both persistent and highly mobile in groundwater. 1,4-Dioxane is one of several stabilizers historically used in industry to enhance the functional life of chlorinated solvents (approximately 90% of its commercial use). The remaining 10% of 1,4-dioxane is used in a wide variety of commercial applications and formulations which will be discussed. 1,4-Dioxane was and is present at residue levels in detergents, shampoos, deodorants, cosmetics, and glycol antifreeze. Surfactants containing residue levels of 1,4-dioxane are still widely used in detergents, cosmetics, and even prepared foods.

Environmentally, 1,4-dioxane has impacted many groundwater supplies across the country in concentrations ranging from part per billion levels to hundreds of parts per million. Difficulties in analyzing 1,4-dioxane as an environmental contaminant are the result of its unique physical and chemical properties. As a result, method detection limits are often elevated and establishing a comprehensive picture of the occurrence of 1,4-dioxane in groundwater plumes has been difficult. When these analytical problems are resolved, 1,4-dioxane groundwater plumes are frequently much larger (and further downgradient) than originally suspected.

US EPA Method 1624 is a powerful analytical framework for the analysis of volatile organic compounds. Through an optimized implementation of US EPA Method 1624 can be reliably quantitated to 0.3 ug/L in groundwater, wastewater and wastewater sludges.

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Multiple Lines of Evidence Approach: Crude Oil Spill Identification and Differentiation

Peter Simon, Philip Simon, Deborah Chiavelli, and Mike Rury

An accurate assessment of the nature and extent of spilled crude oil in the environment and successful identification of related source(s) is extremely important to identify contributors and apportion responsibility for impacts. As on many other contaminated sediment projects, focus on a single source can result in missing other contributors and inaccurate identification and assignment of responsibility. The objective of the forensics effort was to distinguish the remaining spilled crude oil from petroleum hydrocarbons originating from other sources including high residual background hydrocarbons present in the watershed. This paper briefly describes the most recent work completed to locate and characterize the amount of crude oil remaining in a system several years post spill.

Comprehensive analysis of polycyclic aromatic hydrocarbons and sulfur heterocyclic compounds including alkyl homologues (PAH) and petroleum chemical biomarkers was performed on reference oils, globules, sheens, and sediment samples. A detailed forensic evaluation and multiple lines of evidence approach including PAH and petroleum biomarker profiles, spatial patterns, diagnostic crossplots, and a multi-parameter concentration-based mixing model were used to successfully differentiate crude oil residuals in sediments from high levels of residual background hydrocarbons originating from other sources.

The ability to distinguish the remaining spilled crude oil from residual background hydrocarbons originating from other sources present in the watershed was successfully demonstrated through the application of a multiple lines of evidence environmental forensics approach. Reliance on collective results from multiple indicators while accounting for residual background hydrocarbon sources helped minimize false identification and reduced uncertainty in the identification of residual spilled crude oil in this system.

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Bench-Scale Evaluation of the Formation and Reactivity of Iron Sulfide Minerals for Treatment of Chlorinated Solvents

Fayaz Lakhwala, Alan Seech, Daniel Leigh, Josephine Molin, Brant Smith, and Ravi Srirangam

Background/Objective. Reactive iron sulfide minerals are formed in situ under sulfate reducing conditions in the presence of iron and sulfate. This has been observed during applications of in situ chemical reduction and anaerobic bioremediation substrates at sites with elevated sulfate concentrations in groundwater. An advantage of generating reactive minerals in situ is that as formed, they are deposited over a larger surface area as a thin coating on the soil particles. Abiotic degradation of chlorinated solvents occurs at the groundwater and ZVI particle / reactive mineral surface interface, which makes their distribution critical. The objective of this study is to qualify and quantify the generation of reactive minerals in response to various substrate combinations, evaluating reactivity and overall degradation rates of chlorinated solvents relative to the addition of organic carbon and ZVI substrates alone.

Approach/Activities. Batch reactors were set up with soil and groundwater impacted with TCE and amended with various substrate combinations composed of ZVI, organic carbon substrate, reduced minerals, ferrous iron, sulfide and/or sulfate. Both liquid and solid reagents were evaluated. Degradation rates achieved were compared to systems amended with organic carbon substrate and ZVI only. Mineral precipitates formed will be analyzed using sequential extraction analyses and their reactivity will be compared against ZVI and commercially available reduced iron mineral products.

Results/Lessons Learned. Although early results indicate that ferrous iron minerals have a lower reactivity and reduction potential compared to some ZVI products, its significantly larger surface area and distribution properties makes it an important mechanism for in situ remediation applications. Electron microprobe analyses performed on iron sulfide precipitates one year after the application of organic substrate and ferrous sulfate aquifer showed that 1.0 L of groundwater having 3,000 mg/L sulfate can form a 3.0 μm thick FeS precipitate upon reduction and yield about 1.2 ft^2 of surface area.

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Importance of Surfactant Selection in Remedial Applications

Dan Socci

Conventional In-Situ Chemical Oxidation (ISCO) implementations are limited to aqueous phase reactions and require multiple treatments to address hydrophobic compounds that are sorbed in the soil matrix or exist as NAPL (Non-Aqueous Phase Liquid). To overcome these limitations, surfactants can be used to enhance contaminant availability in the aqueous phase for chemical oxidation by desorption, or by facilitating contaminant mobilization for contaminant removal. Because contaminant type, composition and extent is unique at each site, and surfactant performance can vary substantially given this contaminant diversity, it is important that a comprehensive evaluation approach for surfactant selection is used Surfactant screening tests provide an understanding of the phase behavior of soil-groundwater-NAPL-surfactant systems, enabling remedial designs to be tailored to site specific conditions and remedial goals. This presentation will focus on surfactant screening tests for SEPRTM (Surfactant Enhanced Product Recovery) and S-ISCO® (Surfactant enhanced In-Situ Chemical Oxidation) remedial applications. Field case studies will be included which demonstrate the significant advantages of surfactant use for in-situ remediation, particularly for heavy hydrocarbons and NAPL.

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Electrical Resistance Heating Remediation Using High Degree Angled Electrodes at an Active Manufacturing Facility

Lauren Soos and Tracy Edwards

The site, an active manufacturing facility in New Hampshire, is underlain by a thick sequence of heterogeneous glacial and fluvial deposits consisting of silt and sand mixtures grading into a fine to medium grained sand sequences within the targeted remediation zone. In the source area, residual PCE DNAPL was shown to be widely dispersed but in very discrete portions of the vertical profile. Remedial investigations identified vapor intrusion was ongoing into the active manufacturing facility. Vertically discrete soil and groundwater sampling, high volume purge testing, and paired sub-slab/indoor air sampling demonstrated three areas beneath the plant which were likely contributing to vapor intrusion; however, the VOCs were being uniformly distributed throughout the plant through the HVAC system.

Due to active manufacturing operations, most areas of the site are not easily accessible. A combination of mitigation measures including soil vapor extraction, sub-slab depressurization, and HVAC modifications were employed to mitigate VOCs from emanating into the building. Most of these measures were successful at mitigation, but failed to eliminate the source. Electrical resistance heating (ERH), was chosen to eliminate the source of the vapor intrusion in a relatively short period of time. The ERH design team modeled and designed electrodes at high angles under the building and vertically in the adjacent parking lot. This ERH design minimized encumbrances to the existing manufacturing facility operations.

The ERH system design was unique with an electrode layout at high angles (up to 74 degrees from vertical) and a robust vapor recovery system. The presentation will discuss these design features, the measures taken to minimize impacts to the active manufacturing operations during all phases of the project (ERH installation, start-up, and operations), and the performance of the ERH system. The system reduced PCE concentrations by 99% which provides a permanent reduction of the vapor intrusion source.

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In Situ Thermal Remedy Procured Under MATOC/PRAC Contract Vehicle to Ensure Closure at New Jersey Superfund Site

Andrew Small, Will Torres, Chris Blundy, Emily Crownover, Michelle Nanista, and Lauren Soos

TerranearPMC, LLC working under USACE, Kansas City District, with oversight by Philadelphia District USACE and U.S. Environmental Protection Agency (EPA), conducted a final source area treatment at the South Jersey Clothing Company using Electrical Resistance Heating (ERH) in Area 5 and 6. This site was placed on the National Priorities List by EPA in 1989 after receiving complaints from nearby residences and conducting an initial site investigation.

The contaminants of concern are trichloroethene (TCE) and tetrachloroethene (PCE). The site is a former facility that manufactured military clothing. TCE and PCE were used in the former dry cleaning process. According to historical files a fire at the facility may have resulted in the release of an estimated 275 gallons of chlorinated volatile organic compounds (CVOCs).

EPA has been operating a groundwater extraction and treatment system since February 1999. Groundwater treatment and monitoring are ongoing. In 2010, the EPA amended the 1991 Record of Decision (ROD) to include excavation and disposal of shallow CVOC contaminated soil (completed in 2011) and in situ thermal treatment (ISTT) of the deeper CVOC contaminated soil.

The performance criteria were based on temperature and heating duration. Both treatment areas heated to a minimum of 88.5°C in the saturated zone and a 72°C in the vadose zone for a duration of 60 days (or as extended by exercise of contract options or the demonstration of target concentrations achieved). There are no contractual soil or groundwater treatment goals for the project.

TRS completed the installation and start-up of operations in September 2016. The performance temperature specification was achieved after 28 days of heating. All temperature intervals in the vadose zones and saturated zones exceeded target performance temperatures.

Background on the site and remediation timelines will be provided as well as design details, implementation and results of the ERH source removal.

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Developing Background Concentrations of Metals and PAHs in Soil in an Urban Railroad Right-of-Way

Joseph Spencer and Todd Bridgeo

Implementing a soil pre-characterization program within an active railroad right-of-way presents a unique set of logistical challenges. As with any valuable pre-construction program, soil assessment, soil management planning, and regulatory closure planning should lean on existing datasets to the extent feasible. Unfortunately, no such dataset is publically available and/or easily accessible that documents the concentrations of common railroad corridor contaminants in soil.

In recent years there has been increasing pressure on public infrastructure, especially railways in urban areas due to increased demand for public transportation as well as further aging of the existing rail facilities and resources. According to the Federal Transit Administration, personal and freight rail traffic in the northeast corridor is expected to see a 50% growth by 2050. Faced with the challenges of meeting new demands, operators, owners, and project managers will be under increasing pressure to maximize railroad investments and construction efficiency. In addition to the standard design variables and cost benefit analysis, changing environmental standards regarding the handling of contaminated materials during construction will compel these groups to consider environmental impacts with proposed improvements, as they will directly impact future construction costs as well as future environmental liabilities.

This presentation will outline the characterization of environmental impacts associated with a large-scale passenger railroad expansion project in Metro Boston. The method and benefits of characterization will be discussed in terms of cost savings for construction and meeting regulatory requirements. The presentation will close with a discussion of a large-scale dataset of two primary groups of contaminants of concern found within urban railroad rights-of-way, metals and polycyclic aromatic hydrocarbons, developed during the pre-characterization. The discussion will include statistical analysis of the dataset, with a focus on its application to other railroad construction projects.

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Long-Term Molar Trend of CVOCs Post Phased ISCR Approach in a Historically Stalled Shallow Aquifer

Ravi Srirangam, Damian Vanetti, Fayaz Lakhwala, and Ian McNamara

Background: The site is an operating "light manufacturing" facility in New York where historic operations have resulted in shallow groundwater being impacted by chlorinated volatile organic compounds (CVOCs). The source of contamination is suspected to be a historical drain within the facility where CVOCs were primarily discharged. The contamination is expected to have spread to other rooms within the current facility where manufacturing operations are in progress. Historically, the main constituents of interest (COI) are PCE and cis 1,2 DCE that exceed the NYSDEC groundwater cleanup standards. The molar concentrations of daughter product (cis 1,2 DCE) are 3-5 times the concentrations of parent compounds (PCE and TCE) within the treatment zones. The saturated zone impacts ranges between 3-13 ft bgs.

Approach/Activities: In situ chemical reduction (ISCR) was the chosen approach given the presence of a strong abiotic component within the technology is suited to aquifers that have higher daughter products accumulation. β-elimination mechanisms promoted by zero valent iron (ZVI) would typically not accumulate daughter products as the degradation pathways bypass the production of cis 1,2 DCE and VC. A phased approach was carried out over a period of 4 years that involved and a field pilot and two full scale injection events. Post injection monitoring continued until 60 months post injections. CVOCs were reduced by over 99% in the source area below NYSDEC goals in the recent monitoring events.

Results/Lessons Learned: The presentation will focus on trends in molar concentrations of CVOCs indicating multiple reductive dechlorination pathways to differentiate the role of ISCR from conventional anaerobic bioremediation and also the path forward towards site closure.

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A Disposable Sensor for the On-Site Detection of Lead and Cadmium

Connor Sullivan, Guinevere Strack, Michaela Fitzgerald, and Pradeep Kurup

As illustrated by the recent catastrophe in Flint, Michigan—in which up to 12,000 children were found to have toxic levels of lead in their blood—heavy metals present a major risk to human health and the environment. Current detection methods of heavy metal testing require expensive laboratory-based equipment, highly trained personnel, and hazardous chemicals, resulting in high costs and long wait times. To facilitate more frequent and less expensive testing, our research group has developed an environmentally friendly voltammetric sensor strip for the onsite detection of heavy metals in groundwater and drinking water. The sensor strip consists of a novel, bismuth-based working electrode, a carbon counter electrode, and a silver/silver chloride reference electrode. An innovative bismuth layer provides enhanced deposition of lead and cadmium onto the surface of the electrode, thus resulting in the low detection limits that are required for drinking water standards. When combined with a nontoxic reagent—to control pH and minimize sample inferences—the bismuth working electrode enabled square wave stripping voltammetry experiments that detect low parts per billion levels of lead and cadmium in five minutes or fewer. Laboratory tests were performed in a range of water matrices. The sensor was shown to provide accurate measurements for lead and cadmium over a concentration range of 0 to 100 ppb. Additionally, through a partnership with the Massachusetts Department of Environmental Protection, the researcher gathered and tested a number of water samples from contaminated sites, to demonstrate the potential of the sensor for real world applications.

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What You Should Think About When Considering ISCO with Permanganate: Information from Practitioners with 20+ Years' Experience

Stephanie Turkot, Troy Lizer, and Jim Wilson

The selection and implementation of using in-situ chemical oxidant (ISCO) with permanganate has been applied at thousands of sites for well over 50 years. There are countless field-scale application case studies, academic and independent research and factual information available, which proves the success of this technology when adequately applied. Permanganate is an oxidant that is able to degrade a variety of soil and groundwater contaminants, specifically chlorinated volatile organic compounds. Permanganate does not require activation and is applicable over a wide pH range.

The presentation will provide information regarding the different types of permanganate (e.g., sodium and potassium), chemistries, treatable contaminants (well-known and emerging), determination of reagent volume, natural and contaminant oxidant demand values and information, application methods, and other key components, which all play key roles in the successful application of this remedial option. GZA is a 600-person, multidisciplinary consulting firm that provides technical support through all phases of environmental due diligence, site investigations and remediation. Geo-Cleanse is an ISCO remediation vendor, with experience utilizing various permanganate products to remediate traditional and complex sites since 1995. Carus Corporation has been a permanganate manufacturer since the early 1900s and a supplier to the remediation industry since the late 1990s. The presentation will demonstrate understanding of the oxidant (as well as other remedial chemicals), application methods and technology as applied to the field, and lessons learned and the major key factors that come into play when selecting and applying permanganate to obtain clean up goals. The application of ISCO can be complex, with regards to any chemical reagent applied. This presentation will provide factual information and field-scale design and implementation case studies to educate the audience using our experience with regards to ISCO with permanganate.

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Numerical Allocation of Pyrogenic and Petrogenic PAH in Contaminated Soils and Sediments

Allen Uhler and Kerylynn Krahforst

Industrial manufacturing sites often are contaminated by hydrocarbon wastes. Such hydrocarbon contaminants can be of petroleum (petrogenic) origin, i.e., fuels, lubricants and solvents utilized in industrial operations, or from pyrogenic sources (combustion or pyrolysis), such as tar-derived wastes from former manufactured gas plants (MGP). Further, there are other common wastes, notably combustion residues like ash, cinders, and general atmospheric fallout and roadway dust that are enriched in combustion-type hydrocarbons that can often confound the identification of the nature and sources of hydrocarbon-derived contaminants at industrial sites.

This poster presents a methodology to unravel contribution of mixed pyrogenic and petrogenic PAH found in impacted soils and sediments. The method is based on theoretical mix models of alkylated PAHs measured in pyrogenic MGP tar and various petroleum fuels. The mix models are used to predict the contribution of petrogenic and pyrogenic PAH sources to measure PAH in soils and sediments. Application of the methodology is demonstrated in an investigation at a former industrial site impacted by petroleum and MGP tar wastes. We describe how the hydrocarbon sources of PAH at the site are differentiated, and we allocate contribution of petroleum and MGP tar to the PAH found in impacted site soils.

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Evaluation of Monitored Natural Attenuation to Address Legacy Contamination Along a Tidal Estuary

David Winslow, Melissa Dulinski, and Sandra Huber

As part of the redevelopment of a former Chemical Plant in Elizabeth/Linden New Jersey, GZA was tasked with preparing a Remedial Action Outcome (RAO) for soil a separate RAO for groundwater. The RAO for was issued in 2012 and incorporated targeted soil excavation, development features (to be used as engineered controls) and institutional controls. The Groundwater RAO was more complicated and required a longer time frame to achieve. Groundwater at the Site was contaminated with dissolved metals (aluminum, arsenic, iron, lead, and manganese) and volatile organic compounds (VOCs.). The metals were attributed to either background or the historic fill used at the Site and were addressed through an institutional controls (Classification Exception Area). Dissolved VOCs consisted of 1,2 dioxane, benzene, ethylbenzene, toluene and xylenes. Following groundwater remedy pilot tests such as injection ISOC, injection of TPHenhanced, and Vacuum Enhanced Fluid Recovery, dissolved concentrations of VOCs remained above standards but at lower concentrations than prior to the above remedial actions. Based on these results, GZA evaluated the use of Monitored Natural Attenuation (MNA) as the final remedy for dissolved VOCs. The evaluation consisted of the following studies: evaluation of the groundwater to surface water pathway using sediment, surface water and pore water samples; a tidal survey; analysis of biogeochemical indicator compounds; long term contaminant trend analysis; and the fate of the dissolved VOCs in the environment. Based on the results of the investigation it was found that no sensitive receptors were being impacted and that that MNA was occurring albeit at a slow pace due to the site specific geochemistry and hydrogeology. An RAO and a remedial action permit for MNA were prepared for the Site and a CEA was issued.

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Soil: Water Fate and Transport of Three Antibiotics in Laboratory Batch Studies Using Beef Lagoon Water

Katherine Woodward

Antimicrobial overuse and resistance (AMR) are of growing concern to the scientific community. Antimicrobials are used prophylactically and therapeutically during production of meat animals to maintain herd health, and as such, many of these antimicrobial residues end up in runoff water. When runoff water is use as irrigation for crop production, these residues become available for transport in the environment. Therefore, cost-effective methods need to be developed for removing antimicrobial residues from the wastewater. The objective of this study was to identify how select antimicrobial residues are partitioned in runoff wastewater to provided information on how to design more effective control system. Therefore, three radiolabeled antibiotics, ^{14}C-erythromycin (ERY), ^{3}H-chlortetracycline (CTC), and ^{3}H-monensin (MON) were selected for a laboratory soil: water batch study utilizing beef lagoon water and a well-characterized agricultural soil. Liquid scintillation counting and oxidation were used to quantify the radioactivity in the aqueous and sorbed fractions. Slightly more ERY partitioned to the sorbed fraction than the aqueous fraction, and equilibrium conditions existed from 2 to 168 h. CTC partitioning occurred in two phases: a rapid sorption to the particle fraction between 0.5 and 8 h, but desorption beginning at 24 h into the aqueous fraction, suggesting degradation/metabolism to more polar compounds. The most lipophilic antibiotic, MON, quickly and nearly quantitatively partitioned into the sorbed fraction, and remained at equilibrium with the aqueous fraction from 0.5 to 168 h. This information will be used to develop treatment designs and methods for antibiotic removal in lagoon wastewater.

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Sustainable Use of Contaminated Soils with Chromium, Copper, Cadmium, and Arsenic Based on Leaching Characteristics

Pei-Yao Wu, Ping-Hsiung Ni, Shyh-Wei Chen, Jen Wang, Jen-Shen Chou, Mei Shiou Hung, Yu-Jen Liang, and Chien Jung Lai

In this study, cement, brick, and washed soils with contaminated soils are tested with 3 main leaking characteristic procedures: TCLP, SPLP, and CEN/TS 14405:2004. The results show that 30% of total chromium in the cement sample is leached in the TCLP test while less than 5% is leached in the SPLP test. However, the results of CEN/TS 14405:2004 show that the chromium in the tested cement samples complies with the Netherland Building Materials Decree (BMD) standard of 1,500 mg/m^2-100 yr. The results of the CEN/TS 14405:2004 also show that the chromium leaching may cause the violation of the groundwater standard for drinking purposes (0.05 mg/L) in the early L/S ratios, which indicates possible health threats if the downstream groundwater is used for drinking or food processing. The results of the heavy metal leaching in the brick samples are different from those in the cement samples; for example, the chromium leaching concentrations in all 3 leaching tests are insignificant but more than 10% of the total arsenic in the brick samples is leached in the TCLP test. Copper, cadmium, and arsenic are also studied in the 3 leaching tests, and the discussions of the 4 metals leaching characteristics are presented.

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The Effects of Aged Petroleum Hydrocarbon Contaminants in Soil on Bioventing Remediation

Mei Xiao and Richard Zyner

Petroleum hydrocarbon contamination in soil can harm both human health and the environment. Remediation technologies are required to remove the contaminants before the sites, such as brownfields, can be redeveloped. One of such technology is bioventing, which is a low cost and non-destructive *in situ* method for petroleum contamination. This technique stimulates the native bacteria through the addition of nitrogen and oxygen, promoting bioremediation. Bioventing requires minimal equipment and maintenance, making it ideal in remote areas. Furthermore, there is no tailing effect and the extracted air is clean, requiring no additional remediation processes.

Predicting the time required for remediation can be a challenge in field applications due to the diversity of site characteristics. Despite the work that has previously been done to determine the correlation between soil texture, water content, and microorganism count, there is a gap in knowledge regarding the effects of contaminant age. The literature shows that over time, contaminants are sorbed into the soil particles and become harder to reach, requiring additional time for the bacteria to access and remediate, lengthening the bioventing process. To better understand this effect, two soils were spiked with synthetic gasoline and aged. The first order degradation rates were determined to quantify the effects of aging over time, measuring a two-fold decrease when comparing freshly spiked sandy soil to soil spiked and aged for four months. The sorption of contaminants into the soil also significantly decreased extraction efficiencies. In addition, two reactors containing 150g and 80kg of soil respectively were used to examine the scale-up effect. It was observed that the average increase of the degradation rate was 2.3 times from the small-scale reactor to the larger one. These findings suggest that the small rectors can be used to predict field results without the need for large reactors and lengthy experiments.

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Identifying Redox Transition Zones in the Subsurface

Xin Yin, Han Hua, and Lisa Axe

Reactive mineral coatings play an important role in contaminant transformation. This research focuses on identifying and studying redox transition zones where reactive mineral coatings are expected to be significant. To accomplish this study, a 60-foot core was collected from an area of concern at the Chambers Works Site in New Jersey. With stainless steel liners, 2-foot sub-sections of the core were obtained, protected with argon-purged PVC tubes, and stored at 4°C. The cores were jacked in a glove box into a total of 225 2-inch subsamples preserved with triple-layer protection to prevent oxygen permeation and organic interactions with the container. A suite of analytical tools was used on each sample including X-ray fluorescence (XRF) for composition, soil pH, redox potential (ORP), and volatile organic carbon (VOC) concentration in the headspace. From XRF results, iron and sulfur were among the dominant elements present with gradients observed throughout the core. Iron concentrations peaked at multiple depths with the most significant gradients observed from 32' to 38' and 49' to 50'. Sulfur concentrations peak as well at depths consistent with Fe trends and gradients spanning five orders of magnitude; the increases in the S and Fe concentrations are consistent with sulfide precipitation. Over the 60 feet, soil pH ranged from 3.74 to 8.03. Steep gradients in the oxidation-reduction potential included -141.4 – 651.0 mV. VOCs were detected using the photo-ionization detection and reported as chlorobenzene; readings ranged from 0.1 to 6.4 ppm. As a result of this screening process, a number of redox transition zones were identified and include depths 21.0'-22.8', 31.0'-34.3' and 39.0'-43.0'. Other analyses that have corroborated the importance of the zones being studied involve evaluating bacteria abundance and contaminants of concern found in groundwater. A more detailed study is being conducted in four of the transition zones.

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Electro-Fenton Reaction: Performance Under Different Groundwater Flow and Current Intensities

Yuwei Zhao

Electrochemical systems can be used to induce Fenton reaction *in situ*: hydrogen peroxide (H_2O_2) forms through the catalyzed reaction between electro-generated oxygen and hydrogen and further decomposes to hydroxyl radicals ($OH^{\cdot}$) via reaction with ferrous iron (Fe(II)). Evaluation of parameters that influence these reactions in flow-through electrochemical systems is of great importance for the application of (Electro-)Fenton reaction to treat contaminated groundwater. In this study, we evaluated the influence of the flow rate and current intensity on the rate of both H_2O_2 and $OH^{\cdot}$ formation. We measured the production of H_2O_2 and OH· at sampling ports located between the electrodes in the flow-through electrochemical cell. Increasing the current from 60 mA to 250 mA, under the constant flow of 3 mL min^{-1}, adversely affects H_2O_2 production; total production after 2 hours decreased from 0.36 mg to 0.25 mg (accumulated H_2O_2 amount), leading to decreased generation of OH·. Under the flow of 10 mL min^{-1}, the change of H_2O_2 formation was negligibly influenced by the change of current. Under higher flow rates (20 mL min^{-1}, 50 ml min^{-1}, 80 mL min^{-1}), the amount of accumulated H_2O_2 increased with current increase. Since groundwater flow rates can vary significantly, predictions of the systems performance and the ability to maintain the conditions needed for (Electro-)Fenton reaction under different flow rates support the potential for *in situ* implementation of the process for groundwater remediation.

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Drastic Enhancement of H_2O_2 Electrogeneration by Green Electrochemical Modification of Graphite Felt in Low Conductivity, Acid-Free Electrolyte

Wei Zhou

A completely green electrochemical modification of graphite felt in acid-free, low conductivity electrolyte was proposed for improved electrogeneration of H2O2 from anodic O2 reduction. Effective production of H2O2 could support Electro-Fenton system for organic pollutants removal. Cyclic voltammetry (CV), linear sweep voltammetry (LSV), NaOH uptake method, SEM, and contact angle measurement were used to characterize the modified graphite felt electrodes. Key factors affecting the H2O2 generation such as solution pH, current intensity was systematically investigated. Moreover, the influence of electrooxidation products on H2O2 generation and feasibility of simultaneously modification and production by polarity reversal was discussed. Results showed that graphite felt modified in 0.05 M Na2SO4 or simulated groundwater exhibited higher activity toward O2 reduction. Compared with unmodified electrodes, a 25.6-183.3% higher H2O2 concentration was obtained, which was caused by the introduction of oxygen-containing groups (58.3-445.4 μmol/g). Under current of 200 mA, higher electrooxidation time could introduce more functional groups. Lower pH facilitates H2O2 generation for unmodified electrodes, while modified electrodes exhibited a wider pH range (2-7). 100mA was the best current for unmodified electrodes, while 50 mA could support the effective generation of H2O2 for modified electrodes. We also found products of electrooxidation of graphite felt influence the generation of H2O2. Results of simultaneous modification and H2O2 generation show a proper interval time and reactor configuration is important to achieve this process effectively.

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