The 2003 Annual Buyers’ Guide

Impact of Preservation Techniques and GC Injector Temperature on Loss of Fuel Oxygenates by Y. Zhang and R.F. Spalding

Fugitive Methane by Alan Jeffrey, Issac Kaplan, Dachun Zhang, Shan-Tan Lu, Robert Haddad and Jesper Nielsen

Abstracts from the 2002, 18th Annual International Conference on Contaminated Soils, Sediments and Water at the University of Massachusetts Part III
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Coming in December
Our all new and updated State by State Hydrocarbon Standards
Welcome to our annual Buyers' Guide, the 2003 edition. We have many new listings, plus updated information from some of our regulars. This is an important service to our industry, matching manufacturers, distributors and consultants together with our 16,000+ readers. If you missed being listed this year, e-mail your fax number with the subject line "Buyers' Guide 2004" and we'll be sure to forward a form to you before the next Guide is published. Send your e-mails to editor@aehsmag.com.

We've changed our publication by increasing the page count and valuable information in each issue, and updating our schedule to publish four times per year. In December, we'll be bringing you an all new State by State Hydrocarbon Standards issue. Watch in March for another special MTBE issue.

A new columnist joins our group of professionals this month. Venki Uddameri will be writing on the subject of Modeling. He is an assistant professor in the Department of Environmental Engineering, Texas A&M University-Kingsville, where he teaches modeling related courses and carries out research in various aspects related to multiphase and multimedia transport of pollutants. Read the first installment in the new Modeling Column beginning on page 21.

Terry W. Combs
Editor
Nonlinearity in Biology, Toxicology and Medicine
An International Journal

Edward J. Calabrese, Editor-in-Chief
University of Massachusetts, Amherst

Nonlinearity in Biology, Toxicology and Medicine is a quarterly peer-reviewed journal devoted to publication of original findings on the occurrence of nonlinear dose-response relationships across the broad range of biological disciplines including physiology, biochemistry, molecular biology, toxicology, radiation biology, pharmacology, medicine, experimental psychology, plant biology, environmental and related sciences. In addition to descriptive experimental findings of nonlinear dose responses, particular interest will focus on experimental evidence providing mechanistic understanding of nonlinear dose-response relationships.

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Impact of Preservation Techniques and GC Injector Temperature on Loss of Fuel Oxygenates

By Y. Zhang and R.F. Spalding

Commonly-used fuel oxygenates such as methyl tert-butyl ether (MTBE), ethanol, tert-butyl alcohol (TBA), ethyl tert-butyl ether (ETBE), and tert-amyl ethyl ether (TAME) are added to gasoline to comply with air emission regulations and as octane enhancers in the U.S. Oxygenates have been reported nationwide in groundwater beneath leaking storage tanks and pipelines, transportation accidents and refueling spills (US EPA, 1999). Currently MTBE, ethanol, TBA, ETBE and TAME are target analytes at fuel contamination sites.

Aqueous sample preservation is strongly advised and is mandated for many chemicals to maintain analyte stability. It is intended to reduce analyte of interest loss caused by microbiological transformations, hydrolysis, species transformations, sorption and volatilization (APHA, 1998). Common preservation techniques include the addition of inorganic and organic antimicrobials, refrigeration, acidification and freezing.

For example, to minimize loss volatile organic compounds (VOC) from biodegradation during the sample holding, HCl is added to water samples (APHA, 1998). The suggested preservation technique for water samples contaminated by fuel and/or components of fuels is acidification with HCl to pH <2.0 (APHA, 1998). Koester et al., (1999) recommends adding four drops of concentrated HCl in 40-ml vials to minimize bacterial losses of ethylene.

Ether hydrolysis is normally very slow even in aqueous samples acidified to pH<2 (Church et al., 1999). However, acid hydrolysis of MTBE to TBA in groundwater samples was reported when heat, a necessary step in some detection methods, was applied to acidified samples (O'Reilly et al., 2001; Pirkle and McLoughlin, 2002; Rhodes and Verstuyft, 2001; Uhler et al., 2000). Significant ether hydrolysis was observed in groundwater samples in the analysis by purge and trap coupled with GC/MS in which water samples were brought to 80°C prior to purging (O'Reilly et al., 2001).

About 70% of MTBE was hydrolyzed in samples that were acidified samples with HCl to pH 1, while in similarly preserved samples to pH 2 MTBE hydrolysis ranged from 6.1 to 13%. In samples preserved with HCl at pH <2, acid hydrolysis of MTBE, TAME and ETBE occurred during the heated head space method when the samples were heated to 80°C for 30 min. MTBE hydrolysis varied from 22% to 90% and averaged 62% (White, 2002).

O’Reilly et al. (2001) warned that more polar fibers designed for alcohol analysis may be especially prone to promote hydrolysis during rapid heating in the injector of the GC or GC/MS. Consequently, White (2002) recommends the universal use of TSP preservative in water samples collected for fuel component/oxygenate analysis regardless of the temperature requirements of the analytical method.

The objective of this research was to determine if hydrolysis of oxygenate ethers and loss of oxygenate alcohols occurs during standard preservation protocols, long-term storage at 4°C, and analysis by SPME-GC/MS using DVB/Carboxen/PDMS fiber.

Materials and Methods

The combined performance of various preservation techniques to prevent fuel oxygenate loss during storage and ether hydrolysis on heated SPME fiber in GC inlet systems was evaluated. Groundwater for the experiment was collected from Platte River alluvium wells in central Nebraska that were not impacted by fuel contaminants. Samples were fortified with about 30 ppm ethanol and TBA and with about 1.2 ppm MTBE, ETBE and TAME.

Control samples, without preservatives, and samples with three commonly used preservatives were tested over a three month period. Preservation techniques in 40-ml VOC vials included: acidifying to pH<2.3 with HCl; acidification to pH<1.4 with HCl; and addition HgCl₂ (10 ppm). Samples were stored at 4°C for ~3.5 mo. Oxygenates extracted onto DVB/Carboxen/PDMS fibers were injected into a heated injector at 220°C and quantified by GC/MS (Cassada et al., 2000). Analysis was conducted at 0, 21, 42, 63 and 106 days.

The internal standard, n-propyl alcohol, and two surrogate standards, isopropanol and butyl ethyl ether were added to the samples immediately before analysis for quantitation and as measure of sample recovery. Laboratory fortified blanks, lab reagent blanks and 3-point calibration curves were included daily as a standard operating practice. Triplicate analyses for each sample were conducted; the mean and standard deviation values of triplicates for each sample with holding times were obtained for evaluation.

A second experiment was performed at much lower concentrations of the oxygenates. Using the previous groundwater matrix, samples were fortified with 200 ppb ethanol and TBA and about 3.9 ppb MTBE, ETBE and TAME. Samples acidified to pH<1.5 with HCl, and samples containing HgCl₂ were evaluated against control samples having no preservatives. HCl acidified samples were stored at about 4°C for ~27 days. Oxygenates were analyzed using the SPME-GC/MS 0, 2, 9 and 27 days.
Results and Discussion

Acid hydrolysis of MTBE, ETBE and TAME did not occur at pH 1.4 or 2.3. There were no detected oxygenate losses and no increase of TBA concentration during the 106 day experiment (Figure 1). No loss of alcohols was observed, and their concentrations ranged from 86.7% to 108.7% of the initial concentration. In samples preserved with HgCl₂, there was no significant loss of oxygenates during the 106 day holding time or in the heated injector. Recoveries ranged from 86.8% to 113.8%.

Ethanol loss occurred in samples without preservatives added and preserved by refrigeration at 4°C. Ethanol recoveries decreased gradually with increasing holding time, ranging from 86.3%, 77.3%, 73.4% and 57.5% for 21, 42, 63 and 106 days, respectively. In contrast, the concentrations of TBA and three ethers (MTBE, ETBE and TAME) changed little with holding time, with recoveries ranging from 82.1% to 103.8% during 106 days.

Using a factor of 2 lower concentrations did not result in detectable acid hydrolysis of MTBE, ETBE and TAME occurred at pH 1.5 and HgCl₂ (Figure 2). There were no oxygenate losses, and no increase of TBA concentration was observed during 27 day holding time. Ether concentrations remained invariant during the monitored holding period resulting in concentrations ranging from 97% to 106% of the initial. No loss of alcohols occurred, and their concentration ranged from 93% to 107% of initial.

Ethanol loss was observed in control samples where the concentrations decreased from 200 ppb to below 10 ppb with increased holding time. No losses of TBA and the three ethers (MTBE, ETBE and TAME) occurred during the 27 days. Their recoveries ranged from 94% to 106%.

The experimental results are consistent to those of other studies. O’Reilly et al. (2001) reported that if groundwater samples are refrigerated before sample preparation and analysis is at ambient temperature, minimal hydrolysis of the ether oxygenates occurs. White et al. (2002) indicated that, if groundwater samples are preserved at pH 2, they can be stored for several months at 10°C without significant hydrolysis of MTBE in analysis for oxygenates.

Bauman et al. (2003) showed that hydrolysis of MTBE to TBA was insignificant in samples stored acidified at pH values from 1 and 2 and analyzed by the heated (45°C) purge-and-trap
method. No ether or alcohol loss in standards or samples was detected during any stage of the analysis including the heated GC injector port. This suggests that the residence time is too short to promote hydrolysis or that the medium polarity carboxen fiber does not hasten hydrolysis.

Conclusions
Oxgenate losses in acidified aqueous samples stored at 4°C for up to 106 days were insignificant. The results indicate that previous data which were determined with the DVB/Carboxen/PDMS fibers were not adversely impacted by hydrolysis, and indicates that preservation with TSP should not be required for samples that are properly stored (4°C) and analyzed for oxgenates using SPME with DVB/Carboxen/PDMS fibers. Ethanol losses were also insignificant in refrigerated samples preserved by either acidification or HgCl₂ addition.

Acknowledgements
This project was supported by the Nebraska Ethanol Board and Nebraska Corn Board. We appreciate the editorial assistance of Drs Thurston-Enriques and McCallister and the laboratory assistance of David Cassada and Steve Monson. This manuscript has been assigned Journal Ser. No. 14060, Agric. Res. Div., University of Nebraska.

References


Figure 2. Changes in unpreserved and preserved fuel oxygenate concentrations (ppb) during 27 day holding period.


Roy F. Spalding, Ph.D., is professor of Agronomy and Horticulture, University of Nebraska, Lincoln. Yi Zhang, Ph.D. will begin a Post Doctoral appointment at the University of Minnesota in June, 2003.
Methane gas seeping out of the ground is a widespread phenomenon. Marsh gas bubbling up in swampy areas is easily observed, and is a natural feature of this environment. It is caused by microbial conversion of organic matter to methane under reducing conditions. In areas not adjacent to estuaries or swamps, methane seeps are less obvious, and may originate from human activities.

Fugitive methane can pose various levels of concern. In small concentrations, it may be an aesthetic concern, characterized by unpleasant smells resulting from associated volatile compounds carried by the methane. At concentrations above 5% in air, methane can be ignited by flames and sparks. If the methane is pressurized, either by a gas source under pressure such as a gas pipeline, or by containment, such as under the foundations of a building, an explosion can result.

Identifying the source of the methane is important in remediating a potentially dangerous setting. A methane seep caused by rupture of an underground gas pipeline can be eliminated by repairing the pipeline. However, it is unlikely that microbial methane from buried organic sediments can be eliminated. But controlled venting of the methane may eliminate the hazard the fugitive methane poses.

The source of the methane may also determine who, if anyone, is responsible for physical or economic damage caused by the fugitive methane. There may be no responsible party for microbial methane generated from buried organic sediments seeping into the basements of houses in a new subdivision. If, however, the microbial methane is generated from an underground plume of spilled petroleum product, the party that spilled the product may bear responsibility. Similarly, if the houses were constructed on a known methanogenic landfill, or an animal feedlot, the housing developer may bear responsibility.

Hazards

An example of a life-threatening hazard caused by fugitive methane, and of the difficulty in identifying the source and devising mitigation measures, is the explosion at the Ross Department Store in Los Angeles in 1985. The explosion collapsed the roof of the store and injured 23 people, and a plume of flame burned for days. Eventually, a relief well was drilled to vent a pressurized gas accumulation beneath a paved parking lot that was feeding the burning plume. This extinguished the flame and eliminated the immediate problem. However, four years later, pressurized gas again vented in the same area, but did not ignite. The source of the fugitive methane was variously ascribed to microbial methane, petroleum gas leaking from abandoned oil wells, and release of gas from fractured underground petroleum reservoirs undergoing well pressurization.

Processes Forming Methane

The two principal processes that produce methane are biological reduction of organic matter by microbes at relatively shallow depths, and non-biological thermal decomposition of deeply buried organic matter. Biogenic reduction produces methane, with only trace amounts of ethane and higher hydrocarbons. Biogenic methane formation can occur by the following two mechanisms:

Fermentation of organic matter and dissociation of acetate to
CH₄ and CO₂, illustrated by the following equation:

\[ \text{CH}_3^- + \text{CO}_2^- + \text{H} \leftrightarrow \text{CH}_4 + \text{CO}_2 \]

Reduction of CO₂, formed by respiration of organic matter, illustrated by this equation:

\[ \text{CO}_2 + 8\text{H} \leftrightarrow \text{CH}_4 + 2\text{H}_2\text{O} \]

Thermal decomposition of organic matter in deeply buried sediments produces liquid and gaseous hydrocarbons that make up petroleum and natural gas. Ethane, propane and higher hydrocarbons often constitute a significant percentage of natural gas.

These processes can be distinguished by a combination of compositional and stable isotope analysis of the gas. As shown in Figure 1, biogenic gas typically has a high proportion of methane to ethane and propane, and a more negative methane carbon isotope ratio. Thermogenic gas, in contrast, has a lower proportion of methane to ethane and propane, and a less negative methane carbon isotope ratio. Methane hydrogen isotope ratios allow the two biogenic methane mechanisms to be distinguished, as shown in Figure 2. Landfill methane typically falls within the field of biogenic fermentation.

Alteration in the Environment

Unfortunately, biogenic and thermogenic gas may be altered chemically and isotopically during migration to the surface. One common alteration process is the removal of ethane and higher hydrocarbons from a thermogenic gas so that the composition more closely resembles a biogenic gas. However, the methane in the migrated thermogenic gas can still be
Figure 1. Differentiation of biogenic and thermogenic gas.

distinguished from biogenic methane by the carbon and hydrogen isotope ratios.

A more problematical alteration process is the oxidation of methane to carbon dioxide in near-surface soils. This shifts the carbon and hydrogen isotope ratios of the residual methane to less negative values, as shown by the arrow in Figure 2. This can cause biogenic methane to have carbon and hydrogen isotope ratios within the field of thermogenic methane.

Complications due to methane oxidation can be resolved by analysis of the $^{14}$C content of the methane, which is commonly presented as percent Modern Carbon (pMC). Biogenic methane formed in landfills and in swamps contains carbon from organic matter that was part of living organisms until relatively recently. Some examples are household garbage and wood in landfills, and decaying plants in swamps. These materials came from plants and animals that were alive less than 50,000 years ago, and so contain $^{14}$C, which has a radioactive half life of 5,700 years. Values >30 pMC are typical for methane formed from these sources. Thermogenic methane and biogenic methane formed by degradation of petroleum products, in contrast, contain carbon from organisms that died millions of years ago, in which all the $^{14}$C has radioactively decayed, giving a value of 0 pMC.

Determining the Source

Figure 3 shows a flow chart that can be used to determine the source of a fugitive hydrocarbon gas by sequential analysis of the $C_1$-$C_3$ composition, the methane carbon and hydrogen stable isotope ratios, and the methane $^{14}$C content. A low $C_1/C_3$ ratio may be sufficient to identify gas from a leaking gas pipeline or gas migrated from a deep petroleum reservoir. A high $C_1/C_3$ ratio can indicate a number of sources, which can be narrowed by methane carbon and hydrogen stable isotope ratios. But in many cases, particularly if methane oxidation is suspected, which may be indicated by a wide variation in the methane $\delta ^{14}$C values, $^{14}$C analysis may be the only way to definitively identify the source.

References


Alan Jeffrey, Isaac Kaplan, Dachun Zhang, Shan-Tan Lu, Robert Haddad and Jesper Nielsen are with Zymax Forensics, San Luis Obispo, Calif.
Figure 3. Flowchart for identifying the source of a fugitive hydrocarbon gas.
Characterization of “Urban Background” PAH in Sediments

By Scott A. Stout, Allen D. Uhler and Stephen D. Emsbo-Mattingly

Polycyclic aromatic hydrocarbons (PAH) are common contaminants in freshwater and marine sediments worldwide. Naturally-occurring background PAH, derived from natural fires, natural oil-seeps, eroded shales/coal and early diagenetic processes, are present in low concentrations in sediments that pre-date the industrial revolution. However, as fossil fuel use increased and industrialization developed, some hydrocarbons and significant levels of PAH associated with combustion and residual petroleum have contributed an "anthropogenic background" to contemporary sediments in both urban (e.g., Eganhouse et al., 1982) and remote locations (e.g., Ohkouchi et al., 1999).

In urban waterways, the non-point source, anthropogenic contribution of PAH are collectively called "urban background". These PAH arise from a number of non-point sources that include: (1) stormwater runoff, (2) direct deposition (atmospheric fallout) of combustion particles (soot) from vehicle exhaust and factories, (3) surface runoff from roadways, parking lots and bridges, or (4) discharges from recreational, commercial and military boat/ship traffic. These PAH source materials, which often have been entering a waterway for decades, can impart recognizable profiles of anthropogenic background PAH to the sediments (e.g., Daskalakis and O’Connor, 1995).

Recognizing the contribution of anthropogenic background PAH in sediments is particularly important to site investigators attempting to understand the impact of site-specific discharges of PAH to sediments. This assessment can be especially challenging in waterways and coastal areas where multiple point-sources co-exist along with the persistent non-point, background sources (Stout et al., 2001a, 2001b).

In this article, we describe the nature and concentrations of anthropogenic PAH and associated hydrocarbons in sediments from nine U.S. harbors and waterways recently studied (Table 1; Stout et al., in press). The 334 sediments discussed in this article were collected and analyzed over the course of almost four years. The samples included in the study were all collected from the upper 20 cm of sediment, and mostly in the 0 to 10 cm interval. The sediments were analyzed for up to 43 parent and alkyl substituted PAH (Table 2) that have proven effective in reliably distinguishing the relative contributions of any particular source of PAH in sediments, including that of urban background (e.g., Bates et al., 1987; Laflamme and Hites, 1978; Boehm and Farrington, 1984; Stout et al., 2001a).

Table 1.

<table>
<thead>
<tr>
<th>Urban Waterway</th>
<th>Year</th>
<th>n</th>
</tr>
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<tbody>
<tr>
<td>Boston Harbor, Massachusetts</td>
<td>1999</td>
<td>8</td>
</tr>
<tr>
<td>(Channel/Drydock Study)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston Harbor, Massachusetts</td>
<td>2002</td>
<td>55</td>
</tr>
<tr>
<td>(CSO Study)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boston Harbor, Massachusetts</td>
<td>2002</td>
<td>51</td>
</tr>
<tr>
<td>(Narfield/Farfield Study)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eagle Harbor, Bainbridge Island</td>
<td>2000</td>
<td>26</td>
</tr>
<tr>
<td>Washington, Washington</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elizabeth River, Norfolk, Virginia</td>
<td>2002</td>
<td>22</td>
</tr>
<tr>
<td>Long Island Sound, New York</td>
<td>2002</td>
<td>12</td>
</tr>
<tr>
<td>Portland Harbor, Portland, Oregon</td>
<td>2001</td>
<td>23</td>
</tr>
<tr>
<td>Quantico Marine Corps Base</td>
<td>2002</td>
<td>9</td>
</tr>
<tr>
<td>Quantico, Virginia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhode Island Sound, Rhode Island</td>
<td>2002</td>
<td>41</td>
</tr>
<tr>
<td>San Francisco Bay, Alameda Pt.</td>
<td>2001</td>
<td>57</td>
</tr>
<tr>
<td>California</td>
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<tr>
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<td>2000</td>
<td>12</td>
</tr>
<tr>
<td>locations, California</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thea Foss Waterway, Tacoma,</td>
<td>1999</td>
<td>17</td>
</tr>
<tr>
<td>Washington</td>
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</table>

Table 2. Diagnostic PAH used to distinguish among PAH sources.
Figure 1. GC/FID chromatograms for extractable hydrocarbons for sediments impacted by urban background in (A) Thea Foss Waterway, (B) Eagle Harbor, (C) Portland Harbor and (D) Elizabeth River sites (Table 1). IS - internal standards.

Unique Chromatographic Features
The chromatographic character of total extractable hydrocarbons (THC) from most urban sediments exhibit similar features, which is suggestive of the overall similarity in the nature of urban background in different urban settings. Figure 1, which shows GC traces of the THC for four selected sediments from different urban areas, demonstrate this similarity.

Each of the sediments exhibit two characteristic chromatographic features: (1) numerous later-eluting resolved peaks and (2) an unresolved complex mixture (UCM), or 'hump', mostly within the residual oil range. The resolved peaks include various non-alkylated 3- to 6-ring PAH, indicative of the combustion-derived particles in engine exhaust (Laflamme and Hites, 1978; Westerholm et al., 1988; Oanh et al., 1999). The UCM 'hump' is characteristic of a largely residual range petroleum, such as lubricating, hydraulic and waste oil(s), which also are expected to occur in urban runoff (Gogou et al., 2000). Also present in some urban sediments (Fig. 1C) are numerous odd-dominated normal hydrocarbons (n-C_{27}, n-C_{29}, n-C_{31}) associated with plant waxes derived from modern leaf debris in the sediments (Prahm and Carpenter, 1984).

PAH Features Indicative of "Urban Background"
The distribution of PAH in most of the more than 300 sediments exhibit an overall similar character (Figure 2 A-F). The composition of the sediments is dominated by 4- to 6-ring PAH (i.e., high molecular weight PAH: HPAH), the most abundant of which are most often fluoranthene and pyrene. Interestingly, the sediments exhibit variations in the distribution among other prominent HPAH and in the shape of the UCM humps, both features that imply the variable nature of their regional sources. Each PAH homologous series exhibits a decreasing abundance with increasing degree of alkylation, as is typical of pyrogenic PAH (Sauer and Uhler, 1994-1995). It is on this basis that PAH in urban background is described as arising from pyrogenic sources, in spite of evidence for the presence of petroleum (e.g. as is evidenced by the UCM; Fig. 1).

Figure 2G shows the median concentrations (and 25th, and 75th percentiles) for all 334 sediments described in this article. The similarity in the PAH distribution between the median values (Fig. 2G) and the representative sediments shown (Fig.
Figure 3. Histograms showing populations of PAH concentrations (A) Priority Pollutant only and (B) sum all 43 PAH analytes (Table 2) X-axis: max. concentrations in μg/kg dry weight.

2A-F) further demonstrates the overall similarity in the distribution of PAH in sediments impacted by urban background.

In addition to similarity in PAH patterns, the concentrations of total priority pollutant PAH and total PAH$_{43}$ sheds insight into the character of urban background sediments. The vast majority of the urban background-imacted sediments studied contained less than 20,000 μg/kg of Priority Pollutant PAH and less than 30,000 μg/kg of total PAH$_{43}$. Histograms demonstrating this observation are shown in Figure 3.

Conclusions

The nature of PAH found in sediments from different geographic settings in the United States provides a basis to recognize the contribution of "urban background" to PAH loadings. Chromatographic fingerprints of the total extractable hydrocarbons (THC) provides one important tool in recognizing the character of urban background. In addition, evaluation of parent and alkylated PAH data provides a greater ability to assess and compare the nature of urban background from different locations. There is a general consistency in the nature and concentration of the PAH attributable to urban background from different locations, e.g., predominantly 3- to 6-ring, non-alkylated PAH with total priority pollutant PAH typically less than 20,000 μg/kg (dry). There are, however, also definite differences in the PAH character of "urban background" among different locations that speak to the regional influences on the chemical character of sediments. The variation in hydrocarbon character of urban sediments contends that more detailed THC and PAH "fingerprints" such as described in this article should be obtained as part of PAH sediment contamination investigations.

References


Soils Information Resources

By Alfred R. Conklin, Jr.

Geology, Engineering, Physical Geography and Soil Science are four disciplines, which collect data, study and do research on soils. Each area looks at and studies soil in a different way. Geology approaches soil as decomposed rock, the composition of which is dependent on the rock from which it is forming. Soil is a component of the earth's surface and is subject to geological forces. Engineering approaches soil as a medium for building and supporting structures. In this discipline most information about soils will be found in Civil Engineering, which deals with buildings, bridges, waterways, sewerage, systems, etc. Physical Geography studies the relationship between physical features on the earth's surface such as land, water and climate, and human activity.

Soil Science approaches soil as a natural unique component of the environment separate from other components. Soil is not just decomposed rock but is a unique part of the environment just as trees are unique parts of the environment. Soil scientists identify 12 different soil orders depending on their individual characteristics.

Soil science is also involved in studying the relationship between soil, organic matter, microorganisms and plant growth. As a result of this there is a strong interest in studying those mechanisms, which result in the biological availability of inorganic compounds, ions and molecules, and in the decomposition of organic environmental pollutants.

Each Discipline Contains Soil Information

Each of the above disciplines is a source of information about soil and its characteristics as viewed from different perspectives. Introductory text from any of these disciplines will contain information about soil. Depending on the needs of the investigation or project, the sections of these text dealing with the aspect of soil of interest can be consulted.

A particularly important and useful introductory soil science text is The Nature and Properties of Soils by N. Brady and R. Weil, published by Prentice Hall. This book gives an introduction to almost all aspects of soils and soil science.

Soil is composed of many different components including air, water, organisms and inorganic and organic solids. Because of this, there are texts which discuss in detail each of these components. For example, there are texts devoted to soil chemistry, physics, biology, microbiology, biochemistry, geomorphology, morphology, soil-plant interactions, water and soil engineering. They are excellent sources of more specific information about these specific components of soil and how they interact with the environment both generally and specifically.

In certain cases, there are even more specific text and monographs available on specific soils subjects. For instance, text on the chemistry of soil organic matter or nitrogen fixing organisms in soil can be found. These and similar texts provide great depth in the subject.

Publications and Organizations

Much research is constantly being carried out to understand soil and it interaction with various aspects of the environment. This work is reported in a number of scientific journals, some associated with scientific societies and some not. A number of these publications and the organizations or publishers sponsoring or publishing them are given in the table (this is not intended to be an exhaustive listing of such organizations). In addition to these publications, these societies hold regular meetings where soils research is reported. The proceedings of some of these meetings are published and these publications can be extremely helpful and informative.

Additional sources of information about soil, soil characteristics and the environment can be found through the United States Department of Agriculture (USDA), the U.S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA). Included in the information available are maps and soil surveys. Soil surveys are locally available and contain invaluable information about local soils and their characteristics. Soil surveys of an area to be studied are an invaluable source of detailed information about the soils in that particular area.

Local Resources

In addition to these resources, each state and most counties have personnel knowledgeable about the local soils. These include the state soil survey group, state soil scientist, and the soil conservation service. Many local communities have instituted Geographical Information Systems (GIS). The GIS office will be able to provide a lot of information about the soil and hydrology of an area. In addition, they can provide maps, including digital maps, which are compatible with ArcView and other GIS software.

Each state in the United States has a land grant university with an agriculture department or school of agriculture. These universities will also have schools or departments of
engineering, geology and geography. Every nation in the world has at least one university with schools or departments of agriculture, geology, engineering and geography. These universities, schools and departments can prove expertise in all aspects of soil and in environmental clean up and remediation. Many universities have offices specializing in extension. These offices are specifically charged with getting information to the general public and to businesses and organizations.

**Professional Organizations**

Geology, Civil Engineering and Soil Science have professional organizations. These organizations are a source of information about the soil and can provide information about where to obtain specialized expertise about specific soils problems or questions. They publish books, monographs and journals, and also have meetings and outreach programs designed to provide information about their areas of expertise. All are easy to contact since they maintain active web and internet sites.

Several of these organizations and their internet addresses are given in the table. There are some other societies such as the International Society of Soil Mechanics and Geotechnical Engineering (www.issmge.org) which either hold meetings or disseminate information about soils and soil related meetings.

When doing environmental remediation or soils research it is important to have these resources at hand for easy reference. The knowledge and expertise they provide can greatly facilitate the work to be done.

<table>
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<th>Sources of information about soils research in various areas</th>
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<td><strong>Sponsoring Organization/Company</strong></td>
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<td>American Society of Civil Engineers</td>
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<td><a href="http://www.asce.org/">http://www.asce.org/</a></td>
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<td>Soil Science Society of America Journal</td>
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<td>Journal of Environmental Quality</td>
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**Table 1.**

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**We have a new phone number for Advertising.**

For information or to reserve ad space, call Frank Peduto at 518-331-9785
Models: Know Your Type

By Venki Uddameri

It seems as though one cannot practice the environmental profession today without having to deal with modeling in one form or another. A few years ago a gentleman posted a simple question on an environmental list-server asking where he could find a groundwater model in a price range of $200. The query initiated a series of questions from the community willing to help and inquired about his application domain, scale of interest, whether he wanted a steady-state or transient simulation, numerical or analytical formulation and what type of boundary conditions were to be employed and such. Some even admonished him for not being specific enough and suggested that he take undertake a substantial reading of current (and not to mention esoteric) literature before embarking on posting such a loaded query to the list-server.

After a day or two of his original posting, the gentleman embarrassingly confessed that all he was looking for was a plexiglass tank with some sand and tubes that could be used to demonstrate the movement of groundwater to his high-school class and apologized for all the resulting confusion that was created from what he thought was a perfectly benign and easy question. Fortunately, the saga had a happy ending, as there was one other person in that maelstrom who understood what the gentleman was looking for and responded with the contact information of the vendor selling the "groundwater model". To me this list-serve incidence aptly highlights all the hoopla and confusion surrounding models where more questions appear to be generated than answered.

Information Technologies

Advances in information technologies now make it possible to crank large chunks of numbers even on our desktop PCs and help visualize complex interconnected patterns of nature. A review of available computer modeling codes carried out 10 years ago indicated that there were hundreds of models available for groundwater systems alone (Heijde, 1993), assuming similar trends in other environmental compartments the number of all available environmental models must be in the thousands! It is only likely that a decade of fruitful research has since added significantly to that already large body of knowledge.

Clearly all these models can be helpful in making hard environmental decisions with regards to assessing risks, identifying remedial strategies and managing contamination. After all, these challenges are the very reasons why models have been developed (or being developed) in the first place. Yet, skepticism looms large over many modeling applications and practices.

Modeling results are viewed with suspicion and many times rightfully so by several decision-makers and stakeholders, leading to additional project delays and cost escalations. There is no doubt that development and application of models to environmental problems requires significant skill and considerable expertise. Indeed, the vagaries of nature and her intrinsic complexities cannot all be captured with a set of few mathematical equations.

The paucity of data (and yes, good data is always in short-supply) coupled with our limited understanding of the underlying physical, chemical and biological processes make insightful interpretation of results rather arduous. While significant research questions still persist with model development, in my opinion, the challenge with modeling no longer lies in how to make the computer crunch more numbers, but more so with understanding what those numbers mean and how modeling results can be effectively communicated to a diverse group of audiences to help reach scientifically-credible, consensus-oriented, cost-effective and risk-informed decisions.

Knowledge Management

Knowledge management (KM) is an umbrella concept that is based on the premise that effective decision-making requires all stakeholders understand the scientific and technical basis underlying adopted policies and decisions (see Senge, 1990). This precept implies that knowledge related to modeling should not be confined to a few select individuals, but everyone involved in the project should at least possess some rudimentary understanding of what selected models can do and more importantly what they are not capable of (Uddameri, 2002). If one ascribes to this notion, it behooves upon modelers to demystify their rather arcane art and practices. By the same token, all others must make an effort to understand the various facets of modeling and
classification schemes.

Table 1. Model categories based on different model classification schemes.

<table>
<thead>
<tr>
<th>Classification Basis</th>
<th>Model Categories</th>
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<td>Modeling Framework</td>
<td>Conceptual, Physical and Mathematical models</td>
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<tr>
<td>Scientific basis for Modeling</td>
<td>Physically-based and Empirical models</td>
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<tr>
<td>Solution Scheme Employed</td>
<td>Analytical, Semi-analytical and Numerical models</td>
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<td></td>
<td>Linear, nonlinear and combinatorial models</td>
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<tr>
<td>Intended Usage</td>
<td>Screening level and Refined models</td>
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<td></td>
<td>Simulation and Management models</td>
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<tr>
<td>Domain Characterization</td>
<td>Lumped-parameter (box) or distributed parameter model</td>
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its role in informed decision-making.

My intention with this column is to provide some "bite-size" or should I say "byte-size" insights into the internal functions of models used to characterize contaminant movement in soils, sediments and water. While this bird's eye view will not make you a modeler supreme, my hope is it will help you understand how models are conceptualized, constructed and applied in the real world. With this awareness you will appreciate the vital role models can play in environmental practice and be informed of modeling pitfalls and limitations.

Types of Models

But before we begin to look under the microscope to see what lies underneath the models, let's first define different types of models that we may encounter out there. As evident from the list serve incidence, the word model can mean different things to different people.

Webster's Dictionary defines model as a miniature representation of a thing, with the several parts in due proportion; Something intended to serve, or that may serve, as a pattern of something to be made; Any copy, or resemblance, more or less exact.

Thus, models basically, embody how we perceive the system we want to study. Hence, the first-step in the modeling process is to develop a mental or visual picture(s) of the domain of interest (whether we are interested in an aquifer or portion of it, a wetland, etc.), what we intend to model, often called the state variable, (i.e., we want daily or time-averaged estimates for concentration of pollutant X), and what we feel are the most important drivers of that state variable. This visualization is often referred to as the conceptual model and probably is the most important aspect of model building.

Having developed the conceptual model, the next step is to translate it into something tangible for large-scale consumption. Physical models and mathematical models help translate conceptual designs into practical constructs. Physical models typically are laboratory reactors and columns constructed to understand or quantify one or more environmental phenomena, on a large-scale, pilot plants and controlled field facilities fall into this category (the groundwater model the gentleman on the list-serve was looking to buy would be a physical model).

Mathematical models on the other hand use equations, algorithms and other heuristic rules to capture the behavior of systems of interest. Unlike physical models, they are more abstract and harder to visualize, but often mimic the workings of the physical models. One will probably need a computer and specialized software to implement these kinds of models.

Mathematical models come in a variety of types. Physically-based mathematical models are developed using fundamental laws that attempt to describe the underlying physical, chemical and biological processes taking place in the system of interest. On the other hand, empirical models utilize statistics or other heuristic techniques such as neural networks to establish relationship between inputs and outputs (state variable).

Physically-based models are often preferred because they are more generic in nature and can be applied to a variety of situations when appropriate site-specific data are available. Empirical models on the other hand, are strictly applicable to the site(s) from which the original data were derived to develop the model and do not necessarily hold true at other sites.

However, certain empirical models, such as the Darcy's Law (describing the flow of groundwater), albeit were originally stated empirically are noted to hold true in many systems to be of general use. Most mathematical models used in environmental practice typically combine elements that empirically describe certain observed phenomena with those obtained using principles of physics, chemistry and biology.

When one takes an empirical approach to build mathematical models, the resulting model is often an algebraic expression (like a regression equation that establishes the correlation between inputs and the output). On the other hand, physically-based models often result in ordinary or partial differential equations, which require considerable mathematical expertise or specialized programs to solve. Physically-based models that can be directly solved using traditional mathematical constructs are called analytical models.
Many times, the underlying model equations cannot be solved with traditional mathematical constructs. In such situations an approximate solution is sought using numerical techniques such as finite-difference or finite-element calculus, hence the term numerical solution or numerical models. A hybrid variety called semi-analytical solutions has been found useful in some instances (see Javendel et al., 1984).

Analytical solutions to physically-based models are often only possible when the domain under consideration is assumed to be idealized (i.e., have homogeneous properties, time-invariant conditions and such). While these simplifications are in most cases grossly inadequate, analytical models are extremely useful as they are relatively easier to understand and implement, and provide valuable insights on how different processes work.

Also, being more accurate (from a mathematical standpoint) under idealized conditions, analytical models are also used to check the accuracy of more approximate numerical models. While numerical models can handle complex geometries and are capable of better tackling the vagaries of the nature (anisotropy, heterogeneity, time-variant conditions), they are harder to develop and understand and tend to be data-intensive. Fortunately, several excellent general-purpose numerical modeling codes have already been developed for use in environmental practice and are being distributed by federal and state agencies (see references).

While, the availability of a reliable computer program does play a major role in field application of modeling, it is important to remember that the term mathematical
broad class of sites and contaminants. In addition, the data available during preliminary planning stages is often extremely limited. Hence, the assumed conceptual model is fairly simplistic and is often solved using simple mathematical schemes.

On the other hand, more refined models that require a significant amount of site-specific data are employed to support detailed technical and engineering analysis such as installing treatment technologies, and identifying monitoring well locations. Simulation models are used to understand the behavior of systems of interest and can be either empirical or physically-based models employing analytical or numerical solutions.

Management models are models used to guide management and regulatory polices and combine scientific understanding with management concepts like cost-benefit analysis and optimization to seek scientifically-credible and cost-effective solutions. Mathematical models can also be classified based on how the domain of interest is characterized. Lumped-parameter or box models assume the domain of interest if uniform and can be represented by single set inputs.

Given the intrinsic variability of environmental systems, lumped-parameter model can only capture the very-large scale behavior of the system of interest. However, the underlying mathematics is relatively simple and can often be solved using analytical solutions. Distributed-parameter models on the other hand account for the intrinsic variability of the domain. While these models are more realistic, they require more data to represent the variability and almost always require numerical solutions.

Conclusion
In the next installment, I will present some generic conceptualizations used to characterize fate and transport in soil, surface water and groundwater systems and discuss how the fundamental principle of mass balance is used along with energy and momentum balances to develop physically-based models. Bear in mind, the word model can mean different things to different people and take on different connotations. As can be seen, a same model can be classified in more than one manner. So, when in doubt, seek clarification on what the speaker (writer) means by the term model. Doing so early on in the game will lead to a lot less confusion and chaos, and also help provide some insights on the underlying complexity of the model.

On a lighter note: A regulator and a consultant were taking air samples in a hot air balloon, when gusty winds drift them completely off target. The smart consultant quickly estimates the speed of the wind, and yells, “HELP!” with the hope that someone will listen to her distress call and provide assistance.

After a long period of time they hear a faint echo, “Are you lost.” The regulator turns to the consultant and claims that the person answering the distress call is probably a modeler.

“How do you know that?” exclaims the consultant.

“Well,” replies the regulator, “from three things: 1) He was slow to respond, 2) he identified our problem correctly, and 3) his answer, although accurate, was totally useless!”

Indeed, models are only useful when they are able to provide timely, reliable and useful answers. However, it is important to realize that environmental modeling is an iterative process, the speed and utility of which is enhanced when all stakeholders understand and participate in model development and application endeavors.

References


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Result of the Workshop on Environmental Stability of Chemicals in Sediments

By Richard J. Wenning

In April 2003, the second in a series of technical meetings addressing the assessment and management challenges posed by contaminated sediments was held in San Diego, Calif. The three day meeting was attended by well over 250 scientists and engineers representing several state and federal regulatory agencies, academic and research institutions, port and harbor authorities, consulting firms and industry. The workshop was hosted jointly by the U.S. Army Corps of Engineers, U.S. Navy, U.S. Environmental Protection Agency, South-Southwest Hazardous Substances Research Center, National Oceanic and Atmospheric Administration/U.S. Geological Survey and the Sediment Management Work Group.

The objectives of the workshop were to highlight the important biogeochemical and physical factors that control or affect the stability, mobility, and/or bioavailability of inorganic and organic contaminants in aquatic sediments. Invited speakers with expertise in chemical bioavailability, sediment transport, risk assessment, sediment chemistry and regulatory policy led a series of technical discussions intended to explore the fate, effects and risks posed by sediment bound contaminants in both fresh and marine waters.

The intent of the workshop was to establish consensus on general, yet pragmatic, guidelines for the assessment and management of contaminated sediments that may pose an unacceptable human health and/or environmental risk.

Workshop participants were challenged to answer several questions important to the on-going debate concerning appropriate assessment methods, the interpretation of environmental data, and identification of remediation options, regulatory policy and decision-making. Questions included how best to integrate knowledge about sediment chemical stability in decision-making regarding the appropriateness of in-place remediation, sediment removal and natural recovery.

Other questions focused on the identification of appropriate metrics and assessment methods to adequately evaluate environmental conditions before and after implementation of a management decision. Building on a previous workshop addressing sediment stability and held in New Orleans in January 2002, workshop participants focused on further exploration of the science and engineering issues underlying the question of how best to predict contaminant fate and the associated human health and ecological risks with a reasonable degree of certainty.

This summary highlights some of the important biological, chemical and engineering issues discussed by invited experts and scientists, engineers and regulatory officials attending the workshop. By continuing to focus on the science and engineering technical issues that challenge assessment and management of contaminated sediments, remedial project managers, risk assessors, industry, environmental groups, sediment site stakeholders, those involved in sediment remedy evaluation and remedy selection, regulatory management personnel, and contractors assisting regulators and the regulated community will continue to advance risk-based, scientifically sound approaches for evaluation of sediment management decisions.

Addressing Contaminated Sediments in the U.S

Sediments are a complex matrix of mineral and organic (living and non-living) components and, with the possible exception of a few remote and pristine areas, are anthropogenically impacted to some extent. Contaminant locations are biogeochemically varied and toxicologically complex. Identification, assessment and management of risks of contaminated sediments are complex and cannot be solved with a single assessment tool. Sediment management must rely on a weight of evidence approach.

At present, the best available source of information on sediment contamination in U.S. waterways is the U.S. EPA Superfund program. Few, if any, federal, state or regional regulatory and research programs are committed to monitoring sediment quality to the same extent typically practiced in air and water quality (as well as fish) monitoring programs.

In the Superfund program in 2001, approximately 350 contaminated sites were listed as primarily concerned with sediment. Records of decision for cleanup have been issued on approximately 140 of these sites, representing seven water body types and accounting for seven major contaminant classes. The records of decision at these 140 sites include seven risk reduction measures.

The three predominant sediment remedies implemented at Superfund sites have included dredging at 28 sites,
excavation at 23 sites, capping at 11 sites, and a monitored natural recovery (MNRT) program at seven sites. Upland disposal at 81 sites has, or will, involve the removal of greater than 50,000 yds³ of contaminated sediment.

At 74 sites, the remediation costs are estimated to be greater than $10 million. Two years later, in 2003, the Superfund program office estimates that the cleanup of contaminated sediments at 145 sites may cost less than $50 million; however, costs at seven sites may exceed $50 million.

The good news reported at the workshop is the Superfund program is broadening its approach to identifying and selecting sediment remedies. Clean up has been achieved at several sites. Ecological conditions have improved and aquatic biota are recovering in several cases. Technology improvements and increased attention to source control both show promise and may lead to additional remedy options and lower costs in the future.

The bad news, however, is a continued absence of clear scientific rationale between the selected remedy and the expected risk reduction, despite widespread recognition that the goal of risk reduction is not easily measurable. In some situations, unrelated goals such as mass removal or cost minimization compete with risk reduction as the primary criteria for remedy selection.

Notwithstanding other technical challenges, the key obstacles include the difficulty of achieving the low cleanup levels necessary to protect aquatic life, the difficulty in defining sediment quality values, and the challenges posed by contaminant sources outside a cleanup site. Recontamination is a significant problem and the full evaluation of remedy effectiveness continues to be difficult and represents a major hurdle that must be overcome if the Superfund program is to ultimately succeed in addressing contaminated sediments.

**Defining Chemical Stability in Sediment**

Contaminants can pose a risk only if the contaminants are bioavailable. Contaminants that occur permanently below the bioavailable zone in sediment (generally a few inches or more below the sediment surface and below the depth that some benthic organisms may burrow) pose little or no risk. Contaminants that are strongly bound to solid particles and do not partition into pore water are largely unavailable and pose little or no risk. Organic partitioning to pore water is typically biphasic.

In other words, sediment typically has a fast releasing fraction that is largely bioavailable, and a slow or equilibrium limited releasing fraction that exhibits reduced availability or is unavailable. Dissolution in pore water is not a requisite for availability because both the fast and limited releasing fractions are available through direct ingestion of particles. Nonetheless the fraction that resists abiotic dissolution is also less available in the digestive tract.

Exposure to aquatic life requires that contaminant-bound sediments be in or partition to a mobile phase. Sediment bound contaminants in the biologically active sediment layer are generally considered available, though binding to various organic complexes must be taken into account and can affect availability at the sediment surface. It is the mobility, or flux, of the sediment that ultimately defines the magnitude of that exposure and risk. Particle processes such as sediment resuspension, erosion, and bioturbation by deposit feeding or burrowing organisms control mobility for most sediment contaminants.

As a general rule of thumb, chemical stability is high and exposure and risk potential is low for contaminants that have high partition coefficients (which makes them more sorbing). In contrast, chemical stability is low and exposure and risk potential is high for contaminants that have low partition coefficients (which makes them less sorbing). Mobility via molecular diffusion does not differ very much among chemicals and mobility via biological mixing of pore water or sediment overwhelms and is independent of an individual chemicals intrinsic diffusivity.

**Contaminated Sediment Flux versus Biological Response**

Sediments are very heterogeneous, with an organism's exposure to contaminants being dramatically affected by fluid advection, particle transport, and their movement. A "one size fits all" model does not work to predict these processes.

Site-specific characterization of organism (benthic invertebrates and fish) movements versus contaminant distributions is essential for supporting valid conclusions about ecological or human health risks. An excellent "toolbox" exists for conducting assessments of exposure and effects; including field and lab measures of contaminants, biota movements, toxicity and bioaccumulation.

A word of caution, however, is important. It is essential to carefully link exposure and effects measures, in a consistent fashion and use appropriate reference conditions for quantitative determinations of significant differences. This dictates the use of in situ approaches to better characterize critical time periods and exposure pathways (e.g., storm water runoff, diurnal fluxes and reproductive periods). Each assessment tool has unique strengths and limitations; therefore, it is important to use multiple lines-of-evidence to properly understand ecological or human health risks.

Understanding the ecological and human health risks implies that all concerned parties -- members of the public, the field investigator and the environmental regulator -- share the same definition of what is meant by "impairment". In general, the term impairment is used to refer to any changes in the environment that may adversely affect an organism, the function of an ecosystem, or alter the value placed on resources by humans. A focus on biological impairment may be appropriate in most cases.
Use of Sediment Quality Guidelines (SQGs)

The results of a Society of Environmental Toxicology and Chemistry (SETAC) Pellston workshop on the use of SQGs and other tools to evaluate contaminated sediments are directly applicable to the discussion of sediment stability. SQGs are not universally applicable for evaluation of sediments in all aquatic environments. However, applied appropriately, SQGs can provide a basis for determining whether contaminants in sediment in different aquatic environments are unlikely, uncertain, or highly likely to have the potential to pose adverse ecological effects on benthic organisms. SQGs should not be used as regulatory bright lines for determining the need for remediation or corrective actions.

Used appropriately as screening tools, SQGs can help determine whether further assessment is needed using additional biological or chemical assessment tools to evaluate whether and to what extent contaminants in sediment pose ecological risks. However, sediment management decisions should almost always be based on site-specific information due to the unique or varied environmental and ecological conditions that characterize different types of aquatic environments.

Sediment assessment frameworks may vary for different management purposes. Different frameworks should be guided by specific questions that address toxicity, community alteration, bioaccumulation and risks to human health. Sediment assessments should be tiered and involve a suite of tools designed to answer questions established a priori and to generate specific LOE.

An explicit, scientifically defensible weight of evidence (WOE) approach is the appropriate framework in which to place the results from multiple lines of evidence (LOE) to provide meaningful interpretation of ecological significance and to make sound sediment management decisions. Understanding of the ecology, chemistry and hydrodynamic behavior of sediments in estuarine, depositional and non-depositional aquatic environments is essential when using SQGs in conjunction with other assessment tools.

Contaminants Fate, Mobility and Transformation

It is anticipated in the near future that new and emerging tools in the field of molecular biology will help scientists and environmental managers to develop screening protocols for evaluating contaminated sediments. For example, it is anticipated by many scientists that transgenic plants will be increasingly utilized to better understand sediment-contaminant interface processes and to evaluate the potential of improving phytoremediation methods.

At present, methods for calculating excess (i.e., above background level) metal concentrations in sediment typically include a comparison (between 95%
confidence intervals) of the concentrations of the metal of interest (e.g., lead) versus that of a natural or non-anthropogenically introduced metal (e.g., aluminum). Other assessment methods include the assessment of metal bioaccumulation from sediments using simple food chain models.

The use of dietary threshold models to assess the potential for adverse effects of sediment-bound contaminants is possible, but the sequence of chemical and physiological events that occur after the ingestion of food by an organism, particularly chemical bioavailability from the diet, also warrants attention. The use of tissue concentrations to predict biological effects is also possible, but few field studies and models available to evaluate potential tissue residue thresholds. Further, dietary and tissue thresholds are very different; the former requires transfer from prey to the consumers tissue mass, while the latter applies after that transfer has occurred.

Ecological risk assessments have traditionally relied upon chemical-specific factors such as biota sediment accumulation factors (BSAFs) for metals to calculate the transfer of contaminants from one compartment to another. BSAFs for metals are inversely related to exposure concentration (sediment concentration); hence, a single factor is not representative of all sediments. This is, however, contrary to the derivation and use of BSAFs derived for non-ionic organic chemicals.

**Contaminants Fate, Mobility, Transformation and Degradation**

Non-particle contaminant fluxes are one of the fundamental processes that link the sediment to the water column. These fluxes need to be considered in addressing chemical stability in sediments. Non-particle fluxes may represent an important source to the local water column, as well as downstream areas.

Variations in fluxes arise from processes inherent to both the water and sediment portions of this interface. Processes include advection and dispersion of the overlying water, diagenesis reactions that control organic matter and redox conditions, sorption and precipitation reactions during contaminant migration through the interface, and depth scale and activity level in the bioactive layer. Flux rates may vary on different time scales in response to these factors as well as changes that occur on a tidal or seasonal scale.

A number of field-based tools and approaches are available to quantify sediment chemical mobility through various pathways. These can include measures of bioturbation using profiling cameras, tracers such as 7Be, 137Cs, 210Pb, and infaunal census information. Other tools are useful to evaluate diffusive flux such as gradient-based measures using coring, DGT, DET, peepers, and microelectrodes, and in situ benthic flux chambers or ex situ core incubations to evaluate the combined effects of diffusion and bioirrigation. Adective fluxes can be evaluated using devices such as seepage meters and piezometers.

Each of these different tools has limitations that must be understood in conjunction with their application to a particular aquatic environment. For example, variability in physicochemical and microbiological processes that control the mobility and bioavailability of halogenated organic chemicals such as PCBs and PAHs limit the applicability of simple models based on organic carbon control.

Readily desorbed halogenated chemical levels are not consistently related to total organic carbon, suggesting that KOC models may produce significant error. While some variability for PAHs can be explained by sequestration in "black carbon", some level of site specificity remains that may only be accounted for by site-specific analyses.

Chemical mobility and transformation in sediment is closely coupled to, and may be influenced significantly by, water column processes. For mobilized chemicals that enter the water column, important processes that may need to be considered include advective and dispersive transport, partitioning between water and suspended particles, settling, deposition and resuspension, air-water interface boundary fluxes, photolysis and hydrolysis, biotransformation, oxidation, reduction and bioconcentration.

The integration of field-based tools and site-specific analyses with sediment bed and water column modeling approaches can provide a comprehensive means of assessing the importance of non-particle chemical fluxes at a given site. It is important, however, that the selection and application of the proper modeling approach is based on a site conceptual model.

The degree and detail of modeling will depend on the scale and complexity of the site, time scales of interest, data availability and cost. Ultimately, the quantification of both particle and non-particle chemical fluxes is important in the development of a rigorous and scientifically defensible sediment management strategy.

**Modeling Chemical Fate and Effects in Sediments**

Mass balance models should be a routine component of contaminated sediment projects. Mass balance models are valuable tools for understanding a contaminated sediment site, assessing chemical stability, determining potentially effective remedies and assessing the benefits likely to be achieved by remediation. Even simple screening models can provide valuable insights.

At present, the state-of-the-science is such that reasonably robust mass balance models can be developed for most contaminated sediment sites. Although the time and effort to develop meaningful models can be considerable at particularly complex sites, it is worth the effort if the cost is a small fraction of the potential cost and ecological damage that occur during or as a result of remediation.
The successful use of mass balance models requires the participation of "modelers" and an open and interactive process in which the scientists and managers involved in site assessment participate in model development, testing and application. The modeling tools are readily available and the growing experience base provides an ever-improving road map for their use.

It is important, however, that environmental regulators and managers develop a set of site-specific principles that ensure that a sediment assessment provides the information needed to support model development and use. An on-going "post-audit" function is often useful and needed to assess whether the benefits forecasted by a particular models are attained.

**Practical Measurement Strategies and Judging Success**

If there is to be only one advancement this century in the management of contaminated sediments, then it should be improvement in the problem definition phase of an investigation and long-term management effort. The use of a conceptual model and a set of assessment endpoints that are applicable to evaluate potential risk at a particular waterway or type of waterway are essential.

Clearly, if there is a demonstrated risk to individual humans, then remedial goals must be set to reduce or eliminate that risk. Ecological risks are much more difficult to quantify and depend on both spatial and temporal scales. There are distinct sets of measurement endpoints for evaluating the potential threats to terrestrial, aquatic and benthic populations.

Consequently, remediation of ecological risks should be based on a weight-of-evidence approach assigned to appropriate measurement endpoints. SQGs represent only one line of evidence in an ecological risk assessment, and, in most cases, insufficient in themselves to quantify risk and support sediment management decisions.

Because of conflicting societal demands, a remediation effort that achieves regulatory and environmental management goals and is identified as an engineering success may not be universally perceived as environmentally successful. Balancing the short-term and long-term benefits and costs will always remain a regulatory and management challenge.

Nonetheless, all stakeholders should strive to achieve consensus on two important points before a contaminated sediment remediation project begins. These two important points are to identify remedy goals that are technically achievable, and to set performance standards that are capable of assessing and defining the success of the selected remedy.

**Next Steps**

For those familiar with the complex nature of the engineering, ecological and societal issues encompassing this subject, a lot of progress has been made on several technical and decision-making issues over the past few years. More forums such as the San Diego workshop are needed to exchange information and encourage discussions among scientists, engineers, regulatory policy experts and other stakeholders and to build upon the successes achieved to date.

The next sediment workshop is tentatively planned for early 2004 and is likely to focus on the effective assessment and management of risks and uncertainties in decision-making at contaminated sediment sites.

The discussions on sediment assessment and management can be tracked on the Internet at www.smwg.org and www.sediments.org. The executive summary of the recent Society of Environmental Toxicology and Chemistry (SETAC) workshop on the use of SQGs and other sediment assessment tools can be found on-line at www.setac.org. The U.S. Army Corps of Engineers maintains a wealth of technical and research information on contaminated sediments and different sediment technologies, which can be found on-line at www.wes.army.mil/el/dots/doer/. For further information on this workshop and future meetings in this series, contact Steven Nadeau by e-mail at snadeau@honigman.com or Robert Engler at robert.m.engler@erdc.usace.army.mil.

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**Author's Note**

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Clean Environment Equip.  
Duncan Enterprises (D)  
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EPC Companies, Inc.  
Facet International (M)  
Geotechnical Services (D)  
Highland Tank  
MCighe Industries  
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Aqua Technologies (D)  
Aqua Technologies, Inc.  
Aquarep, Inc. (M)  
Barneby Sutcliffe  
Carbonair Envir. Systems  
Carbrotol Corp.  
Enviro Supply & Service  
Enviro-Tech Comp. (D)  
EPC Companies, Inc. (M)  
Facet International (M)  
Highland Tank  
MCighe Industries  
Purolite (M)  
Schraeder Envir. Services  
Sevenson Environmental  
TIGG Corp. (D)  
Trans World Equip. Sales  
TurnKey Solutions, Inc.  
Xerxes Corporation (M)

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Aquarep, Inc. (M)  
Carbonair Envir. Systems  
EarthCare Corporation (M)  
Enviro Supply & Service  
Environmental H2O  
EPC Companies, Inc. (M)  
Facility & Res. Mkt (D)  
Falmouth Products (M,D)  
King, Buck Tech. (M)  
KV (K-V Associates, Inc.)  
Piper Environmental Group  
Remediation Service, Intl.  
ReRem Equipment  
Schraeder Envir. Services  
Sevenson Environmental  
Tarmac, Inc.  
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Varco
pH Meters and Electrodes
Astellon (D)
John L. Biesz (M,D)
CHEmetrics, Inc.
Durham Geo Enterprises
Environ Supply & Service
Envir. Services & Prod. (D)
EPG Companies, Inc. (D)
Forestry Suppliers, Inc. (D)
Geotechnical Services (D)
I.E. Monitoring Instru.
North East Scientific (D)
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Durham Geo Enterprises
EPG Companies, Inc. (M)
Fluid Metering, Inc.
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Repirimeter
Columbus Instruments (M)

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Duncan Enterprises (D)
Environ Supply & Service
Forestry Suppliers, Inc. (D)
Geotechnical Services (D)
I.E. Monitoring Instru.
Spill Prevention Contain.
Thermo Gastech

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Astellon (D)
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ESS, Inc.
Fluid Metering, Inc.
Forestry Suppliers, Inc. (D)
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North East Scientific (D)
Peregrine Tech. Serv. (D)
Sensidyne, Inc. (M)
Solinst Canada Ltd.

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Parificks (M)
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Trans World Equip. Sales
Varco

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Enzyme Tech. (M,D)
MicroBac Intl (M)
Osprey Biotechnics (M)
Sevenson Environmental
Varco
X-19 Biological Products

Soil Sampling Equipment
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Duncan Enterprises (D)
Environ Supply & Service
Forestry Suppliers, Inc. (D)
Geotechnical Services (D)
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Thermo Gastech

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EcoVault, Inc. (M)
EPG Companies, Inc. (D)
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Safe-T-Tank Corp. (M)
Tarmac, Inc.
Xerxes Corporation (M)

Tanks, Monitors
Envir. Lab. Network
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Thermo Gastech

Tanks, Underground
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Aromatic Plant Production on Polluted Soils
Valtcho Zheljazkov, Department of Plant and Animal Sciences, Nova Scotia Agricultural College, Truro, NS, Canada

A two year field experiment was conducted in the vicinities of Pb-Zn smelter near Plovdiv, Bulgaria, at the presence of both soil and aerosol metal pollution to evaluate productivity and phytoremediation potential of coriander, sage, dill and chamomile. Crops were grown in the vicinities of the smelter at distances of 0.8, 3.0, 6.0 and 9.0 km (the latter was unpolluted and regarded as a control).

The level of pollution at 0.8 km from the smelter reduced yields of fresh herbage and essential oil from all tested crops compared to the control and the yields at 3 km from the smelter. Despite the yield reduction of 12-20% (relative to the control), coriander, sage, dill and chamomile can be successfully grown and remain profitable crops on heavy metal polluted sites. Heavy metal concentration in the plant tissue reflected the level of soil and aerosol pollution in the area. The highest removal of metals with the yields was as follows: Cd up to 180 g/ha; Pb up to 660 g/ha; Cu up to 180 g/ha, Mn up to 350 g/ha, Zn up to 205 g/ha.

The accumulation of heavy metals in the above-ground herbage of the four crops is tabulated. Overall, there was less variation in Zn content and uptake between plant species than with other elements.

Essential oils from the four crops were free of metals. The concentration of Cd, Pb, Cu, Mn and Zn in the essential oils was below 0.06, 0.62, 0.25 and 0.3 mg/L respectively, i.e. below the detection limit of AAS.

Pre- and Post-Mitigation Measurements of Indoor Radon in Homes with Excessive Radon Concentrations
Douglas G. Mose, Fiorella Simoni and George W. Mushrush, George Mason University, Fairfax, Va.

Using year-long alpha-track radon detectors, indoor radon measurements from about 2,000 homes in Virginia and Maryland were mostly found to be between 1 and 30 pCi/L. In approximately 200 of the homes, sub-slab ventilation was installed to reduce the indoor radon concentrations. By random selection, the mitigation by sub-slab ventilation used either 2-inch, 3-inch, or 4-inch diameter exhaust pipe from the basement floor penetration site through to the externally located exhaust fan.

Approximately 90% of the homes showed successful reductions in radon concentrations to below 4 pCi/L, the EPA recommended maximum for the sale of homes. Most of the unsuccessful homes were those in which the sub-slab ventilation system used 2-inch diameter exhaust pipe. The homes in which 3-inch and 4-inch exhaust pipe was used showed approximately the same success rate.

Indoor Radon Measurements from Homes in Southern Poland
George W. Mushrush, Fiorella Simoni and Douglas G. Mose, George Mason University, Fairfax, Va.

In the northern and central parts of Poland, thick layers of glacial deposits contain low uranium concentrations and the homes have low indoor radon concentrations (most less than 1 pCi/L). In southern Poland, in the Sudety Mountains, mountain core crystalline rocks contain numerous sites of uranium mineralization, some of which were extensively mined 50 years ago. Most of the mineralization occurs as small veins of uranium minerals, mineralized fault zones, and zones of hydrothermal enrichment around the perimeter of formerly molten chambers of granite.

Soil developed on this terrane has relatively high soil-gas radon concentrations. The measurements of soil radon above the Sudety Mountain granites, gneisses and schists have a geometric mean of about 2000 pCi/L. The highest measurement in the crystalline terrane found to date is about 40,000 pCi/L.

Over 50% of the homes have indoor radon concentrations in excess of 4 pCi/L, the EPA recommended maximum for home sales. In Poland, where a large portion of the population lives in the same area for most of their lives, we anticipate that radon potential based on soil radon and permeability will show a positive correlation with the incidence of lung cancer.
Does RBCA Work?
Emil Onuschak, Jr., PG, State of Delaware, Department of Natural Resources and Environmental Control, New Castle, Del.

Since adopting a risk-based site assessment procedure in 1999, both the number and percentage of "old" leaking underground storage tank sites closed in Delaware have increased markedly. Many of these "old" sites previously were undergoing prolonged groundwater monitoring with no clear criteria for their closure.

Summary of Toxicological Benchmarks and Soil Remediation Goals to be Protective of Environment
Chunhua Liu, Ph.D., Jacqueline Travers and Todd Heino, Parsons, Canton, Mass.
Dave Babcock, Parsons, Liverpool, N.Y.

Establishing soil cleanup goals to protect human health and the environment is a key remediation issue. However, because of the complex nature of soils and limited knowledge of the contaminant's toxicological effects on the environment, there is no general consensus on the ecological soil remediation goals. A series of toxicological benchmarks have been published by the Risk Assessment Program Oak Ridge Health Science Research Division (Oak Ridge) for wildlife, terrestrial plants and soil and litter invertebrates, etc. Oak Ridge, EPA, Canada, Ontario, and the Netherlands have proposed soil screening/remediation goals for certain chemicals. Although these published benchmark values and remediation goals can provide a readily available source of soil quality standards, the specific applicability of the benchmark values or remediation goals to a particular site is uncertain, due to differences in geography, ecological receptors and pollutant bioavailability.

This presentation compares the published benchmark values with the soil remediation goals and reviews the approaches used to derive the remediation goals. In addition, the presentation proposes consideration of affected populations in setting up soil remediation goals. Finally, an example of site-specific soil remediation goals that are protective of the environment is presented and compared to the published benchmark values and remediation goals.

Undertaking Risk-Based Remediations in Brazil

Like a number of other countries in Latin America, Brazil is currently in the process of developing a formalized regulatory system (i.e. regulations, guidance documents, generic risk-based cleanup standards, etc.) to manage and remediate hazardous waste sites. In the interim, responsible parties have some flexibility in making decisions from state to state using an informal system that currently exists. In general, the Brazilian agencies are accepting risk-based cleanup plans developed either using the risk-based framework developed by the Dutch environmental agency or by the U.S. Environmental Protection Agency (EPA).

This presentation will discuss: 1) current risk-based remediation approaches being used in the states of Sao Paulo and Rio de Janeiro; 2) the similarities and differences between Dutch and EPA risk-based remediation approaches (e.g. risk targets, toxicity factors, default exposure assumptions, etc.); and 3) the potential implications of selecting either the Dutch or the EPA approach on cleanup levels and remediation.

The Organoclay/Carbon Combination of Efficient PCB Removal

Organoclay have been used for the removal of small amounts of oil from water very effectively for some 15 years. What is still less known is the effectiveness of an organoclay/carbon combination, when the filter vessels are placed in series, for the removal of PCB and pesticides.

What has been learned is 1) Organoclay is very effective for removal of PCB’s by itself. 2) In combination with carbon, non detectable amounts of PCB are routinely reported. The reason: Organoclay has a large capacity, 50% by weight or more, to remove transformer oil and PCB from water. Activated carbon, on the other hand, is excellent at removing the small quantities of PCB from water, down to 10 ppb or less.

This paper/article will describe the removal mechanisms for PCB removal by the two media, and show actual case histories to prove the point.
Assessment of, and Risk-Based Cleanup Approach for, a Large Volume Jet Fuel Spill

Kiran K. Srinivasan and Christina Robinson, ENTRIX, Houston, Texas

Due to corrosion, a large volume of Jet Fuel (JP-8) spilled from a 14-inch, high-pressure subsurface pipeline. The spill was detected during routine overflight and reported to Federal, State, and Local authorities. The product was initially contained in a small area, until a 10-inch rain carried it to surrounding wooded and swamp land, creeks and roadside ditches, threatening nearby federal marshlands. Government authorities were preparing to federalize the site and assume site oversight.

To prevent federalization and assist in cleanup, a professional spill management team was mobilized. This team gained site control and enhanced ongoing product recovery. Critical pathways were continuously monitored for product flow. Permits were obtained in record time and structural controls were installed to inhibit migration. These actions prevented federalization.

The authors developed a Data Quality Objectives- and risk-based assessment and closure plan, and negotiated regulatory approval. Based on data from site visits, aerial photographs, and maps, a Conceptual Site Model identified media, release pathways and mechanisms, and receptors. The authors developed an exposure-based sampling plan using a "weighted grid" pattern based on visible evidence of product.

The objectives were to delineate lateral and vertical extent of contamination to State risk-based standards, and obtain data for use in risk-based closure. A separate plan was developed to sample landowner water wells, ponds and yards. By fingerprinting the released product, BTEX, MTBE, Naphthalene and TPH were identified as critical contaminants.

This plan was implemented and soil, sediment, surface water and groundwater samples were collected from approximately 20 acres of affected land. Thiessen Polygons were drawn using preliminary analytical results to identify patterns of contaminant flow and evaluate the need for additional assessment. Human health and ecological risk assessments are being conducted to evaluate potential residual risks and develop bases to support remedial decisions, regulatory closure and NRDA action.

Immediate Response Actions Designed to Address Impacts to Residential Receptors

Janine Commerford and Paul Locke, Massachusetts Department of Environmental Protection, Boston, Mass.
Millie Garcia-Surette and Gerard Martin, Massachusetts Department of Environmental Protection, Lakeville, Mass.
Laurel MacKay, Massachusetts Department of Environmental Protection, Willimington, Mass.

If Potentially Responsible Parties (PRPs) are unable or unwilling to conduct the response actions, the Massachusetts Department of Environmental Protection (MADEP) may undertake or arrange for response actions as it reasonably deems necessary. In cases where significant evidence exists of an Imminent Hazard (IH) condition to public health, safety, welfare or the environment from oil and/or hazardous materials at/or from a disposal site, the MADEP is required by statute to immediately ensure that action is taken to control the potential for health damage, human exposure, safety hazards and environmental harm through the appropriate measures. These measures may include, but not be limited to, limiting access to the site; evacuating the area or relocating residents; providing alternative water supplies; or taking other similar temporary action that will remain effective until other comprehensive remedial measures can be implemented by the PRP.

Based on this requirement, the MADEP employs a standard approach to conducting IRAs to address residential receptors using state funds. This approach considers the circumstances under which the MADEP initiates the work, the types of response actions likely to mitigate the specific exposure, criteria by which the MADEP would provide alternative housing (with re-entry strategy) and an exit strategy designed to outline when the MADEP completes the state-funded response actions. This presentation highlights selected case studies where the MADEP has initiated or conducted response actions to address impacts to residential receptors, including private water supply wells, indoor air and soil.
Emerging Water Contaminants: Technical, Legal and Policy Challenges
Rula A. Deeb, Ph.D. and Michael C. Kavanaugh, Ph.D., Malcolm Pirnie, Emeryville, Calif.

Approximately 120 new chemicals are created each year due to ever-improving industry and technology markets. Releases of new contaminants into the environment can occur during production, use and disposal of these chemicals, thereby leading to potential contamination of water supply sources. Very few emerging contaminants are regulated. In addition, knowledge gaps regarding emerging contaminants include health effects, occurrence (either because these compounds are not measured or because concentrations are below detection limits of readily available analytical techniques), and fate and transport in the environment, especially with regards to mobility and persistence.

The sources of these compounds are numerous. One source is treated wastewater which is re-injected into groundwater aquifers for indirect potable reuse purposes. Emerging compounds of concern can be classified in various classes. This presentation will focus on contaminants which have emerged in the last 10 years, including pharmaceuticals (antibiotics/drugs), personal care products (polycyclic musks), pesticides/herbicides, industrial solvents (1,4-dioxane), gasoline additives (MTBE), disinfection byproducts such as NDMA (N-nitrosodimethylamine), and inorganic compounds such as perchlorate and arsenic.

This presentation will present technical, legal and legislative challenges posed by the presence of these contaminants in water. Background information including chemicals history of use, sources in the environments, nationwide occurrence, physical and chemical properties, behavior in the environment and technologies for removal from soil and water will be presented.

In addition, case studies on MTBE, pharmaceuticals and personal care products, 1,4-dioxane, arsenic and NDMA will be discussed.

Proposed New York State Dredged Material Assessment and In-Water or Riparian Dredged Material Management Guidance
Arthur J. Newell and Alex Lechich, Division of Fish, Wildlife & Marine Resources, NYSDEC, Albany, N.Y.

The proposed guidance was developed jointly by the Divisions of Water and Fish, Wildlife and Marine Resources to provide Department staff with guidance on the statutory and regulatory requirements for dredging activities, and to promote uniformity in the management of dredge material throughout the state. The guidance applies only to dredging operations in in-water or riparian management of dredged material.

To clarify the sampling, testing and permitting process, the guidance provides an explanation of state law requirements for dredging projects with a general overview of relevant federal requirements. The guidance is offered as a clear approach to environmental review of navigational dredging projects, dredging of channels and berths, dredging of ponds, and other incidental dredging in both marine and fresh waters of the state.

The guidance includes environmental objectives for dredging; best management practices for dredging and disposal; sediment quality parameters to measure and sampling requirements; effects based sediment quality threshold values; dredged material management options for three classes of sediment quality; guidance on evaluation of toxicity and bioaccumulation test results; mixing zone analysis; and monitoring requirements.

While this guidance contains numerical assessment criteria, it is not law or regulation. Discretion in applying the sediment quality parameters and the associated best management practices is expected and is defensible as long as human health and the environment are effectively protected.
Asbestos in Soil: An Owner’s Perspective
John M. O’Donnell and Mark Roberts, Division of Capital Asset Management, Boston, Mass.

Most major construction sites in urban areas encounter contamination due to past industrial, retail and/or residential uses of the property. Typically, evaluation of contamination at these urban sites has focused on Polycyclic Aromatic Hydrocarbons (PAHs), petroleum and metals. However, there has been an increased focus on asbestos in soil/fill due to historic demolition and urban contamination (e.g., automotive brake dust).

As contractors and developers gain experience in this area, they are testing for and identifying asbestos in the soils and fill on these properties. As such, the presence of asbestos can have major cost and schedule issues for construction projects in urban environments. The authors will present an overview of asbestos issues in soil and recount two case studies to illustrate the Commonwealth of Massachusetts, Division of Capital Asset Management’s experience in redeveloping urban properties in Massachusetts.

The paper will discuss the regulatory framework that relates to asbestos fibers in soil/fill and will include a discussion of applicable Massachusetts Contingency Plan (MCP) and waste prevention regulations and policies. Case studies will be used to illustrate discrepancies between the programs. Analytical methods available for testing of asbestos-containing materials in soil and the potential inaccuracies of these methods will also be discussed, as well as a risk-based approach to developing site specific risk values. The paper will address these issues through case studies on actual urban construction projects. Finally, the paper will identify areas that may need to be further evaluated or considered by the regulatory and regulated communities to improve addressing asbestos in soil.

Developing Soil Re-Use Criteria in California for the Alameda Corridor Project
Carl Peter Ripaldi, URS Corporation, Los Angeles, Calif.

In California, there are ample regulations regarding the management and disposal of hazardous and contaminated soils as waste under the jurisdiction of CalEPA’s Department of Toxic Substances Control (DTSC) and the Regional Water Quality Control Board (RWQCB). However, there is a lack of specific guidelines for contractors to use when it comes to evaluating the suitability of soils for re-use as fill. Impacted soils may have trace amounts of contaminants that are not considered hazardous but may be regulated under these agencies depending on the circumstances.

In some cases, background levels of heavy metals or petroleum hydrocarbons may exceed waste discharge criteria (WDRs) established by the regulatory agencies, presenting the possibility that native soils can’t be legally re-used as fill. This presents a great dilemma to the construction industry regarding the establishment of acceptable re-use criteria for soils used as fill.

Typically, soil brokers check the soils only to see if they are below hazardous levels for the criteria pollutants established by the agencies. It also presents scenarios in which millions of tons of soils being re-used as construction fill may exceed acceptable contaminant levels resulting in the potential of cross contaminating building sites with soils believed to be clean, but unacceptable under currently established regulations.

Such actions open up the possibilities of enforcement actions, penalties and fines under federal and California law. They further cloud the acceptability of such sites for redevelopment by a skeptical general public.

The Alameda Corridor Transportation Authority (ACTA) dealt with these issues as it struggled with the need to re-use thousands of tons of impacted soils as construction fill within the project. This became both a cost and schedule consideration. Following considerable investigations, the establishment of background levels for metals and fuel hydrocarbons in native soils, the interpretation of existing regulations and waste criteria, and agency negotiations, an acceptable criteria was established, allowing for the re-use of considerable amounts of soils within the project confines.

The ACTA experience merits careful consideration by other projects in order to avoid regulatory actions, conserve resources and facilitate construction.
Army and Commonwealth of Massachusetts: Partnership for Compatible Training and Sustainable Environmental Protection in Cape Cod, Massachusetts

LTC Brian D. Rogers, Department of the Army, Office of the Assistant Secretary of the Army, Environment, Safety & Occupational Health, Washington, D.C.
COL Joseph Materia, Army National Guard Environmental Readiness Center, Camp Edwards, Mass.
CPT Anthony Sciaraffa, Massachusetts National Guard, Adjutant Generals Office, Milford, Mass.
LTC Timothy A. Mullen, Massachusetts Air National Guard Headquarters, Otis ANGB, Mass.

Historically, there has been much controversy over contamination of groundwater supply in the Upper Cape, and the effects of past military training. The need for military training and environmental protection led to divisiveness between the military and the communities located adjacent to the Massachusetts Military Reservation (MMR). Realizing the need to minimize these tensions or face losing a vital training area, the Department of the Army (the Army) and the Massachusetts Army National Guard (the Guard) developed a partnership-based plan with the Commonwealth of Massachusetts to ensure continued military training that does not harm the Cape's natural resources.

The first tier of the Guard’s two-tiered plan is an Environmental Impact Report (EIR) that articulates Environmental Performance Standards (EPS) for training that exceed current regulatory requirements, but that still accomplish the military’s training mission.

The second tier is a Memorandum of Agreement (MOA) with the Commonwealth of Massachusetts for long-term environmental management of the MMR. This MOA created a three-member Environmental Management Commission (EMC) to oversee training on the base to ensure environmental compatibility, an Environmental Officer to work daily with the military, a Community Advisory Council (CAC) and a Scientific Advisory Council (SAC).

This presentation will describe how this MOA was developed and signed by Department of the Army and Commonwealth officials, including the Governor. This partnering approach is being touted as a national model that meets the needs of the military and the environmental constituencies alike.

Nanoparticle Iron for Source Area Treatment

Richard W. Arnseth, Tetra Tech NUS, Oak Ridge, Tenn.
Keith W. Henn, Tetra Tech NUS, Pittsburgh, Penn.
Mark Peterson, Tetra Tech NUS, Jacksonville, Fla.
Dan Waddill and Dana Gaskins, Southern Division Naval Facilities Engineering Command, North Charleston, S.C.

Aquifers contaminated with chlorinated organic solvents present two distinct problems -- treating the dissolved plume and addressing the source area. Numerous remedial technologies have been developed to address the dissolved phase contamination in groundwater. A different range of technologies has been developed to treat source areas where a reservoir of contaminant is often stored in a fine-grained matrix.

In recent years, the focus of remedial technology development has been on in situ and passive methods for contaminant destruction. Typically, in situ and passive technologies have been applied to the dissolved plume, and more active remedial technologies have been applied to the source area.

Nanoparticle (NP) iron may offer a means to combine the advantages of in situ and passive treatment with aggressive source treatment. Iron nanoparticles are submicron (<10-6 m), bacteria-sized particles of zero valent iron (Fe0) with (or without) a trace coating of noble metal catalyst (e.g., palladium or platinum). NP iron large surface area (>30 m2/g) promotes rapid reactions with dissolved chlorinated organics. Because of their high reactivity and extremely small particle size (typical particle diameters range from 100-200 nanometers), NP iron may be delivered directly into a fine-grained source area where rapid dechlorination of dissolved phase contaminants may speed the dissolution of residual held in the fine-grained matrix.

The NP-water slurry can be injected under pressure or by gravity to the source area through existing wells or minimally invasive drive points. There are no depth limitations for the NP treatment technology. The Navy is preparing to test NP iron to treat the source area near Hangar 1000 at Naval Air Station Jacksonville, Florida. Source area delineation is being refined to better target the NP application. NP delivery methods will be tested as well methods for evaluating the distribution and effectiveness of the NP.
In Situ Remediation of TCE in Clayey Soils Using the Lasagna Process

Chris Athmer, Terran Corporation, Beavercreek, Ohio

The remediation of solvent contaminated low permeable soils poses a significant problem for many facilities. A consortium of industrial partners (Monsanto, Dupont and GE), the USEPA and the DOE jointly developed a technology that integrates electrokinetics with in situ treatment of chlorinated organics to address this problem.

The process, called Lasagna™, utilizes a DC electric field to move pore water and contaminants uniformly through the soil mass to treatment zones emplaced within the contaminated area. The emplacement is performed using common piling technologies and results in little or no wastes. The treatment materials emplaced are typically iron, coke and kaolin.

After two field demonstrations, a full-scale Lasagna remediation system was implemented at the DOE facility in Paducah, Ky. The system was installed and operated over a two-year period by CDM Federal Programs, Kevil office. The process was shut down in December 2001 after meeting the cleanup target of 5.6 mg/kg specified by the ROD for the site. A description of the Lasagna process will be presented as well as the full-scale system design, operations, costs and results.

Lasagna is a registered trademark of Monsanto Company, St. Louis, Mo.

In Situ Thermally Enhanced SVE with Bioventing for Treatment of Phenols and BTEX in Soils

M. Talaat Balba, Ph.D., Darlene Coons, Cindy Lin, Ph.D., Susan Scrocchi and Alan Weston, Ph.D., Conestoga-Rovers & Associates (CRA), Niagara Falls, N.Y.

Historic activities at a chemical manufacturing facility in New York have resulted in the contamination of the soil and groundwater with a wide range of contaminants, including elevated levels of phenols, benzene, toluene, ethylbenzene, and xylenes (BTEX), polyaromatic hydrocarbons (PAHs), and chlorobenzene. A laboratory treatability study was conducted to assess the feasibility of in situ bioremediation of the vadose zone soils using slurry microcosms supplemented with nutrients and oxygen. The results showed that the current levels of contaminants at the Site are inhibitory to microbial activity and biodegradation.

CRA concluded that an alternative treatment technology to quickly reduce contaminant concentrations was required before enhanced biodegradation would be effective. CRA selected thermally enhanced soil vapor extraction (SVE) treatment as the knock-down step followed by bioventing as the polishing step for the treatability testing.

Three 20-gallon treatment vessels were filled with representative Site soils and two were fitted with a vapor extraction system, which included an activated carbon trap to remove vaporized chemicals from the air stream. The two treatment vessels were placed in a chamber heated to 35°C, and the third (without SVE) was used as a control tank, and was maintained at room temperature.

The SVE phase of the study ran for three months. Approximately 10 pore volumes of air were removed per day. The extracted air stream and the soils were sampled during this time, and the results showed that the concentrations of BTEX and phenols had been reduced by more than 99 and 75%, respectively. The reduction in phenols and BTEX was accompanied by a significant increase in the microbial population.

The two test vessels were converted to bioventing by reducing the airflow to one pore volume per day. One of the vessels was removed from the heated chamber and maintained at room temperature. Bioventing was performed for an additional three months during which biodegradation of contaminants was monitored. The rate of contaminant removal was calculated and the final contaminant concentrations were compared to applicable cleanup standards. The treatment results will be used to design a field pilot test, which will be performed to finalize the full-scale treatment design.
Controlled Environment Biopiling for Contaminated Land Treatment
Cyrille Berton, Gordon Lightbody, University College Cork, Cork, Ireland
Martin Hill, D. Arrigan, National Microelectronic Research Centre, University College Cork, Cork, Ireland
Michael Swainson, Building Research Establishment Ltd, Garston, Watford, Hertfordshire, United Kingdom
Bridget Corcoran, Response Environmental Technologies Ltd, Malby, South Yorkshire, United Kingdom

TerraNova is an EU Fifth Framework project for the remediation of polluted lands in Europe to prevent groundwater contamination. The Aim is to develop an accelerated ex situ soil bioremediation system. The degradation takes place in a totally contained vessel to prevent further pollution propagation. In addition to oxygen supply and the biopiles regular inoculation with fresh microorganisms from a NovaCell™ fermenter, a novel aspect of TerraNova is the soil temperature control via inserted pipe matrixes. The leachate is returned via the NovaCell to promote the bacterial cocktails adaptation to the pollution.

Prior to bioremediation, the polluted soil is mixed with BioGel™, which contains the same microorganisms, along with nutrients to promote rapid initial growth. Preliminary laboratory tests suggested that very high initial bacterial activity occurs when the microorganisms are degrading the provided nutrients. Heat generation due to bioremediation resulted in high temperatures (up to 57°C) in bench scale which totally incapacitated the micro-organisms. A temperature control system was implemented to a 3m3 pilot-scale TerraNova.

The soil was polluted with 10g/kg of 60% creosote, 30% diesel and 10% lube oil. The pollution was reduced by 68% after seven weeks. As expected, a heat generation peak occurred at the start of the remediation and was contained by the temperature control system.

These encouraging bioremediation results suggest that efforts should now focus on improving our understanding of the other key processes governing biodegradation. A comprehensive model of the TerraNova process is currently been developed using a Finite Element Method. While this model will be used for simulation and optimization of the bioremediation, it will also support the design and tuning of model-based controllers for parameters such as soil temperature and moisture content. The projects ultimate target is to develop a stand-alone ex situ bioremediation plant to allow SMEs to remediation European polluted lands.

PCB Contaminated Soil Remediation in a Wetland Buffer Zone using UVF Screening and Weighted Averaging
David Billo, Paragon Environmental Services, Norwood, Mass.
Steve Greason, SiteLAB Corp., Hanover, N.H.

In November 2000, Paragon collected 37 soil samples from a disposal site in eastern Massachusetts to delineate polychlorinated biphenyl (PCB) concentrations in soil prior to a proposed remediation. SiteLAB provided on-site analysis of these samples for PCBs via ultraviolet fluorescence (UVF). UVF data was used to delineate approximately 35 cubic yards of shallow (located in a wetland buffer zone) containing PCB contamination exceeding five parts per million (ppm).

In order to avoid destroying a portion of the wetland and because of the costs involved with PCB disposal, Paragon decided to limit soil removal to the identified soil volume exceeding five ppm in the wetland buffer zone. Paragon notified the local Conservation Commission of the plans via submittal of a Notice of Intent. The Commission granted approval for the project and issued an Order of Conditions allowing Paragon to proceed.

In December 2000, Paragon’s contractor cleared and chipped brush from the disposal site and excavated 65.96 tons of PCB-contaminated soil directly into two trailer dump trucks. The soil was transported to an out-of-state hazardous waste landfill under Hazardous Waste Manifests.

Paragon collected 12 post-excavation soil samples from within the excavation and submitted the samples for laboratory PCB analysis by EPA Method 8082. The laboratory analyses determined that PCB concentrations remaining within the excavation ranged from less than 0.086 milligram per kilogram (mg/Kg) to 3.8 mg/Kg.

Paragon used these results along with concentrations of soil samples previously collected from soil outside of the excavation (the applicable UVF pre-excavation sample results and other laboratory results generated during previous Paragon investigations between 1997-2001) to calculate a weighted average PCB concentration for the site of 1.74 mg/Kg. This concentration is less than the Massachusetts Department of Environmental Protection’s risk characterization standard of 2 mg/Kg; thus, supporting the submittal of a closure report for the disposal site.
Remediation of Perchlorate Contaminated Groundwater and Soil at Naval Weapons Industrial Reserve Plant (NWIRP) McGregor, Texas

Ronnie Britto, Dan Cowan, Alan Jacobs, and Michael Perlmutter, EntSafe, Memphis, Tenn.
Mark Craig, Southern Division, Naval Facilities Engineering Command, North Charleston, S.C.

Beginning in 1999, interim stabilization measures were implemented to abate offsite migration of perchlorate—a chemical that was just surfacing as an environmental pollutant with significant health implications—from NWIRP McGregor. The Navy targeted perchlorate-contaminated groundwater that was exfiltrating to surface water before migrating offsite, source area groundwater, and impacted surface soils. In three years, the Navy mitigated offsite perchlorate migration by rapidly and effectively developing perchlorate treatment technologies from conception through bench and pilot scale testing to full-scale implementation.

The Navy installed trenches to cut off and intercept groundwater before it surfaced via springs and seeps. The trenches also effectively served as PRBs that fostered anaerobic zones using in place natural organic media and supplemental soluble carbon sources. Perchlorate concentrations in groundwater were biologically reduced from 20 to <0.004 mg/L using in situ techniques.

Ex situ treatment systems, including static- and fluidized-bed bioreactors as well as an ion exchange unit, have also been used effectively to address contaminated water pumped from the collection trenches. Effluent concentrations have routinely been below detection limits.

The Navy developed engineered and in situ anaerobic soil treatment systems, which biologically reduced perchlorate concentrations from 1,800 mg/kg to below detection limits. The in situ soil units also allow amendment-rich water to infiltrate to address source area groundwater and provide polishing for ex situ treatment systems.

Because of site hydrogeology and seep concerns, the Navy also installed 200 amendment-filled bioborings to passively address offsite groundwater contamination in situ. Perchlorate concentrations have been reduced by an order of magnitude in the study area.

Next generation PRBs were installed in July 2002 to treat perchlorate- and VOC-contaminated groundwater. The PRBs included a variety of organic media as well as a multipurpose piping system to inject/infiltrate additional soluble amendments over time.

The precedent-setting remediation effort at NWIRP McGregor has received regional and national recognition for its environmental achievement.

Methane Recovery and Generation Pilot Testing from a Solid Waste Management Unit


A methane and recovery generation pilot testing program was conducted within a solid waste management unit at Fort Bragg, N.C. The tests were conducted to address soil gas methane concentrations that were potentially in exceedance of North Carolina Department of Environment Natural Resources regulations. The SWMU was historically used to contain construction and demolition debris.

Two in situ recovery tests were completed. Each test involved the extraction of methane gas through one extraction well and measuring the induced subsurface vacuum at three monitoring points located at distances of 5, 10, and 15 feet from each well. Three vacuum rates were applied to each wellhead. Applied wellhead vacuums ranged from 10 to 30 inches of water column. The corresponding extraction flow rates ranged from 80 to 140 scfm.

At one location, the methane concentration in the soil gas at the beginning of the extraction test was 54% and declined to 30% at the conclusion of the three hour test. At the second location, the methane concentration was initially 59% and declined to 45% at the end of the test. Initial methane recovery rates for each test area were estimated at 4,355 and 1,038 pounds of methane per day, respectively.

Eight methane generation tests were conducted in the SWMU. At each generation test point prior to the start of the test, the soil gas was evacuated to reduce the methane concentration to generally <5%. The methane concentration in the soil gas at each point was then measured over a 48-hour period. The increase in methane concentrations (and also the declining oxygen concentrations and increasing carbon dioxide concentrations) indicated that methane was being produced in the soil at each test point.

At the conclusion of each test, the soil gas methane concentration generally ranged from 30% to 55%, similar to pretest concentrations. The rate of methane generation was calculated using the methane generation rate in percent per day, the air fill soil porosity, the soil bulk density, and the methane gas density. In one area, the methane generation rates ranged from 2.6 to 13.8 mg/kg/day. In the second area, the rates ranged from 19.0 to 26.8 mg/kg/day.
Rapid Remediation of Jet a Fuel Contamination at the Former Stapleton International Airport in Denver

Dale W. Christensen, Parsons, Denver, Colo.
Paul Kieler, Department of Aviation, Denver, Colo.

At 4,700 acres, the former Stapleton International Airport (SIA) in Denver is currently the largest municipal brownfield redevelopment project in the country. Detailed long-range planning, extensive cooperation among all parties, and aggressive remedial actions at the former airport will result in complete remediation of SIA by April 2004, less than four years after commencement of the SIA remediation project.

In the years prior to and following closure of SIA in 1995, limited environmental investigations and remedial actions were implemented. However, widespread areas of jet-fuel-contaminated soil and groundwater remained, which prohibited sale of the property for redevelopment. The Jet A fuel was released over many years of airport operation, with numerous sources primarily associated with the airport fuel handling system.

In one case, the resulting free product plume extended more than 2,000 feet from the source area. Most of the remaining mass of fuel occurs in the 1- to 6-foot-thick "smear zone" where free product came in contact with and adhered to soil as groundwater levels fluctuated over time.

With a stringent timeframe imposed by the City of Denver and the developer (Forest City), an aggressive remedial approach was necessary. Due to the low volatility of Jet A fuel, the large areal extent of the residual product in the smear zone, and the shallow nature of the smear zone, excavation and offsite disposal was selected as the primary remedy. Significant groundwater contamination was limited because the volatile organic content of the weathered Jet A fuel was relatively low.

Since October 2000, Parsons has remediated 46 of approximately 110 acres directly impacted by contaminated soil. The State has issued No-Further-Action (NFA) determinations for four areas of concern (that directly impacted approximately three acres) within the 100-acre Regional Retail Center parcel, which enabled construction of the retail hub to commence less than eight months after the start of remediation.

By October 2002, Parsons anticipates that 90% of the impacted areas at SIA will be remediated and NFAs will have been issued for an additional 35 acres, which would release more than 600 acres of the former operational area of the airport for redevelopment construction.

This presentation will demonstrate/illustrate the rationale, planning and execution behind this successful brownfield redevelopment project, which will result in completion of the remediation project and property transfer less than five years after the initial agreement was signed with the developer.

Optimization Strategies for Remediation Systems

David E. Fulton, IT Corp., Trenton, N.J.

Over the next decade, the Department of Defense will spend over $1 Billion per year on the operation and maintenance (O&M) of environmental remediation systems. Each of these systems has a life cycle cost that includes the remedial design, construction and O&M. While the remedial design and construction represents a significant project cost, the O&M phase of the project is where the achievement of the remedial action objectives are realized. Therefore, a systematic and comprehensive approach is needed for evaluating and improving remediation system performance in order to maximize risk reduction, reduce operating and monitoring costs, accelerate site closure, and ensure protection of human health and the environment.

This presentation discusses strategies for optimizing the performance of remediation systems to achieve the remedial action objectives at the lowest cost and within the quickest timeframe. A remedial process optimization (RPO) approach is defined that includes project set-up, project evaluation, data collection, data analysis and implementation of RPO strategies.

Specific approaches include data and cost analysis techniques that focus on system operations, maintenance, and value-added modifications that result in enhanced performance, reduced project costs, and focusing the remediation system towards site closure. Examples of strategies that have been implemented and the resulting cost savings and enhanced performance are presented.
Electrolytic Aeration of Anoxic Groundwater: A Lab Scale Study and Modeling of the Process

Ramesh K. Goel, Graduate Student, Lubo Liu, Graduate Student, Dr Joseph Flora, Associate Professor, and Dr Michael E. Meadows, Associate Professor, University of South Carolina, Columbia, S.C.

Bioremediation is at the forefront of a larger group of innovative remediation technologies being applied at hazardous waste sites worldwide. During its application, this process may require the addition of nutrients and/or electron acceptors to stimulate appropriate biological activity. For aerobic degradation, oxygen must be available for indigenous microorganisms as a terminal electron acceptor. The most common means of increasing the dissolved oxygen content of groundwater used in situ bioremediation are injection of air, liquid air and hydrogen peroxide. The research investigates the electrolytic method of aerating anoxic groundwater to enhance in situ bioremediation by indigenous microbes.

Experiments were performed in 7.25 ft x 2.75ft wide x 1.75 ft deep horse feeding toughs. The soil used in this study was collected from one of the South Carolina Electric and Gas Company’s gas filling stations, which was reported to be contaminated with PAHs and had high amounts of ferrous iron.

In lab experiments, tap water was used and sodium sulfite was used to deoxygenate water to create anoxic environment in the tanks. Doses of sodium sulfite used were in excess to those obtained by stoichiometry required to react with dissolved oxygen. Experiments were also performed with oxygen releasing compounds (ORC), a commercially available technology for aerating anoxic groundwater. This was done to compare results with electrolytic aeration technique and to check the viability of electrolytic aeration.

The results obtained so far show that electrolytic aeration of groundwater with 100 mA electric current is possible and the method is very much competitive with ORC technology. Dissolved oxygen level as high as 2-3 mg/l were obtained in the well located 2-3 feet downstream of oxygen producing well.

In on going study, we are in the process of developing a numerical, which will predict oxygen transport under the conditions used during actual lab scale experiments. Based on the experimental setup, a two-dimensional mathematical model will be developed to simulate and evaluate oxygen generation in the tanks.

The physical parameters required for the model were measured in situ. The first-order rate constants describing the consumption of sodium sulfite and oxygen generation were obtained by fitting the model to the tank data. With these parameters, the model will be subsequently used to predict the performance of electrolytic cell in contributing to DO levels downstream of electrolytic probe well.

Lessons Learned from Relying on Data from Improperly Constructed Monitoring Wells

Joseph R. Havasi, URS Corp., Cleveland, Ohio

A phased Remedial Investigation (RI) was conducted at a government facility from 1995 through 2000. The facility is being converted to an industrial park under an aggressive re-use schedule. Chlorinated solvents (primarily cis-1,2-dichloroethylene and trichloroethylene) were detected in groundwater at one of the sites on base.

The solvents were detected in two monitoring wells, D1MW12 and D1MW13, located approximately 10 feet and 75 feet hydraulically downgradient of a former construction and demolition debris (CDD) landfill where solvent wastes were also improperly disposed. The wells were installed by another agency in 1994 and used with wells installed by URS during the RI.

This paper will present data utilized from these wells that were used for assessment and preliminary remedial planning purposes, and discuss the perilous fate of these wells and suspicions that were raised during well decommissioning with regard to the adequacy of the well construction.

In addition, this paper will present the likely cause of inflated concentrations of contaminants in groundwater at D1MW12 and D1MW13, a summary of remediation activities that were to be conducted to address contaminated groundwater, a revised data set based on replacement wells, the current status of groundwater issues at the site, and some lessons learned from relying on improperly constructed monitoring wells.
Optimization of Air Sparging/Soil Vapor Extraction Treatment System: Proven Practical Measures

This paper describes the optimization measures that ENSR implemented at an air sparging/soil vapor extraction (AS/SVE) system. In 1998, ENSR designed, installed and operated an AS/SVE system at a former industrial site in Massachusetts to remediate dissolved toluene in groundwater. The original system consisted of 100 driven sparge points and 40 SVE wells over 1.5 acres.

Significant mass removal of toluene (> 6,000 lbs.) was achieved within the first year of operation, and a large portion of the site was remediated to below the groundwater standard. However, groundwater in one area of the site was not being remediated, some critical AS points were not working effectively, and field staff experienced difficulties in collecting O&M measurements. ENSR evaluated the original system design, and implemented the following practical measures to optimize system operation:
• Replacement of driven sparge points with augered wells with a sand pack,
• Replacement of the sparge screen placement in the zone of contamination (not below it), establishing horizontal air flow through more permeable layers,
• Refinement of instruments and sampling ports to allow easier, more consistent measurement of system operation by field staff, and
• Down-sizing and reconfiguring the treatment system to target the area still needing remediation.

System improvements were implemented in 2000 and 2001. A significant increase in mass removal was observed following each phase of optimization. Remediation after optimization was achieved with reduced O&M and lower operating costs. Only one well at the site remains above the groundwater standard. The demonstrated improvements that ENSR implemented at this site are now used at other AS/SVE treatment systems.

Evaluation of the Dynamic Operation of a Large Scale Active Soil Gas VOC Collection System

The former Raymark Industries and its predecessors manufactured brake linings and related parts from 1919 to 1989 on a 34 acre parcel in Stratford, Conn. The site was identified as a federal Superfund site due to past on-site disposal of chemical and asbestos-related waste products, and is currently under the management of the CTDEP.

Extensive remediation work performed by the Army Corp of Engineers and its contractors to address contamination from historic on-site waste disposal practices included the installation of a clay and flexible membrane liner, an above-liner drainage system, and conventional and enhanced soil gas collection systems. Treatment systems installed at this site include a DNAPL recovery system, a gas vent sand layer with perforated horizontal gas conveyance collection piping (conventional), vertical air injection and vapor extraction wells (enhanced), and soil gas treatment systems employing thermal oxidation and activated carbon. Currently, a retail shopping complex is being constructed on the site.

The treatment systems have been in operation since 1997 and a significant set of operational data has consequently been produced. This work evaluates this five year set of operational data. The data include groundwater and soil gas monitoring data, and soil gas and DNAPL recovery data. Multi-level groundwater monitoring wells are sampled for geochemical parameters, VOCs, SVOCs, PCBs and metals. Air flow-rates, soil gas concentrations, and the vacuum underneath the protective site-wide cap are monitored.

The data show decreasing contaminant concentrations in soil gas and in several of the groundwater wells, with concomitantly increasing methane concentrations in the soil gas. The efficiency of the thermal oxidation system has increased by transitioning the enhanced soil gas treatment system from the originally designed full-time operational scheme to operating the system in cycles. Finally, using this data set, additional variations of the soil gas treatment system and groundwater monitoring program are currently under evaluation.
Electrical Resistance Heating for Remediation of Chlorinated Solvents in Low Permeability Soils

Electrical Resistance Heating (ERH) is being utilized to treat chlorinated solvents in soil and groundwater at a former Navy Dry Cleaning facility site. Electrical resistance heating is an in situ technology that uses commonly available electricity and applies it into the ground through electrodes. These electrodes can be installed either vertically to any depth or horizontally underneath buildings, operating facilities, and in the presence of buried utilities. The technology is equally effective in soil and groundwater.

ERH is a Thermal Enhancement for Soil Vapor Extraction that is effective in removing volatile organics by boiling groundwater in situ over an extended period of time at a controlled rate resulting in volatilization and steam stripping of sorbed compounds. Tetrachloroethene (PCE), a typical dry-cleaning solvent has been released at the site and sequential dechlorination products of PCE have been detected in soil and groundwater several orders of magnitude above regulatory standards.

PCE has migrated vertically downward as a dense non-aqueous phase liquid through subsurface soil and into the shallow groundwater (3 to 5 feet below ground surface) until encountering a clay unit ranging from 8.5 to 13.5 feet below ground surface across the site. DNAPL has not been observed in groundwater samples but is suspected to be present based on analysis of dissolved phase PCE in concentrations up to 120,000 ppb.

The objectives of the ERH implementation are to achieve between 90% to 95% reduction in groundwater concentration of the total chlorinated solvent concentrations in the target treatment area (16,525 square feet, 6700 cubic feet) and to achieve removal of any DNAPL residual or pool(s) to the extent practicable.

Enhanced Recovery of Light Non-Aqueous Liquids Utilizing Preferential Pathways Induced by Subsurface Utilities
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At the study site, light non-aqueous phase liquids (LNAPL) are present as a result of historic operations. The recovery of LNAPL poses a remediation challenge in any geologic media. Efforts to recover the LNAPL at the study site have been additionally challenged because the majority of the LNAPL is present beneath a semi-confining peat layer. Remedial investigations have indicated that, to remove the LNAPL, it is necessary to depress the water table below the semi-confining layer.

The semi-confining layer is discontinuous in nature and interrupted by the presence of subsurface utilities. Two 24-inch drainage lines transect the site and provide a boundary for the largest continuous mass of LNAPL. In addition, these 24-inch drainage lines interrupt the peat layer and provide a preferential flow mechanism for the LNAPL through the surrounding bedding material. The 24-inch drainage lines have been sliped to prevent LNAPL infiltration into the lines.

Remediation efforts have included groundwater and LNAPL recovery via recovery wells placed in the vicinity of the 24-inch drainage lines. These efforts have resulted in greater than expected LNAPL recovery by taking advantage of the preferential flow induced by the surrounding bedding material around the lines. In addition, the drainage lines likely interrupt other discontinuities and preferential fractures within the peat, therefore providing additional flow mechanism for LNAPL toward the recovery wells.
Beneficial Reuse of Diesel-Impacted Soil from Pipeline Release on Tribal Land

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Rick Greiner, Geoscience, Conoco, Houston, Texas
Seth Makepeace, Confederated Salish and Kootenai Tribes, Pablo, Mont.

A pipeline failure on tribal reservation land in 1987 resulted in the release of approximately 162,000 gallons of diesel fuel. The fuel spread over and within an alluvial fan deposit up to 400 feet from the release point. Emergency response efforts terminated the release and partially remediated the site through trenching and excavation, burning, and free product recovery. Subsequent site investigations and remedial activities characterized the extent of the release in alluvial sediments consisting mostly of sand, gravel, and silt. Groundwater impacts were limited to the area just downgradient of the release point.

Soil and groundwater remedial systems selected for the site included an active bioventing system, free product recovery wells, and monitored natural attenuation. A source assessment showed that although these remedial systems were reducing diesel concentrations in soil, the estimated time for remediation was excessive. A remedial alternatives analysis included excavation and disposal at a landfill, in situ or ex situ thermal treatment, and an engineered in situ bioremediation.

Through the combined cooperation of several entities both public and private, another alternative was discovered which became the most cost-effective and timely solution for site soils. Coordination between state agencies, tribal environmental and cultural branches, and Yellowstone Pipe Line was achieved to excavate and use over 130,000 cubic yards of impacted and unimpacted soil as road base for a local highway project. Soil with relatively low impacts was used as basecourse and traffic gravel, while more impacted soil was isolated by placement in a single 6-inch lift directly beneath the asphalt cap. Crushed gravel from the site was used to manufacture asphalt and chip seal. The mining and subsequent reclamation were completed within one year, and the site is currently under a vegetation management program to control noxious weeds.

Evaluation of Aerobic Degradation of Pentachlorophenol in Groundwater Using ORC

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Scott J. MacEwen, CH2M HILL, Herndon, Va.
Dawn M. Hayes, Commander, LANTNAVACENGCOM, Norfolk, Va.

A pilot study using Oxygen Releasing Compound (ORC™) has been recently completed to evaluate its effects on pentachlorophenol (PCP) in groundwater at a CERCLA facility in Virginia Beach, Va. The site is a former PCP wood treatment dip tank at a military installation where past operations resulted in releases of PCP and diesel fuel to the surrounding soil and water table aquifer. The study was conducted over a period of seventeen months, which included the installation of groundwater monitoring wells, collection of baseline groundwater samples, injection of ORC slurry into the surficial aquifer, and post-injection groundwater monitoring. Approximately 1,400 pounds of ORC were injected into the groundwater over the 750 square foot area where the dip tank was formerly located. The injection was completed using direct-push (Geoprobe) methods and included the entire 17 foot interval (6 to 23 feet bgs) within the surficial aquifer.

The contaminated soil above the water table had been excavated prior to the pilot test. Groundwater monitoring was performed at up-gradient, injection area, and down-gradient monitoring wells at six periodic intervals for fifteen months after the injection. Monitoring parameters included semivolatile organic compounds, metals, ferrous iron, chloride, carbon dioxide, and alkalinity, in addition to standard field parameters. Results of groundwater monitoring show an average PCP degradation of 92% in the four monitoring wells that demonstrated the highest initial concentrations. Remaining maximum concentrations of PCP are approximately 100 mg/L and minimum concentrations are at or below the laboratory detection limit of approximately 20 mg/L. PCP concentrations in these wells continue to decline with each round, and dissolved oxygen concentrations in these same monitoring wells remain elevated over baseline conditions by an average of 216%, after 15 months of monitoring. Therefore, the ORC appears to be further degrading PCP at the completion of the pilot study.
Evaluating the Success of Groundwater and Soil Cleanup at Sites Impacted by Fuel Oxygenates
Maryline Laugier, Rula A. Deeb, Ph.D. and Michael C. Kavanaugh, Ph.D., Malcolm Pirnie, Emeryville, Calif.

Fuel oxygenates are added to gasoline to increase combustion efficiency and to reduce air pollution in order to meet the requirements of the 1990 Clean Air Act Amendments. The most commonly used oxygenate is methyl tert-butyl ether (MTBE). In the United States, the use of MTBE as a gasoline additive started in the late 1970s.

Over the past decades, MTBE use has increased significantly. As a result of its widespread usage, reports of environmental contamination by MTBE in the vicinity of Leaking Underground Storage Tanks (LUST) and dispensing equipment have increased as well. Because of its specific physical and chemical properties, MTBE is highly soluble in water, does not strongly sorb to soil particles and strongly partitions into the aqueous phase.

As a consequence, MTBE tends to be highly mobile in subsurface environments relative to other gasoline constituents and can potentially migrate at groundwater velocities. Recent reports of MTBE detection in drinking water wells have led environmental managers and regulators to reassess cleanup strategies at MTBE-impacted sites.

Concerns have mostly focused on the feasibility of removing MTBE from contaminated groundwater in a cost-effective manner. This work will include a review of the fate and transport of MTBE following accidental releases of MTBE-blended gasoline with an emphasis on the relevance of these fate and transport characteristics on the appropriate strategy to select for cleanup.

State of the art information regarding groundwater and soil cleanup at MTBE-impacted sites will be evaluated using recent successful case studies. A short description of the technology used at the site, discussions of the effects of contaminant and site characteristics, evaluation of the technology success and limitations will be presented for each case study.

Finally, general cleanup cost estimates will be discussed in an effort to illustrate how the presence of MTBE impacts the costs of remediating gasoline-impacted sites.

Characterization and Remediation of a Former Drop Forge

In 1987, a release of petroleum was identified at an undeveloped property downgradient of a former drop forge. The drop forge operated from approximately 1900 through 1979. Subsequent delineation of the release determined that the source was within the industrial building area housing the drop forge.

In August 1990, nine fuel oil underground storage tanks (USTs) were removed from the industrial complex. While installation dates are not clearly documented, the tanks may have been installed as early as 1909. During the removal, large holes were identified in the USTs where gauging sticks had punctured the bottom of the tanks.

The site is surrounded by water on three sides and throughout the investigations sheens have been observed on the surface water. In 1992, three 36-inch recovery wells were installed in two areas of the site to prevent future outbreaks of fuel oil to the adjacent surface water.

In the 1990s, a detailed hydrogeologic investigation was completed to identify the presence of preferential pathways and provide data for the design of a comprehensive hydraulic and physical barrier. An extensive soil boring program, including the use of a cone penetrometer, was undertaken. The results of the investigation indicated that the majority of contaminant transport is occurring through a sand and gravel layer.

In 1997, seven additional recovery wells were installed in one area of the site to prevent additional outbreaks to the adjacent ponds and canal. However, very low groundwater removal rates were obtained due to the minimal thickness of the sand and gravel layer across this portion of the site.

In 1999, a Waterloo® Barrier was installed in a V-shaped pattern to prevent outbreaks to the surface water bodies and provide a pooling-effect to assist the recovery wells in removing petroleum-impacted groundwater from the area. Following the barrier installation, soil excavation was conducted to remove petroleum-impacted soil from the downgradient side of the barrier. To date, very few recurrences of sheens have been observed on the adjacent canal and ponds and the pumping rates have significantly increased in this area of the site.
Lessons Learned in the Use of Modified Fentons Reagent for the Treatment of Petroleum Contaminated Soil and Groundwater
Brian V. Moran, Charles P. Young and Melissa Parker, Norfolk RAM Group, Holliston, Mass.

Norfolk RAM Group (formerly Norfolk Environmental) has been successfully using Fenton's Reagent (catalyzed hydrogen peroxide under acidic conditions) since 1996 to replace traditional "excavate and haul" approaches that were not practical or too costly in many situations. With the number of successful projects completed now approaching 100, our experience with Fenton's Reagent in small scale remediation projects has produced a number of practical considerations which have been incorporated into each project undertaken.

Of paramount importance is the optimization of the delivery system used to introduce Fenton's Reagent into the contaminated medium (soil and/or groundwater). Key factors to consider during the design of the delivery system include unsaturated zone soils, soil permeability and the proper use of catalyst.

Stoichiometric calculations based on the known release volume or the average contaminant concentrations can be used to provide a quick feasibility evaluation for practicality and cost considerations. Since many of these small scale petroleum remediation projects involve residential fuel oil releases, reaction monitoring is of primary importance where occupants are at home during treatments.

Real time air monitoring and effective controls on off-gassing and ventilation are necessary components of each delivery system installation. Although much has been written concerning the controlling of, or lack of control during the reaction of Fenton's Reagent and petroleum, several steps can be taken to maximize the control of each application reaction.

Considerations influencing control of the application reaction include the concentration of hydrogen peroxide used, the proper concentration of catalyst applied, the judicious use of off-gas venting controls, the rate of application, the time between each application, the presence or absence of free phase petroleum present and the use of water to cool and dilute.

AMHERST SCIENTIFIC PUBLISHERS ANNOUNCES A NEW TITLE: IMMEDIATELY AVAILABLE

A Common Tragedy: History of an Urban River
Edited by Timothy J. Iannuzzi, David F. Ludwig, Jason C. Kinnell, Jennifer M. Wallin, William H. Desvouges, and Richard W. Dunford

The rise and fall, and rise again of an American river is the theme of A Common Tragedy: History of an Urban River. This work traces historical events along a waterway in one of our nation's most congested metropolitan centers. The authors investigate the delicate dance between man and environment from pre-history through the events of today. In many instances, the magnitude of some of these events could not be fully recognized until an historical survey such as this laid them out for the modern reader.

This "Passaic River" study is scholarly with scores of charts, lists, chronologies, footnotes, and a rich bibliography for the specialist. From the earliest geological and historical descriptions the reader is transported through time to the beginning of reconstitution of a "dead" or the "second worst polluted river in America" into a recovering and rediscovered asset. The cycle of life emerging from water may well be reenacted on the Passaic River today.

Topics included in this Passaic River compendium include its geological and historical past; the role of the Dutch, English, and American developers; the changes in shoreline and wetlands over three centuries; and the role of industrialization and urbanism.

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Eleven Years of Permeable Reactive Barrier (PRB) Technology for the Remediation of VOC Contaminated Groundwater

Stephanie O'Hannesin, EnviroMetal Technologies Waterloo, Ontario, Canada

In the eleven years since the initial research-scale granular iron permeable reactive barrier (PRB) was installed to remediate volatile organic compounds (VOCs) in groundwater, the technology has been applied around the globe, with installations in North America, Europe, Australia and Japan. In varying geologies and geochemical conditions, the technology has proven to be very robust. To date, no site has required rehabilitation, confirming that PRB technologies represent a predictable, long-term-treatment solution in most hydrogeologic environments.

The initial capital costs to install VOC PRB systems are typically equivalent to those costs associated with installing a pump-and-treat (P&T) system, and PRB technology offers significant cost savings due to the very low, long-term operating and maintenance costs. When comparing costs using a net present value analysis for the life cycle of these systems, the cost savings for these PRB systems far surpass those of P&T.

Another benefit is that granular iron PRB system completely destroy VOCs, as opposed to P&T where the contaminants are simply transferred to the another medium, such as the atmosphere, or to granular activated carbon which requires further disposal or regeneration.

Over the past decade, the cost to install these PRB systems have decreased dramatically, as the costs of granular iron have been reduced by over 50% and as contractors have become more familiar with PRB installations and have developed cost effective installation methods. The influence of key design parameters such as groundwater velocity variation have been incorporated into the PRB design improving the effectiveness of the technology. PRB systems are remediating sites and bringing closure for many site owners.

A Case Study For Design/Build of a Multi-Phase Extraction System at a Gasoline Station

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Denise Wallace, Fort Drum Military Installation, Public Works, Environmental Div., Fort Drum, N.Y.

A case study is presented for a multi-phase extraction (MPE) interim remedial measure (IRM) at an active gasoline station at the Fort Drum Military Installation to address subsurface petroleum hydrocarbon contamination. The subject site is situated on lacustrine deposits consisting of sand and silt. Groundwater is present from 21 to 26 feet below ground surface, with hydraulic conductivity estimated at 20 ft/day.

Previous investigative activities revealed petroleum-imparted soil, separate-phase product, and a dissolved-phase petroleum hydrocarbon plume were present hydraulically downgradient of the former underground storage tanks. The dissolved-phase plume had also impacted a downgradient wetland area and extends in the direction of a nearby river.

A Corrective Measures Study (CMS) was conducted which developed, screened, and evaluated potential corrective measure alternatives to address contaminated soil and groundwater. The CMS recommended MPE to remediate subsurface soil and groundwater in the upgradient source area, and aquifer air sparging (AAS) with ozone and tiered monitoring to address the downgradient dissolved-phase hydrocarbon plume.

MPE combines two remedial technologies: soil vapor extraction (SVE) and liquid recovery. SVE is designed to volatilize low molecular-weight compounds using relatively high volumes of air, while liquid recovery involves the direct extraction of LNAPL and groundwater from the subsurface. With the concurrence of the New York State Department of Environmental Conservation (NYSDEC), EA performed design/build services for both an MPE system and AAS with ozone system at the site.

This paper discusses lessons learned during the design, implementation and operation of the MPE system. Value-added engineering during the design/build process was critical in reducing project costs and facilitating construction. The MPE system consists of 10 recovery wells, extraction piping, and process equipment (vacuum pump, air/liquid separator, oil/water separator, and air stripper). EA is currently operating the MPE system to evaluate the effectiveness of this technology at the subject site and its potential for use at other sites on the Installation.
The Resolution of Tight Emulsions in Industrial Scale Waste Processing
Robert Scalliet, Dilitec Corp., Houston Texas

Waste processing applies scientific principles to the creation of technologies to restore air, water and soils to their status before pollution, transform the pollutants in a manner that they are no threats for the environment anymore and recycle what can be.

As waste such as contaminated soils is a mixture of solids and of one or two liquid phases, recovery and reuse of any of its components require prior separation of the phases. In the laboratory, small scale separations can be done with sophisticated methods but, most often, these methods are too expensive to be applied to large scale operations, especially when the cost of processing is higher than the value of the recovered components.

Initiating the processing, then, needs another incentive that overrules this consideration such as damages inflicted on the environment or a threat to public health. The separation methods generally used on an industrial scale: solvent extraction, filtration, centrifugation, thermal processes are summarily reviewed.

But organic and mineral materials mixed with water are most often a stable emulsion, which has to be economically broken before those means are applied. The innovative process proposed is to submit it to the high shearing forces of a ball mill. The process that incorporates this piece of equipment as well as the equipment configuration, are patented under US Patents #6,056,882 (May 2, 2000) and #6,214,236 (April 10, 2001) and described in this paper.

Containment of NAPL and Passive Hydraulic Control at a Former Manufactured Gas Plant Site
Edward P. Zimmerman and Mark Haney, Harding ESE, Merrimack, N.H.

Harding ESE was engaged by Northern Indiana Public Service Company to design a containment barrier and a groundwater management system that would prevent the migration of separate phase and dissolved phase hydrocarbons from the site into the neighboring Grand Calumet River while having the structural integrity sufficient to allow for future sediment removal in the river.

In order to maximize containment, reliability and structural integrity, low permeability sheet piling was selected as the preferred containment option. However, the barrier would create mounding of the groundwater, allowing this groundwater to mingle with the site contaminants and then migrate around or through the sheet pile. To prevent this circumvention of the barrier, it was necessary to provide a form of hydraulic control.

Pump and treat, funnel and gate, and passive controls were evaluated for this purpose. The classic pump and treat system was rejected due to long term operating costs. Funnel and gate technology has lesser operating costs, but due to the heterogeneous nature of the site contaminants, location of the gates was problematic and the use of this technology was restricted.

Harding ESE determined that the most appropriate remedy is a passive system that relies on the stagnation of site groundwater created by the barrier and a preferential pathway similar to a French drain that diverts the upgradient groundwater around the site, avoiding contact with the site contaminants. A 3-D MODFLOW model was used to design the passive hydraulic control system.

The remedy incorporated a low permeability vegetative cover that restricts rain water infiltration and phreatophyte trees that extract groundwater through water-conducting tissues in their root system. This utilization or uptake of groundwater combines with the other mechanisms to avoid mounding and produce acceptable groundwater elevations and flow patterns, thus achieving the remedial objectives. In addition to managing groundwater, the root zone of these trees will be expected to stimulate biological activity capable of degrading the site contaminants as well.

By utilizing passive hydraulic controls rather than the conventional active pump and treat technology, it is estimated that the costs of the remedy have been reduced by as much as $1,000,000. Due to this innovative approach, Harding ESE was given project responsibility from conceptual design through construction, including permitting and Agency coordination, and has been hired as the Design/Build Contractor to construct the remedy of this site.
Differences in the Dermal Bioavailability of Toluene and Phenol Aged in Soil

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When organic chemicals age in soil, they become more sequestered with time and less bioavailable. The dermal bioavailabilities of toluene and phenol aged for three months in two soils (Atsion and Keyport) were compared to the bioavailabilities of the chemicals without soil (pure chemicals), and freshly spiked in soil. In vitro flow-through diffusion cell methodology measured the amount of radioactive chemical which penetrated dermatomed male pig skin into receptor fluid and which became bound to skin following soap and water decontamination, as well as the volatility of the chemicals.

Although the majority of pure toluene was volatilized (88% of initial dose), 9% of the remaining dose penetrated skin. Because the volatility of pure phenol (39% of initial dose) was less than toluene, the total penetration of phenol (sum of initial dose in receptor fluid and bound to skin) was 52%. Therefore, the bioavailabilities of the chemicals after volatilization were 77% and 84%, respectively, for toluene and phenol.

Adding the chemicals to soil for a brief time (16 h), reduced toluene bioavailability to 4-6% and phenol bioavailability to 26-30%. After aging, the bioavailability of toluene (3-4%) was similar to toluene in soil for a short time. However, aged phenol was decreased to 15-22% bioavailability.

As a result of decreased bioavailability, the environmentally acceptable endpoint (EAE) of toluene would increase about 25-fold after aging in soil relative to pure toluene. In contrast, the EAE of phenol would be about 6-fold higher relative to pure phenol.

The data indicate that chemical characteristics such as volatilization not only produce differences in the bioavailabilities of toluene and phenol but also impact the EAEs of the compounds. (Supported through funding from the Hazardous Substance Management Research Center and the New Jersey Commission on Science and Technology).

Communicating Risk to Diverse Stakeholders: A European Case Study

Candace S. Chandra and Daniel Merendoni, Canary Strategies, Florence, Italy

Many European ports are beginning the lengthy and costly process of clean up. Remediation technologies are being reviewed and considered. Policymakers are considering with the longevity and cost of different technologies. Furthermore, local public groups are just becoming aware of the environmental and public health concerns associated with large scale cleanup projects. Finally, the industrial groups which have been closely associated with ports are concerned about changing legislation and resulting responsibilities and possible negative press.

With the integration of policies and standards around the European Union, many port sites are struggling with changing cleanup standards for various contaminants. For instance, sediment standards are just being set now around the EU. Quite often, the remediation engineering firms chosen to work at particular sites are from different countries, and therefore language and work culture are completely different. All of these variables make clear communication between stakeholders crucial in a port remediation project.

Bilbao, Spain provides an interesting case study of the diversity and scope of stakeholders at a European port site. The primary concerns are to clean the surrounding freshwaters and sediments and to involve industry in the process (to ensure less contamination in the future). The political situation in Bilbao makes for many levels of bureaucracy and oversight from the EU, federal, regional and local governments. Furthermore, the surrounding population is very concerned about environmental health problems coming from the ports remediation project.

To date, many scientific reports have been issued on the quality of water and soil within Bilbao's port. However, to ensure different stakeholder acceptance, an integrated and proactive communication strategy is necessary, to translate the technical information to non-scientific stakeholders. Additionally, the flow of information must travel in the other direction (from the non-scientific community to the engineering firm and scientists) to address local concerns and changing perspectives.
Oral Bioaccessibility of Dioxins/Furans at Low Concentrations (50-350 ppt TEQ) in Soil


Animal studies in rodents have indicated that the oral bioavailability of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in environmentally contaminated soils can range from 0.5 to 50%. To estimate the oral bioavailability of TCDD, and the 16 other 2,3,7,8-substituted dioxin/furan congeners, this study used a physiologically based extraction test, designed around the anatomic and physiologic characteristics of the human digestive tract.

This test measures the fraction of dioxins/furans in soil that would be solubilized in the gastrointestinal tract (i.e., that would be bioaccessible), and therefore available for absorption. The concentrations of TCDD in the eight soils tested were 1.7 to 139 pg/g (ppt), while the total TEQ concentrations were 6 to 340 ppt. Bioaccessibility of dioxins/furans from these soils ranged from 19 to 34% (averaged across the 17 2,3,7,8-substituted dioxin/furan congeners), with an average of 25%. The total organic carbon (TOC) in these soils was low less than 4% particularly for the soil series from which they were collected. Bioaccessibility of individual congeners did not appear to be correlated with degree of chlorination; however, it did appear to be inversely related to TOC. Even though these dioxin/furan concentrations are much less than studied previously, these results are consistent with those from animal studies at other sites, which have generally yielded values of 2050% relative bioavailability of TCDD in soil.

The Assessment of Toxicity and Biodegradability of New Energetic Ingredient Hexanitrohexaazaisowurtzitane (CL-20) in Soil

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The energetic compound, hexanitrohexaazaisowurtzitane (2,4,6,8,10,12-hexanitro-2,4,6,8,10,12-hexazatetrayclo[5.5.0.05,9,0.3,11] dodecanec), also known as CL-20, is a high power low signature explosive that has the potential to replace currently used high explosives due to its higher performance in terms of ballistics, detonation velocity and safety. In addition, CL-20 containing no halogens is expected to be more environmentally friendly as compared with older propellant formulations.

The widespread, high-level interest in CL-20 has resulted in an increase in its industrial production up to several thousands of pounds per year and its eventual environmental fate and transport. The aim of the present study was to assess the potential impact of CL-20 on natural environments such as soils and soil organisms including microbes, animals and plants.

Small amounts of CL-20, provided by the U.S. Army, Picatinny Arsenal N.J., was added to forest and meadow soils (New Jersey) at a rates 0, 500, 1000 and 2000 ppm and incubated at 20°C and constant soil moisture 50% of WHC.

In the first series of experiments, the natural input of organic carbon was simulated by soil amendments with glucose, starch, or cellulose at a rate 1,000-4,000 ppm. During one month of incubation, respiration (CO2 formation) was continuously recorded using an IR gas analyzer (Li-800) and the composition of microbial community followed by direct microscopy (bright field, UV, AMF, SEM) and isolations. We were able to identify soil fungi, microarthropods, and some bacterial species. No evident changes in the composition of the soil community was established, while soil respiration was slightly stimulated (by 1-5%) after addition of CL-20, the stimulation being proportional to CL-20 amendment rate.

In the second series of experiments, soil was mixed with 2000 ppm of CL-20, planted (bean and ryegrass) and incubated under artificial light (300 mmols/m2/sec of PAR) with 16:8 h light: dark cycle. The plant photosynthesis and soil-plant respiration was recorded continuously with Li-800 during two months from the seedling stage to flowering and seed formation. Contrary to our expectation, the effect of CL-20 on plant growth was stimulating rather than toxic: the standing plant crop and photosynthesis rates were 10-20% higher than those of the control, and senescence stage was significantly delayed.

In the third series of experiments, we followed the dynamics of residual CL-20 in soil samples incubated at 10-60°C by spectrophotometry of the soil extract. It turned out that decomposition dynamics followed first order kinetics with 50%-decay time varied from seven days (40°C) to several years (10°C). Thus, we can conclude that CL-20 has no toxicity to soil community and has unusual bio-simulative effects needed further clarification.
Risk Assessment Applications in Atypical Circumstances
Christopher M. Teaf, Ph.D., Center for Biomedical & Toxicological Research, Florida State University, Tallahassee, Fla.
Douglas J. Covert and R. Marie Coleman, Ph.D., Hazardous Substance & Waste Management Research, Tallahassee

Historically, the phrase "Risk Assessment" would bring to mind a three inch thick Superfund-type baseline risk assessment document filled with pages of tables with endless seemingly unrelated algorithms and numbers. Over the past decade, the principles of risk assessment have gained much more wide-reaching acceptance and risk-based solutions may be utilized for many environmental, occupational or other technical problems.

The typical objective of the classic risk assessment is to evaluate current risks or future projected risks from exposure to contaminated media within the framework of state or federal waste management and remediation programs. In addition to those still-viable applications, risk-based techniques also are increasingly being used on a voluntary basis (i.e., outside of the standard regulatory arena) to demonstrate the presence, absence or extent of environmental or health-related concerns in specific exposure circumstances.

Likewise, a risk evaluation may be useful in determining the need for, or the legitimacy of, a public health advisory, alone or in conjunction with remedial actions. Finally, risk-based techniques often find their way into the courtroom.

Three case studies are presented in which risk-based solutions were employed in a somewhat unconventional manner to assist in the resolution of environmental or health-related issues: reversal of a fish consumption advisory, evaluation of arsenic in soil on and adjacent to a school facility and challenge to a case of alleged methyl bromide exposure in a litigation context.

Groundwater to Indoor Air - The Exposure Pathway of the Future
David L. Thompson, P.G., Todd. Huffman and Joseph M. Sorge, J M Sorge, Somerville, NJ.

The Federal government and several states are focusing attention on the often neglected exposure pathway associated with groundwater contamination off-gas effects on indoor air quality in buildings. Currently, the state of the science required to assess this exposure pathway is primitive at best. There are only a few models available for the projection of indoor air quality effects associated with groundwater off-gas and soil vapor.

To date the Johnson and Ettenger model is the most comprehensive model available, yet it falls short of providing reliable and reasonable results for all but the simplest of sites and the possible input parameter values are seemingly limitless. Other more direct methods such as soil gas sampling and indoor air sampling are also fraught with uncertainty in obtaining reliable results and comparing them to meaningful standards.

Since indoor air quality effects associated with site remediation are obviously going to be a major exposure pathway to consider, especially in the new age of natural attenuation, additional, significant research is needed to adequately evaluate this exposure pathway.

Biological Effects Associated With Sediment Contamination in San Francisco Bay
Dr. S. Ian Hartwell and Dr. M. Jawed Hameedi, NOAA/NOS, Silver Spring, Md.

In 2000, NOAA initiated a two year comprehensive study to describe biological effects associated with sediment contamination in San Francisco Bay. The objectives of the study are to; (1) estimate the spatial extent and patterns of chemical contamination, toxicity, and macrobenthic community structure, (2) identify the incidence and severity of sediment toxicity, (3) estimate relationships between toxicant concentrations and measures of sediment toxicity and, (4) describe spatial associations among sediment contaminants, toxicity test results and, macrobenthic assemblages.

The study area extends from the Delta to the Golden Gate to Guadelupe Slough using a stratified-random design. The technical basis for stratification, the apportionment of sampling effort into the strata, and their sizes and dimensions were determined collaboratively with study partners and coastal resource managers.

In 2000, sediment and biological samples were collected from 86 sites. An additional 96 sites were sampled in 2001. Preliminary analyses of samples indicate that chemical contamination is widespread throughout the estuary. Elevated contaminant levels in tributaries and harbors/marinas were site specific with locally very high concentrations. Source and deposition patterns were contaminant-specific. Open water sites had marginally higher concentrations of contaminants in southern San Francisco Bay than in San Pablo or Suisun Bays.

Aggregate toxicity index results correlated with ERM quotients. Benthic community response to contaminants was confounded with salinity and bottom type, but correlations with contaminant levels were evident. Introduced species were the dominant biota at many sites, which complicated analyses. Additional analyses will be conducted when YR2001 data are available.
Volatile Air Emissions from Soil or Groundwater - Are They as Significant as Models Say They Are?

Jackie Wright and Martin Howell, URS Australia Pty Ltd, North Sydney, Australia

Human health risk assessments often involve the evaluation of volatile chemicals in either subsurface soils or groundwater. The inhalation of volatile chemicals following volatilization and diffusion to the soil surface is often found to be the most significant exposure pathway. This is primarily due to the use of models to predict the transport processes and emissions across the soil surface for volatile chemicals present at depth in soil or groundwater. These models are simplistic and often result in conservative and unrealistic results leading to over-estimations of chemical concentrations in breathing zones. The implication of the use of vapor transport models has been investigated by URS at a number of sites in Australia over the last seven years. Modeled estimates of surface emission rates have been compared with measured emissions data (collected using a surface emissions flux hood and a soil gas probe).

The results of these investigations bring into question the validity of these models for use across sites with varying subsurface chemicals and characteristics. Commonly used simplistic models (such as the Johnson and Ettinger Model and others as recommended in RBCA guidance) were found to over-estimate the measured surface emission rate to varying degrees at all sites.

For some chemicals, such as benzene, the modeled results were inconsistent, ranging from an order of magnitude to several orders of magnitude greater than the measured results (depending on subsurface conditions). However, for other chemicals, particularly chlorinated hydrocarbons such as vinyl chloride and 1,2-dichloroethane, the use of models greatly over-estimated the measured surface emissions rates.

This observation was consistent at a number of sites with varying subsurface conditions resulting in the model predicting unrealistic and inaccurate air concentrations in breathing zones both indoors and outdoors. This paper presents the results of comparisons undertaken at a number of different sites in Australia and discussion on the observations made and potential use of models in predicting emissions from a range of subsurface sources.

Utilization of the DQO Process in the Application of Sediment Data to the Sediment Quality Triad and its Outcome


Nearshore sediments near a former waterfront paint stripping, metal refinishing, metal plating shop and associated hazardous waste storage, were impacted from activities associated with the operations of this military facility from 1935 to 1980s. Sediment analyses in 1993 indicated PCBs, PAHs, pesticides and metals above screening benchmark values throughout the area. Survival effects were noted in sediment toxicity tests performed with the opossum shrimp, Mysidopsis bahia, but not observed in tests with the sheepshead minnow, Cyprinodon variegatus. However, sublethal effects were observed in the sheepshead minnow test.

In 1995, two hurricanes, Erin and Opal, were experienced in the Pensacola Bay area. In 1998, a third hurricane, Georges, was experienced. The effect of the hurricanes on the site sediments is uncertain. In addition, past data collection efforts focused on the top six inches of sediment only, and now there is concern about chemical concentrations at greater depth. Dredging could possibly uncover contaminated sediments. Therefore, decision-makers (i.e., EPA, FDEP and Navy) agreed to investigate the area to establish current site conditions.

Using the Data Quality Objective (DQO) process, the investigation was designed to assess whether the sediments create a condition adverse to benthic communities. If adverse conditions do exist, do they warrant remedial action?

Before collecting any samples onsite, the inputs, boundaries, and decision-making rules were established. Sampling techniques, chemical analysis, toxicity analysis, detection limits, and order of sample collection were discussed and consensus was reached. A decision-making triad was also developed to direct how the data were to be used. Investigators weighed possible options for the site and explored all potential outcomes prior to entering the field and collecting the first sample. This technique saved valuable time at the end of the study, where decisions were made. In addition, decision-makers were able to fully support the final decision for the site.
New Depth Filter Technology Boosts Filter Life and Dirt Holding Capacity

GE Osmonics, Minnetonka, Minn., offers a new filter technology. The technology, called Z.Plex™, produces filters with up to 100% greater filter life and dirt holding capacity than conventional melt blown depth filters at equivalent competitive efficiencies. The cost savings come largely from the ability to use fewer filters to fulfill the same processing needs due to the significantly improved filter performance.

Proven in multiple field trials, filters produced with Z.Plex technology are substantially out-performing competitive filters at equal efficiencies (removing equal percentages of same size particles). In addition to longer filter life, filters produced with Z.Plex technology decrease pressure drop by up to 50%, which saves energy costs. The new technology enables end users to reduce costs of filter change-outs, equipment downtime and waste hauling and disposal.

GE Osmonics 800-848-1750

Characterization and Remediation of Lead-Contaminated Soils at Closed Small Arms Firing Ranges is Focus of Latest ITRC Product

The Interstate Technology and Regulatory Council (ITRC) has just released a document to assist owners/operators, consultants and regulators in making decisions about the best ways to clean up soils contaminated with lead and other contaminants from small-caliber ammunition. Characterization and Remediation of Soils at Closed Small Arms Firing Ranges (SMART-1) presents a logical and easy-to-follow decision tree to assist in planning, evaluating, and approving lead soil remediation systems. The document defines site parameters and appropriate ranges of criteria necessary for characterizing, testing, designing and monitoring lead soil remediation technologies. Among the issues explored by SMART-1 is the regulatory status of reusing soil from the backstop of a closing range on other active ranges.

At some ranges, it may be possible and desirable to reuse the soil from the backstop of a range that is being closed to construct a new berm or rebuild an existing berm located in another area of the same property or facility. It is the position of the U.S. Environmental Protection Agency that ranges that reclaim and recycle lead bullets or lead shot may place the soil that is generated during the reclamation process back onto an active range on the same property or facility or a property adjacent to and under the same ownership as the property where the soils originated without testing the soil for hazardous waste characteristics.

In addition, the Small Arms Firing Range Team identified several pathways for lead removal, direct disposal, and soil reuse. Depending upon the characteristics of the site, there are technologies to separate, stabilize, and extract lead. In many cases, these technologies provide better solutions than simply disposing of soil as a hazardous or solid waste.

The Small Arms Firing Range Team is one of 15 currently active ITRC technical teams that are producing guidance documents and conducting training on the deployment of innovative environmental technologies. ITRC technical teams have produced more than 40 guidance documents, all of which are available online at the ITRC Web site at www.itrcweb.org. Click on "Guidance Documents" and then "Small Arms Firing Range" to download ITRC's newest product.
Revolutionary New Micro Bladder Pump

Solinst, Georgetown, Ontario, offers the 3/8" diameter and flexible new Model 407M Micro Bladder Pump. The 407M provides all the advantages of a Bladder Pump in a size that is ideal for VOC sampling in DP equipment, CMT and Waterloo Multilevel Systems, and in other narrow diameter applications as small as 1/2" ID.

The inexpensive pump uses coaxial Teflon™ tubing, is easy to deploy because of its flexibility, and is ideal for dedication. Operation is easy using the pre-set pumping rates and fine tuning controls built into the Solinst Electronic Control Unit. The pump manifold attaches to the Teflon sampling tube, and has a quick-connect attachment to the drive air/pump controller. Offering a flow rate of 20 to 150 ml/min, the Micro Bladder Pump is excellent for low-flow sampling procedures.

Solinst Canada Ltd. 800-661-2023

Keep Biohazard Disposal Bags Open & Ready to Use

Bel-Art Products, Pequannock, N.J., offers the Clavies Biohazard Bag Holders are part of Bel-Art's complete line of biohazard containment systems. The economical bag holders are designed with a stainless steel wire frame and a polypropylene bottom, which also serves as a containment tray in the event of bag leakage. The trays are safety orange in color for easy identification as a biohazard containment system.

Available in three sizes (small, medium and large), the bag holders are also autoclavable at 121°C (250°F) to maintain sterility. Units are shipped unassembled for more economical transportation. Assembly takes only minutes.

Bel-Art Products 800-423-5278

New Dust Suppressant Technology Tests Just Published by U.S. EPA ETV Program

Midwest Industrial Supply, Canton, Ohio, has announced the U.S. EPA Environmental Technology Verification Program just completed and published the results of a 100-day study evaluating the effectiveness of two new dust suppressant technologies. These new technologies achieved PM2.5, PM10 and Total Particulate control efficiencies of 100% over a 90-day period. In addition, the products achieved almost 100% elimination of silt loading.

These new products are EK35® and EnviroKleen®, the most advanced dust suppressant technologies introduced in North America over the past 25 years. Midwest Industrial Supply, Inc.'s Research and Development laboratory has worked five years on the development of EnviroKleen® and EK35®. These products effectively control dust and sediment on unpaved or open surfaces and meet the highest standards for environmental efficacy.

Midwest Industrial Supply 800-321-0699

Molded Liners for Standard 96 Well Microplates

Biotech Solutions, Mount Laurel, N.J., introduces the new Molded PTFE/Silicone or Silicone Only Liners, designed for use in many of the round or square 96-well standard microplates. The Liners have 96 round or square plugs that lock into each of the cylindrical or tapered wells. The tight seal eliminates sample cross contamination and reduces the chance of sample evaporation. The liners reseal after multiple injections, thus preventing coring and tearing. Our PTFE/Silicone Liners offer superior chemical compatibility and are made from Teflon lined (not coated) medical grade Silicone. The Dark Blue Silicone Liners are designed to withstand temperatures of -80°C. All of the liners are autoclavable and are available pre-scored for easy penetration.

Biotech Solutions 877-651-1768
Proven, Low-Cost Groundwater Cleanup Technology May Help Solve Perchlorate Contamination Crisis

Regenesis, San Clemente, Calif., offers that perchlorate, in many cases, can be eliminated from groundwater simply and very cost-effectively by enhanced bioremediation, using a patented formulation called Hydrogen Release Compound®, or HRC®, to speed the action of perchlorate-destroying microbes that occur naturally in soil and groundwater.

A powerful oxidizer, perchlorate has been widely used since the 1950s to make munitions, solid-rocket propellants, airbags and batteries. It has emerged recently as a health concern because it interferes with the body’s production of thyroid hormones, especially in young children and pregnant women. Potential health impacts include thyroid tumors, Graves disease (hyperthyroidism) autism, and growth or developmental disorders.

With the introduction of improved detection methods in the late 1990s, the compound could be detected in extremely low, but still potentially harmful concentrations. To date, the EPA has identified more than 75 perchlorate releases in 22 states, most in the South Central and Western U.S., but also as far east as Maryland and Cape Cod.

The issue is most acute in parts of the West and Southwest, where perchlorate may affect the drinking water of more than 15 million people in California, Arizona and Nevada alone. The cost of perchlorate removal has been estimated in the billions of dollars, but Regenesis scientists believe that figure may be sharply reduced by as much as one-third to one-half with readily available bioremediation technologies.

Bioremediation is now well-established as a reliable and highly cost-effective in situ remediation technique for many contaminants.

Hydrogen Release Compound is an all-natural, environmentally safe, food-grade compound designed to release lactate slowly into groundwater and soil. The lactate serves as food for indigenous microorganisms, enabling them to degrade a variety of toxic wastes.

Since its commercial introduction in 1998, HRC has been widely recognized as a groundbreaking technology that causes rapid, complete in situ elimination of anaerobically degradable contaminants, including chlorinated solvents, pesticides, explosives and dyes as well as perchlorate. A viscous, honey-like fluid. HRC is injected into soil and groundwater with a simple direct-push apparatus. Contact with anaerobic microbes initiates a sequence of chemical processes that cause a slow, steady release of hydrogen. Microbes that flourish in the hydrogen-enriched environment convert the perchlorate or other contaminants into harmless end-products such as ethene or ethane via a process known as reductive dechlorination. In situ treatment of groundwater contaminants is generally preferred to off-site treatment because there is no need to dig up or transport the soil. In situ clean-up procedures also tend to be very economical, and they reduce the publics exposure to hazardous chemicals.

Perchlorate contamination of drinking water supplies is particularly troublesome because the compounds chemical stability and high solubility enable it to form underground plumes that can contaminate drinking water supplies many miles distant from a source. Neither the EPA nor any state agency have prescribed a safe level for perchlorate in drinking water, but the EPA has recommended a maximum of 1 ppb (part per billion) and the California EPA is proposing a limit of 2 to 6 ppb. In Penn State tests, perchlorate concentration in contaminated soil and groundwater samples fell from as high as 2,600 ppb to below currently detectable levels (< 4 ppb) a few days after application of HRC.

Regenesis 949-366-8000

Thern Portable Davit Cranes Are on a Roll

Thern, Winona, Minn., announce that portable davit cranes become roll-around shop cranes by slipping easily into these new wheel bases. Maintenance crews can now easily lift grates, motors and other heavy loads from floor level or below.

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Thern, Inc. is a major designer and manufacturer of winches, cranes and hoists for virtually unlimited industrial applications. Founded in 1948, Thern is headquartered in Winona, Minn. and markets its products worldwide.

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AnchorSoft Introduces Mechanical Seal and Pump Tracking Software

AnchorSoft, Coraopolis, Penn., has announced the commercial availability of its first release of software specifically designed for reducing manufacturing costs by enhancing mechanical seal and pump tracking efforts. The software enables manufacturers to collate data, but it also generates eight reports that help identify the root causes of seal and pump failures. Each report provides a different operational perspective of the plants mechanical seals and pumps.

By comparing the information provided with the physical evidence on a failed seal or pump, a plant team can diagnose and correct process problems. The user can also examine the costs involved with new seals, labor, parts, inventory and the cost of downtime. Ultimately, an effective mechanical seal tracking system, guided by the data and reports from AnchorSoft, can enable plant managers and maintenance managers to make smart, technically-sound decisions about their manufacturing operations.

AnchorSoft, Inc. 412-865-1051

OSHA Expands NSF's Testing Accreditation

NSF International, Ann Arbor, Mich., The Public Health and Safety Company™, expands accreditation under Occupational Safety and Health Administration's (OSHA) Nationally Recognized Testing Laboratory (NRTL) program. NSF certification now includes all electrical components related to food equipment and water treatment devices.

NSF is one of a select group of laboratories in the world to be recognized by OSHA as an NRTL. To review the electrical standards to which NSF is now certifying products, visit www.nsf.org/info/accreditations.html

NSF International, a not-for-profit, non-governmental organization, is the leading global provider of public health and safety risk management solutions. NSF provides product certification and safety audits for the food and water industries. Other services include management systems registrations delivered through NSF International Strategic Registrations, Ltd., and education through the NSF Center for Public Health Education. NSF is a World Health Organization Collaborating Centre for Food Safety and for Drinking Water Safety and Treatment.

Accessories to make the Versa Vial™ More Versatile

J.G. Finneran Associates, Vineland, N.J., introduced the revolutionary 2.0mL Versa Vial™. With its largest target area and increased neck length designed for autosampler accommodation, the Versa Vial eliminates problems generally associated with crimping and decapping of aluminum seals. Now, in 2003, inserts and a plastic version of the plug have been added to the series, accessories that will make this unique vial even more versatile. The inserts are available in both glass and plastic, both with a 250μL capacity.

The flange of each insert is designed to set in the bottom portion of the finish of the vial-right at the opening of the vial body. When used with one of the Versa Vial plugs, it performs as the Step Insert, hanging precisely in the neck of the vial.

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We are happy to invite you to exhibit at the 19th Annual International Conference on Contaminated Soils, Sediments, and Water at the University of Massachusetts, Amherst. The Contaminated Soils Conference has become a leading national/international conference in this important environmental area. The conference attracted over 800 attendees last year including a wide variety of representation from state and federal agencies; the military; various industries including railroad, petroleum, transportation and utilities; the environmental engineering and consulting community; and academia.

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14th Annual West Coast Conference on Soils, Sediments and Water

March 15 – 18, 2004
Mission Valley Marriott, San Diego, California

Conference Overview

The Soils, Sediments and Water Conference is a highly successful and nationally known conference focusing on important and timely environmental issues related to soil, sediments, and water. Attracting between 400 and 600 attendees annually, participants include a diverse representation of state and federal regulatory agencies, the petroleum and chemical industries, transportation and utilities, environmental engineering and consulting firms and academia.

The ultimate goal of the conference is to provide a forum for the presentation and debate of relevant information related to soil, sediments, and water. This year the conference promises to be an exciting opportunity for professionals who are concerned with developing creative, cost-effective assessments and solutions as they work with the regulatory community.

Session Topics

- Acid Mine Drainage and Recovery of Metals
- Bioavailability
- Chemical Analysis
- Cleanup Standard Setting
- Contamination at Military Installations
- Depleted Uranium
- Environmental Forensics
- Environmental Fate and Modeling
- Heavy Metals
- Innovative Remedial Technologies/Corrective Actions
- MTBE/Oxygenates
- Natural Attenuation
- Perchlorates
- Phytoremediation
- Regulatory Programs and Policies
- Risk Communication
- Sediments
- Site Assessment/Field Sampling
- Soil Chemistry
- Case studies on any of the above

The West Coast Conference Invites You to Exhibit

Benefits of exhibiting:
- Exhibit space is limited to approximately 30 booths to ensure a high ratio of attendees to exhibitors
- The conference is sponsored in part by major industries, including Shell Oil Company, Gas Research Institute, the Port of Los Angeles, the U.S. EPA - all of whom encourage attendance by their employees
- Major Naval and other federal agency participation
- Attendees include representatives from the oil industry, transportation and utility industries

The rental fee for an 8' by 10' exhibit booth space is $1095.00. The price of the booth space includes:
- 8' x 10' exhibit booth space with back and side draping; includes 1 - 6' table, 2 folding chairs, wastebasket
- Promotion of your company name in conference flyers and programs
- Coffee/refreshment breaks
- List of conference attendees (electronic), sent after the conference
- Exhibitor staff badges (4 per booth)
- One complimentary conference registration

For more information about the conference, exhibitions or sponsorship information visit our website at www.aehs.com

or contact the Conference Coordinator Brenna Bartell at AEHS • E-mail: brenna@aehs.com
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Conference Directors: Paul T. Kostecki, Ph.D. and Edward J. Calabrese, Ph.D. University of Massachusetts, Amherst, MA
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