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Abbreviations and acronyms used throughout articles include:
EPA Environmental Protection Agency
UST Underground Storage Tank
ppm parts per million
ppb parts per billion

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Soil in a day’s work

In this issue, a majority of the pages is devoted to our second annual Buyers Guide. This is our attempt to serve the industry by providing a directory of who is in business, what they’re doing and how to find them. Such a project cannot help but focus attention on the business of soil remediation. And how is business?

For more than two years, I have been getting a sense of a business that is poised in a “justas oonas” mode. “Justas oonas the regs kick in... Justas oonas they unsnarl the permitting process... Justas oonas the new presidential administration focuses their environmental posture... Justas oonas as Congress reauthorizes the laws... Justas oonas we get out of this recession... Justas oonas (your theory here)...”

Everyone is ready. Businesses have their solutions in hand, their shiny new gadgets and cures. People have their contaminated sites, dripping and oozing down toward the water table. But we’re all in the stands, waiting for someone to throw out the first pitch.

There is no shortage of “guessperts,” trying to predict where the industry is headed, how the market will develop. I am not one of those... my crystal ball is in the shop. I do know a lot of businesses are struggling for all the justas oonas reasons. In my opinion, the quickest fix should be permit reform—by far the slighest roadblock in the business.

In California, the only legislation being sponsored this year by Cal/EPA is a permit reform bill. The bill is designed to eliminate multiple layers of permit hurdles from state and local agencies. They propose to consolidate the process by setting up a lead-permit agency designate that would be responsible for issuing one permit that incorporates all the requirements of interested state agencies.

It will be interesting to watch the progress of this proposal. It is encouraging that it is being structured to function within existing agencies—not creating yet another layer to deal through. Under the proposed bill, when more than one Cal/EPA board or department is responsible for issuing permits to a single facility, one of the boards or departments would be designated as the lead-permit agency.

On the one hand, the soil remediation business exists because of the regulations. On the other hand, it exists in spite of them. I know for a fact, the permitting vise has choked some businesses out of existence. They could not wait out the process. I know of companies that have relocated in a desperate effort to reposition themselves in a more advantageous permitting climate—raw survival.

To be fair, I don’t think it was the intention of the permitting process to strangle the industry. I suppose the intention was to protect human health and the environment, insure cautious practices. By accident or design (probably design), issuing permits quickly became a revenue center for the agencies, a fact that no doubt takes a lot of the air out of any reform balloon. Many agencies have come to rely on permit fee income. And that’s okay. I get the feeling the industry doesn’t mind the fees as much as they mind the delays. The regulators need to be assured we will still pay the permit fees, but the time has come to edit the intensive case-by-case scrutiny charade. This is especially true as more cleanups become more routine.

The whole point of treating petroleum contaminated soils separately in the regulations (as non-hazardous under the Resource Conservation and Recovery Act) was to expedite cleanup of the huge volumes of soil at so many sites. But that point is nearly lost when getting the permit is so cumbersome.

I do not want to be perceived as optimistic about permit reform. While the California initiative is encouraging, I am skeptical that it will speed cleanups along. And, the permitting situation in some states seems hopeless for reform.

What I am optimistic about is the industry’s ingenuity in hacking through the permit jungle. I believe it was Shakespeare (or maybe Vince Lombardi) who said, “The business of America is business!” I submit that, “the business of America is waiting for a permit,” and you can quote me on that.

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ASTM releases new assessment standard

Here's a close look at how the new guideline works

By James E. Fleer

Photo courtesy of Environmental Science & Engineering, Inc., Peoria, Ill.

The long awaited standard for the performance of a Phase I site assessment from the American Society for Testing and Materials (ASTM) has been released. It is important because it establishes a set of baseline criteria to ensure that the site assessment accomplishes the objective that created the Phase I market. That is, the purchaser can assert the "innocent landowner" defense provided in CERCLA (Comprehensive Environmental Response, Compensation and Liability Act) and its amendments if a Phase I assessment has been performed.

Any firm providing Phase I services can tell you that there are many sources of guidelines and procedures for conducting Phase I assessments other than the new ASTM standard. Other sources include those established by agencies of the federal government—such as the FDIC (Federal Depository Insurance Corp.) and the RTC (Resolution Trust Corp.). Some state governments have guidelines, including Connecticut, Minnesota and Oregon. Trade associations have them, including ASCE (American Society of Civil Engineers) and NGWA (National Ground Water Association). Even some financial institutions, like Chemical Bank and Bank of America have guidelines.

The reason to use and accept the ASTM standard as a basis for Phase I type assessments is that it has been developed by a broad cross-section of advocates as the industry standard for proving "due diligence" and asserting the "innocent landowner" defense.

CERCLA establishes the framework

Under CERCLA and its amendments, strict liability, and joint and several liability, is imposed on those parties responsible for a release or threatened release of a hazardous
substance to the environment. The definition of who comprises responsible parties is very broad. In essence, there are four types of responsible parties:

1. The present owner or operator of a facility,
2. Any person who owned or operated a facility at the time hazardous substances were disposed there;
3. Any person who arranged for the treatment, disposal or transportation of hazardous substances to the facility (not limited to the generator), and;
4. Any person who accepted hazardous substances for transport to a facility.

The only defenses to liability under CERCLA and its amendments are that the release or threatened release must be caused solely by: an act of God, an act of war or an act or omission of a third party with whom the person did not have a contractual relationship.

Until CERCLA was amended in 1986 by SARA (Superfund Amendments and Reauthorization Act), the use of these defenses was very limited. SARA defines contractual relationships to include land contracts, deeds or other instruments that transfer title or possession, unless the real property on which the facility is located was acquired after the disposal or placement of the hazardous substances. However, in order to use the “innocent landowner” defense, the purchaser also has to show that, at the time of acquisition, he or she did not know—and had no reason to know—that any hazardous substance was disposed on, in or at the facility. In addition, the purchaser must show that he or she exercised due care with regard to the hazardous substances and took precautions against foreseeable acts or omissions of the third party.

SARA further clarified the applicability of the defense by requiring the performance of “all appropriate inquiry into the previous ownership and uses of the property consistent with good commercial or customary practice in an effort to minimize liability.” Congress established five factors for the courts to use to determine if “all appropriate inquiry” was made:

1. Any specialized knowledge or expertise of the buyer/owner;
2. The relationship of the purchase price to the value of the property if uncontaminated (underpriced properties may indicate the purchaser’s awareness of contamination);
3. Commonly known or reasonably ascertainable facts about the property;
4. The obviousness of the presence or likely presence of contamination at the property; and
5. The ability to detect such contamination by appropriate inspection.

Hence, the birth of the Phase I assessment performed by an environmental professional.

Due to continuing concern over the

Continues on page 8

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conducting site assessments of commercial property as required for the “innocent landowner” defense under CERCLA. To begin, ASTM developed a two-tier approach to site assessments. The first tier is called, Transaction Screen Process. It allows a buyer or seller to perform a limited review of records and a visual inspection which guides the user to conclude whether further inquiry is needed at that site. When this option is used appropriately, it should constitute all appropriate inquiry as required under CERCLA.

The second tier is entitled, Phase I Environmental Site Assessment Process. It requires that an environmental professional be employed to conduct all appropriate inquiry, and involves a more substantive review and inquiry process.

Process designed for use by non-professionals
The Transaction Screen Process is a site characterization tool to aid the user in determining if a Phase I assessment is necessary. The user reviews available records and data to determine whether the transaction (to buy or sell) would be advisable, but the process cannot determine the extent of the environmental liability that might be present at the site.

This tool is designed to be used by non-professionals. The process includes:
1. A questionnaire regarding current and past uses of the property,
2. An inquiry and review of governmental records and historical sources pertaining to hazardous waste activity on or near the property; and
3. A site visit to complete the observation checklist.

Based on the information gathered during this process, the user should be able to determine if there is any “recognized environmental condition” at the site. A recognized environmental condition is defined as, “the presence or likely presence of any hazardous substance or petroleum product on a property under conditions that indicate an existing release, past release or material threat of a release of any hazardous substance or petroleum product into structures on the property or into the ground, groundwater or surface water of the property.”

The ASTM recognized that, when a user is conducting a Transaction Screen Process, he or she may find that prior Phase I assessment reports exist. ASTM states that use of such prior reports is acceptable, as long as they meet or exceed the ASTM standard for Phase I assessments, and that site conditions have not materially changed to alter the findings or conclusions of the prior reports. So, users should only use prior reports with extreme caution.

In general, a prior assessment report may be used if it was completed within 180 days of the user’s inquiry. Even with a recent report, the Transaction Screen Process requires that a new site visit and checklist be completed to meet the standard.

In most cases, an industrial property will fail the Transaction Screen Process and require a full Phase I assessment to be performed.
Phase I to be used by professional environmental consultants

ASTM has identified four principal components to a Phase I assessment:
  * records review,
  * site reconnaissance,
  * interviews with current owners and occupants of the property and with local government officials, and
  * a report.

ASTM requires the use of an “environmental professional” to conduct a Phase I assessment, and they intentionally left the definition of an “environmental professional” vague. The definition states that an environmental professional is “a person possessing sufficient training and experience necessary to conduct site reconnaissance, interviews and other activities in accordance with the standard, and, from the information generated by such activities, having the ability to develop conclusions regarding recognized environmental conditions in connection with the property in question.”

Components of Phase I records review

The standard divides records review sources into four classes:
  * standard environmental records at the federal and state level,
  * additional environmental records at the state and local level,
  * physical setting, and
  * historical use.

Standard environmental record sources have been established, along with minimum information search distances, to determine the impact on the subject property from adjacent properties. Figure one, page 10, outlines these sources and distances. Reviewing the information in the records and databases provides details about the site and surrounding properties. Often, this information identifies regulatory agency concerns. In some cases, the current owner is completely unaware of these concerns. Certainly, the information can be useful in directing the interviews and performing the site reconnaissance.

The purpose of reviewing the additional state and local sources is to enhance, verify or supplement the federal and state sources. Examples of some additional sources include:
  * records of emergency releases under SARA Section 304,
  * records of analytical data on local wells,
  * fire department records,
  * building and zoning offices,
  * local electric utility companies, regarding PCBs.

The sources may show prior contamination, which would automatically require a Phase II assessment. In many cases, information about an area is not duplicated within the records of various agencies or response organizations. Therefore, each organization should be asked to produce any information that may pertain to the site or its neighbors.

To satisfy the standard’s physical setting source requirements, a 7.5 minute USGS (U.S. Geological Survey, Department of the Interior) topographic map is a required record, unless it is not reasonably available. Other physical setting records that may be useful include groundwater maps, bedrock geology, surface geology and soils of the area. These records help to determine the impact of activities or releases at the property.

Historical use information establishes baseline expectations of the kinds of recognized environmental conditions that may exist due to routine site operations. The standard requires land uses be identified back to 1940, and, for properties used before 1940, back to the time the property was undeveloped. For purposes of the standard, development is defined as the time when the site was first used, but also includes when fill was first placed at the site.

For the period of 1940 to the present, as many sources as necessary to document site activities must be searched. For the period prior to 1940, only one source is required. Applicable sources include aerial photographs, fire insurance maps, property tax files, zoning and land use records and the like.

Continues on page 10→
ASTM’s new standard, from page 9

Site reconnaissance spelled out
A thorough examination of the site must be performed, including the interior and exterior of all buildings, property boundaries and ancillary facilities. In addition, adjacent properties should be studied for evidence of or potential impact on the subject property. Other site characteristics such as roads, sewage disposal systems, water supply and geologic, hydrogeologic, hydrologic and topographic conditions should also be described in the report. The standard explains in detail the areas and observations that should be noted to ensure all appropriate investigation has been completed.

Interview guidelines
The interview portion of the standard requires documented interviews with key site managers and local government officials. These discussions should focus on potential recognized environmental conditions and clarify any concerns revealed in historical reports, information from other sources and any legal proceedings involving the property. As another information source, interview questions may closely follow the guide for owner/occupant inquiry provided in the transaction screen process.

Table of contents for Phase I report
ASTM has prepared a recommended table of contents and report format for the Phase I assessment. In essence, the report format organizes all the information. The purpose of the

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format is to assure consistency in reports prepared under this standard. In all cases, the standard requires that the report include a statement of compliance with the standard or the identification of specific deviations from the standard where any may have occurred.

As with the transaction screen process, the use of prior assessment reports is acceptable, provided that the prior reports meet the standards outlined. If the report was completed within 180 days of the current Phase I assessment, in addition to a new site reconnaissance, updated interviews and a records review must be performed. If a prior report is used as a source, it must be cited in the report, and a copy of it must be attached.

New standard does not address all pollutants

The ASTM Phase I assessment standard is designed specifically to satisfy the “all appropriate inquiry” requirement to apply the “innocent landowner” defense. Toward this end, the only areas required to be addressed in the standard are those that affect CERCLA and petroleum products. ASTM added petroleum products only because these segments of the Phase I assessment have become routine, and they did not feel they could omit them. Other areas not addressed by the standard (Friable asbestos, lead paint, radon, wetlands, polychlorinated biphenyls, etc.) can be added.

Because the standard targets CERCLA, other state and federal laws may require the user to expand the scope of the assessment to comply with a more stringent standard.

Standard reflects industry-wide input

Publication of the ASTM standard represents an industry standard, developed by a widely recognized organization representing all interested parties. Such a standard will help ensure consistency in purpose, scope and data collection for the Phase I assessment. In general, an ASTM Phase I should accomplish at least four of these eight possible objectives of Phase I assessments:

1. Identify contamination sources,
2. Establish baseline environmental conditions to support or deny future claims of environmental impairment,
3. Verify representations and certifications through an independent third party,
4. Support the CERCLA “innocent landowner” defense with a comprehensive product,
5. Evaluate property devaluation due to historic activities at the site and how they impact planned activities,
6. Assess environmental health and safety compliance status,
7. Assess severity and probability of risks to consider in decision-making,
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Last year, in our first Buyers Guide, we listed over 400 firms engaged in soil remediation service activity. We expected this Guide to be bigger, and it is—listing nearly 800 firms across the nation.

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Keep the Guide as a reference throughout the year. If you have questions or suggestions to improve the Guide, or if you wish to be included in next year’s Guide, please mail or fax:

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Sensitive immunoassay results require a close look

New developments in field testing continue to find ways to pry the secrets out of a site with increased speed and efficiency. Immunoassay technology for field testing is enhancing traditional methods by providing rapid, accurate, on-site analysis of soil and water contamination. Stringent state and federal regulations governing the environmental sector have prompted the development of new immunoassay-based methods that correlate well to traditional laboratory analysis results.

"Field testing can identify hot spots, monitor the progress of remediation, select samples for laboratory analysis and assess health risks," says Bruce Crane, marketing manager for D Tech™, a new detection system developed by EM Science of Gibbstown, N.J., and Strategic Diagnostics, Inc. (SDI) of Newark, Del., that can be used in the field by non-laboratory personnel to test for a variety of organic pollutants in soil and water.

The D Tech method combines the properties of immunoassay with a hand held field test meter to identify and quantify compounds. The instrument provides field technicians with a quantitative value for each sample, or a visual comparison with a known reference, thereby providing an immediate yes or no answer to contamination levels. The meter interprets test results based on a color reaction.

For some applications, the human eye is sensitive enough to detect the color change. However, the human eye is limited when it comes to making fine color and color intensity...
comparisons. Quantitative analysis requires a detector that is more accurate and less subjective than the human eye.

According to the manufacturer, the meter displays results, along with sample number, date and time of analysis. Results for up to 127 samples can be stored in memory. The meter operates on the principle of reflectometry. It has two built-in light sources. When activated, each light source emits a flash that reflects from a surface. One of the surfaces is a test circle (the sample), the other is a reference circle. A light meter in the instrument measures the amount of light reflected from each circle, computes the difference and displays the results. A calibrator is provided with each meter.

Immunoassay is a technique to detect and measure a target compound using an antibody. A sensitive antibody can detect even small amounts of analyte in the sample. A specific antibody binds primarily (if not exclusively) to the target, and ignores other, similar compounds. This high specificity permits the test to work in the presence of compounds of non-interest in the sample.

Much of the growth of immunoassay in the past four to five years can be attributed to the recognition by the regulatory community that immunoassay saves time and money in assessing environmental contamination. The growth was further enhanced by the motivation by government and private industry to streamline the monitoring and analysis process to expedite cleanups.

"On-site testing with immunoassay techniques essentially takes an instant snapshot that enables environmental engineers to make immediate decisions," says Crane. "It eliminates the two to four week waiting period usually associated with laboratory analysis."

Test samples collected and tested with immunoassay kits on a systematic grid can be used to construct a map of contamination at a site. Such a map can be a valuable tool to determine site boundaries, define the extent of contamination, assess risk, formulate a remediation plan, optimize addition sample collection and make more accurate cost and time predictions.

Field technicians can process 50 to 100 samples per day using immunoassay kits. Site analytical costs can be reduced as much as 40 percent over use of traditional methods, according to the company.

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June July 1993 Soils 39
Screening around tanks: choose the right method

VOC methods may not catch diesel and other heavy fuels

By Edmund Manke and Donald Lavery, Ph.D.

Various field screening methods for petroleum hydrocarbons in soil each have strengths for particular applications. It helps to know the characteristics of each method when choosing the technique to use for a particular site.

Three methods often used for field screening for petroleum hydrocarbon contamination are: direct analysis of soil for total petroleum hydrocarbons (TPH) using an infrared analyzer in a modified version of EPA method 418.1; soil gas survey for volatile organic compounds (VOCs) using organic vapor monitors; gas chromatographic methods as in EPA methods 8015, 8020 or modified 8100.

True gas chromatographic methods are usually done only when a mobile lab with a laboratory grade gas chromatograph with temperature programming is available. A gas chromatograph takes a complex mixture and separates it into its components by passing the sample through a chromatographic column. By comparing the elution patterns and peak areas of soil extracts or headspace samples to known standards, it is possible to identify and quantify pollutants. Extraction methods are often used, but may result in loss of the light volatile organic compounds, while headspace techniques may not see the heavy, semi-volatile fraction effectively. Typically, samples for gas chromatographic analysis are collected, stabilized and sent to a certified lab for analysis. Field measurements are more commonly done by simple total petroleum hydrocarbon screening and by infrared and by volatile organic measurement with organic vapor monitoring—or both.

Portable total organic vapor monitors used in soil screening typically use a flame ionization detector or photoionization detector to measure the volatile organic compounds trapped in the interstitial spaces in the soil. Various techniques are used for field sampling, including sample wells, hollow probes and purge and trap.

In an organic vapor monitor using a flame ionization detector, hydrogen and air generate the flame in which the sample is ionized. As organic compounds thermally crack, ions form. The extent of ion production is small, but sensitivity is good and the dynamic range is broad. The flame ionization detector is generally considered to be a mass sensitive hydrocarbon detector.

If the instrument uses ambient air in the sample as the oxygen source, trace levels of low molecular weight, high vapor pressure compounds normally have sufficient oxygen for uniform combustion. As the concentration of organic vapors increases, the amount of oxygen required to maintain uniform combustion increases. Ultimately, the oxygen is depleted and the flame goes out. Research published in the Journal of Chromatographic Science, volume 20, by G.D. Mitra and S.K. Gosh, showed the effect of internal air on the hydrogen flame in an ionization detector. The data showed that air flow could be optimized and that increasing or decreasing the air significantly altered the response. In soil gas sampling, the flame ionization detector may be oxygen deprived, causing the response to be disproportional to the concentration present.

The flame ionization detector is usually calibrated with an alkane standard, such as methane or hexane. Total hydrocarbon concentration is measured and the output expressed as a standard hydrocarbon equivalent response. Conversion to parts per million for an individual component is calculated with a relative response factor for a known concentration of the compound to an equivalent concentration of the standard.

When using a flame ionization based organic vapor monitor, it is possible for methane to obscure the signal from other volatile organic compounds. Biogenic methane is often found in the field. This is methane which is naturally generated from decaying vegetation, or from biodegradation of petroleum in older sites. When trapped in high concentration pockets under asphalt or in clayey soils, it may mask the presence of other volatile organic compounds.

Photoionization detectors use an ultraviolet light source to ionize the sample and measure the current flow between two electrodes produced by the ions. The photoionization detector is more sensitive to aromatics than the flame ionization detector, and requires no

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hydrogen fuel. Isobutylene is typically used as a calibration standard. The photoionization detector has selective detectability, based on the ionization potential of the compound and the energy of the ultraviolet lamp.

Users of a photoionization detector must consider two factors. First, water vapor has a significant effect on response. Second, sensitivity of the photoionization detector decreases significantly in the presence of high concentrations of methane. These factors are important to consider at underground storage tank sites, since tanks are frequently excavated from sites with standing water, methane rich environments—or both.

Still, organic vapor monitoring is useful for measuring the volatile fractions of gasoline (benzene, toluene, ethylbenzene and xylenes, and low molecular weight hydrocarbons). It is less useful for heavier molecular weight, low vapor pressure hydrocarbons found in other petroleum fractions such as diesel fuel, heating oil, jet fuel and crude oil. Sites with weathered petroleum contamination, where chemical and biodegradation have occurred may no longer emit volatile organic compounds, but are still contaminated by the semi- or non-volatile fraction.

Use of an organic vapor monitor alone may result in a false reading, leading to a decision to prematurely close a site. Direct total petroleum hydrocarbon measurement with Freon 113 extraction and infrared analysis (described in detail in the January-February 1992 issue of Soils magazine, “Simplified Method Cuts Sampling Costs,” by D.S. Lavery and E.C. Manke, page 34) can be used in place of, or in conjunction with volatile organic compound analysis to confirm the extent of contamination before any final decision is implemented.

The standard method for analysis of total petroleum hydrocarbons (TPH) in soil is commonly Method 418.1. In fact, 418.1 (Petroleum Hydrocarbons, Total Recoverable, Spectrophotometric, Infrared) is a water analysis method that is usually modified for soil by using a Soxhlet or manual extraction followed by the sample cleanup and infrared analysis as described in 418.1. There are other modified methods to allow total petroleum hydrocarbon analysis to be performed in the field. These modifications are useful in a mobile laboratory, but are not ideally suited to on-site measurement at an excavation site.

One field method uses disposable components to do a single stage, Freon-113 extraction, with a solid-phase extraction using silica gel for sample cleanup. Detection is accomplished with either a single, referenced infrared absorbance or dual, referenced infrared absorbance measurement. By comparison, classical extraction methods attempt to remove all the analyte from a sample matrix, quantitatively dilute the extract and measure the concentration of the final solution. Typically, the original sample is extracted at least three times, many more times in the case of a Soxhlet extraction. Single stage extraction with a measured volume of solvent measures the concentration of hydrocarbons extracted into the Freon 113. The partitioning of hydrocarbons strongly favors the Freon 113 solvent phase, so the concentration of hydrocarbons present in the solvent closely approximates the soil concentration. Since sampling variability and sample degradation during transportation and storage tend to dominate the variation in environmental analyses, the sample partition loss of a single stage extraction done on site should be unimportant.

Infrared based field instruments can be scanning or interference filter based. Measurement of absorbance is done at 3.4um, as specified in Method 418.1. Simultaneous measurement at a reference wavelength where hydrocarbons are transparent may or may not be done. The use of a reference wavelength has advantages which include canceling short term source and electronic fluctuations (noise) as well as longer term source and optical component changes (drift). The

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Write in 261
June July 1993 Soils 41
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Figure one: infrared spectra of light aromatics

Screening around tanks, from page 41

use of a simultaneous measurement at a reference wavelength, where the absorbance at the analytical wavelength and reference wavelength are continuously ratioed has direct advantage for soil analysis. Clay and limestone samples can produce interferences in infrared total petroleum analysis. It seems likely that this is due to fine particulates that cause broad band scattering. Some single wavelength analyzers cannot distinguish scattering from a hydrocarbon absorption, but a referenced wavelength system would be similarly affected at both wavelengths so the effect would, to a large extent, be canceled.

Dual wavelength infrared analysis extends the infrared method to reveal more information about the sample than single wavelength methods. The two wavelength approach measures both the conventional 3.4μm absorbance due to aliphatic hydrocarbons as well as the absorbance at 3.3μm which is characteristic of aromatics. The two wavelength approach separately measures and scales the absorptions characteristic of the two classes of hydrocarbons, which gives a better measure of the overall contamination.

Most infrared based instruments that use the standard method of measuring at 3.4μm are essentially insensitive to aromatic compounds (generally more toxic) and rely on the calibration standard to have about the same aromatic content as the sample. This is what the synthetic oil standards specified in EPA standards do. A more complex site could contain multiple sources and non-fuel products so that the aromatic content of samples might vary from zero to 100 percent. In these cases, direct detection of aromatics is extremely valuable.

The variation in aromatic content of petroleum fuels is fairly significant—zero to 40 percent. Volatile organic compound analysis measures the aromatics well, but may be subject to methane interference. Direct measurement of the aromatic fraction in the soil by infrared analysis is not affected by methane. During excavation, infrared analysis of aromatic content indicates where the more toxic soils are located. This helps reduce worker exposure, and identifies samples which must be removed to a hazardous waste facility.

Calibration of the infrared total petroleum hydrocarbon analyzer uses EPA reference oil as defined in EPA 418.1 as 37.5 percent isooctane, 37.5 percent hexadecane and 25 percent chlorobenzene. Response is typically output in mg/L or absorbance units. Dual channel analyzers are calibrated using reference oil for the aliphatic response, and benzene for the
Each channel of the dual channel analyzer is linearized within the calibration range. The response of the dual channel analyzer on the aromatic channel is corrected for interference from absorption on the opposing channel by a matrix circuit built into the analyzer. The dual analytical wavelength analyzer provides information on total petroleum content, as well as supplemental information on the aromatic contribution.

Although Method 418.1 calls for use of a reference oil prepared with 37.5 percent hexadecane, 37.5 percent isooctane and 25 percent chlorobenzene by weight, use of chlorobenzene as an aromatic standard seems a poor choice. Figure one, page 38, shows the infrared spectra of benzene, toluene, xylene and chlorobenzene. The weight contributed by the chlorine in chlorobenzene is significant, but contributes nothing to the aromatic absorbance. The result is a disproportionate reduction in the aromatic contribution to the standard. In addition, the chlorobenzene absorption is both unusually weak and significantly displaced in wavelength from the bands that are characteristic of the aromatic compounds actually found in petroleum. Note the poor response of chlorobenzene at 3.4μm.

Calibration of a single channel unit or the aliphatic channel of a dual channel unit can be also be done using actual samples of gasoline, diesel, kerosene, etc., or by using synthetic reference oil standards. Standards may be chosen based on the type of contamination found on a given site, but care must be taken to prepare a standard which emulates the characteristics of the condition of the site. For instance, at an older site, known to be contaminated with gasoline, a gasoline standard may not be appropriate, since weathering and biodegradation may have significantly altered the chemical composition of the gasoline. Dual channel instruments can be calibrated with the 3.4μm channel spanned on hexadecane (C16) and the 3.3μm channel span set on benzene. This scheme, rather than using reference oil for the aliphatic channel calibration, yields data on the aliphatic and aromatic contributions individually.

A dual wavelength measurement calibrated for aliphatic and aromatic response shows the contribution ratio of aromatic vs. aliphatic for gasoline and diesel fuel. Separate measurement of the aromatic fraction allows for easy identification of gasoline from diesel fuel. Such data are useful to distinguish a gasoline from a diesel leak in the case of a fresh spill, and can aid in determining the age of a known gasoline spill. Loss of the aromatic response of a known gasoline spill would indicate an older spill, in which significant degradation and subsequent loss of the volatile BTEX fraction had occurred.

Direct concentration measurement capability of some infrared units allows direct sampling of soil in the field to compliment volatile organic compound analysis in site screening. Total petroleum hydrocarbon analysis in conjunction with volatile organic compound analysis promises to eliminate costs associated with premature closing of sites due to false negative results.

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June July 1993 Soils 43
Lecithins line up to trap oil

These molecules may be the next rage in remediation

Lecithin molecules may be the next rage in soil and surface water remediation. Researchers at the Hebrew University of Jerusalem, Israel, are preparing to field test the technique.

Lecithins are a by-product of the production of edible oils derived from plants, like cotton, rape seed, soya and canola.

The molecules of lecithins are hydrophilic (attracted to water) on one end, and are electrically charged. Their "tail ends" are lipophilic (attracted to fats and repelled by water). So, when lecithins come into contact with water, they organize themselves into bilayers whose heads all face the water and tails are all directed toward each other. Under the right conditions, these
bilayers form particles called liposomes—ball-like structures which trap water.

When spread over surface water fouled by oil spills, the liposomes change the properties of the oil. The lecithin molecules coat the oil with a uni-molecular film, thereby stopping the spread of the oil and breaking it down into sticky droplets which continue to float for easy collection. Breaking up the oily surface into droplets also enables oxygen to seep down into the water, enhancing the survival chances of marine life below the surface. The treatment is said to be effective in both fresh and salt water, and is almost temperature independent, as well as pH independent.

The researchers, who developed and have been refining the process for several years, are biochemistry professors Yechezkel Barenholz and Shimon Gatt of the Hebrew University’s Hadassah Medical School. The method, based on the use of natural materials which are not harmful to the environment, has been tested successfully in pool-sized areas using a broad spectrum of oils, including light, heavy and weathered. With innovative techniques that produce huge quantities of liposomes from lecithin, large-scale field tests are now being planned to demonstrate the practicality of the approach. Barenholz and Gatt believe the procedure will prove effective in dealing with petroleum spill disasters, such as occurred during the Gulf War, and in Alaska, as well as recent spills such as in the Shetland Islands.

Another effect of the technique is that the physical change generated by liposomes in the spilled oil improves the ability of oil-eating bacteria in the water to remove some of the spill by biodegradation. Dispersing oil into droplets permits bacteria to work more effectively.

Experiments conducted with H. Bercovier, also at Hadassah Medical School, prove the bacteria-enhancing qualities of the liposomes. In oil-soaked ground taken from Israel’s oil terminal at Eilat, liposomes encourage the growth of these bacteria by providing them with enriched supplies of the nitrogen and phosphorous they require. By enriching the liposomes with other nutrients, growth of these bacteria can be enhanced even further.

The professors point out that the lecithins which constitute the liposomes are natural substances, inexpensive, non-toxic and readily available. Current methods, using straw, detergents, or mechanical trapping and pumping can cause polluting side effects.

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Bacteria prefer to dine in swanky places

Probiological approach considers abiotic factors in the overall soil matrix

By Ted Brewster

When microorganisms are asked to "dine" on petroleum molecules in a bioremediation project, their surroundings, and the ambiance of their "restaurant" can make a difference in their appetite. Probiological remediation technology looks at the performance of microorganisms in the overall context of the effects of complex organic compounds and other abiotic environmental improvement factors in the matrix. These abiotic factors affect the microorganism behavior in the biological remediation of contaminant compounds in soil and aquatic environments.

Microorganisms such as bacteria, fungi and actinomycete have been applied to specific contaminants in troubled environments with great success, but are not always successful in every field application because of uncontrollable environmental factors. However, probiologial technologies, enable control of environmental factors (except the weather) so optimum conditions can be maintained for better microbial degradation of contaminants. These technologies are called abiotic processes, whether chemical changes or other controlling factors, such as temperature, moisture content, aeration, etc. This is accomplished by detoxifying environments with organic buffering agents, highly available organic microbial residues, and elements which are required for environmental control.

Problems associated with organically based waste products, such as petroleum products released from leaking underground storage tanks, are effectively reduced or completely eliminated from the environment through biological processes. Degradation of petroleum products by microorganisms involves the conversion of energy stored as petroleum hydrocarbon chains into microbial byproducts such as water, carbon dioxide, cellular biomass, organic matters, organic acids and other beneficial inorganic compounds and elements. However, this not only involves many biological reactions, but also many abiotic reactions as well.

The probiological approach uses beneficial organic materials to create an environment where microorganisms can perform their natural remediation functions efficiently. As a result, an environment which supports and sustains the growth of contaminant degrading organisms is promoted. Toxic compounds are buffered or

Ted Brewster is an independent consultant and is the biological remediation specialist for BRS Inc., Gilbert, Ariz.
neutralized by the probiological constituents, enabling the target organisms to better attack and degrade harmful compounds in a more controlled environment.

Probio logic technology was first applied in the agriculture industry to improve soil formation and function. Once established in agronomy, the technology was applied to the wastewater industry. The technology proved valuable there, and only then was applied toward the cleanup of hazardous materials in soils and waters. The success was overwhelming, but not readily accepted because of poor scientific methods to measure the success of such a new technology.

Probio logic processes include the use of beneficial soil microorganisms, microbial byproducts and highly degraded organic matters which increase aeration and water holding capacities of soil. These natural elements also increase soil forming mechanisms and cation exchange capacities in the soil, which assist in the health and production of plant life and indigenous and non-indigenous microbial forms.

Naturally occurring organic materials are mined from surfaces of coal field deposits. These complex materials are converted to liquid form and applied to problem soils to create a more hospitable environment for microorganisms to thrive. The materials provide and free up valuable nutrients and oxygenated compounds which, under toxic conditions, may be unavailable for microbial assimilation. These natural substances, comprised of complex humic materials, assist in the degradation and mineralization of petroleum based chemicals. This is accomplished abiotically and biotically, transforming complex organic molecules and carbon chain compounds into more favorable molecular structure for microbial degradation. This is partly accomplished by a natural chemical mechanism called chelation. Chelation is the bonding of an organic compound to a single element or compound at several points instead of one single point of contact.

Refined petroleum products (gasoline, diesel, jet fuel, etc.) actually go through an abiotic transformation in which the organic complexes play a key role. Organic complexes added to petroleum polluted environments lengthen hydrocarbon chains and remove side chains from alicyclic and polyaromatic carbon chains. This, in turn, allows for easier microbial breakdown of the petroleum hydrocarbons.

When specific organic acid complexes are applied to an environment affected by petroleum contamination, the contaminant can be pulled from the matrix of the saturated soil particles without the aid of surfactants or other chemical components. At the same time, the contaminant becomes a readily available food source for microbial assimilation. The organic complex

Continues on page 48

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binds to the contaminant and creates a longer chained hydrocarbon. The smaller chain hydrocarbons in the C5 to C10 ranges (carbon chain lengths of five to ten carbon units) become less toxic to the microbes by becoming longer. The longer hydrocarbon chains become less soluble and less volatile, and can be better regulated by the attacking microbes.

Small chain hydrocarbons can be very toxic to microbes because the microbes cannot regulate the intake of the compounds. This results in the over intake of the harmful compound, killing the microbe cell. It has been documented that the addition of specific organic acid complexes can cause carbon chains in the length of C5 to C10 to increase to lengths of C8 to C14. Ranges from C10 to C18 have increased to C14 and C24, and ranges of C18 to C30 increase to C24 and C36+. This is readily seen in bioremediation projects that use EPA testing method 8015 modified in the determination of analytical data.

In November 1991, a remediation project was completed in Prescott, Ariz., that demonstrated the probiological technology phenomenon. The preliminary biofeasibility study reported a decrease in total petroleum hydrocarbon (TPH) levels from 1,500 ppm to 10 ppm in seven weeks. Arizona Department of Environmental Quality standards of <100 ppm was accomplished in 10 days. In the actual on-site project, TPH levels decreased from 1,500 ppm to 21 ppm in five months, with only one mechanical aeration procedure. The carbon ranges reported by EPA modified method 8015, increased from C10 to C22 range to C16 to C36+ range. This has been reported in many studies conducted in laboratory and field projects. TPH levels were reduced to <120 ppm within 10 weeks, but the desired TPH levels took longer to accomplish because of the non-homogenous nature of the decomposed granite soils.

Generally, longer chained hydrocarbons are more easily bioremediated by aerobic organisms than shorter chained. Because most microbes favor longer chained hydrocarbons as a food source, the newly formed petroleum complex is more readily degradable and prone to microbial degradation. The microbe can “choose” the compounds it desires for energy. The result is the orderly degradation of the original petroleum product from longer chains to shorter. This was recently outlined in a biofeasibility study completed for a proposed in-situ bioremediation project in Fallon, Nev. EPA test method 8015 modified reported a decrease in the C6 to C10 range from 520 ppm to 52 ppm. Petroleum products in the C10 to C22 range decreased from 4,100 ppm to 22 ppm. Products in the C22 to C36 range decreased from 170 ppm to <5 ppm. Over all TPH reduction over three weeks was from 4,790 ppm to 74 ppm, a 98.5 percent decrease.

This suggests that the upper level hydrocarbon lengths are more readily remediated biologically than the lower chain hydrocarbons. However, the TPH level reported in the lower carbon ranges may also be the result of broken chains or partially remediated compounds within the various products of petroleum fuels. This may explain why TPH levels below 500 ppm are not readily remediated biologically compared to those in higher TPH ranges.

The complex molecules that attach to the various hydrocarbon chains are loaded with six carbon and five carbon ring structures, oxygen, oxygen-hydrogen groups and other organic compounds. Since aerobic microbes favor biologically pre-manufactured complex organic molecules with attached oxygen groups, the microbes attack the newly formed complexes and degrade them at an accelerated rate compared to those without the oxygen and oxygen-hydrogen groups. Because oxygen carrying compounds are available in these special complexes, fewer mechanical aeration procedures are required. The organic complexes are readily degraded by the microbes for construction of new cells and the production of energy. In fact, the organic complexes themselves are the remains of ancient microbial cells which were once formed under aerobic conditions. Many organic complexes found in peat bogs and coal fields were formed under anaerobic environments. These compounds are full of poor chemical complexes, such as formaldehyde, ketones and alcohols, all of which are preserving agents that inhibit the biodegradation of organic compounds, such as petroleum products, under aerobic conditions.

Another feature of the complexing process is the decrease in volatilization of the smaller chain hydrocarbons, as well as the tie-up of harmful metals such as sodium, chlorine and other heavy elements. Because the hydrocarbon chains are lengthened or altered (complexed with the organic compounds), the contaminant structure is less volatile and cannot readily escape into the atmosphere.

Hydrocarbon side chains, which normally inhibit microbial degradation processes, are removed and complexed as well. Heavy metals are chelated or complexed to the organic compounds. The result is a complexed metal that cannot harm the microbes because it has been chemically entrapped by an organic compound—a process that could be referred to as detoxification of the microbial environment. The metal can then be worked on or avoided by the microbes in the affected environment. While there has not been a great deal of research on exactly what happens to these chelated complexes, evidence in other areas of study suggests that biotransformation, leaching, or other natural phenomena occur to reduce the metals.

After the detoxification process has begun, nutrients and microbes can be added to the environment. Many nutrients are used in bioremediation processes, but are added in low doses. The microbial use of macronutrients such as nitrogen, phosphorus and potassium, is greatly inhibited without the presence of micronutrients such as magnesium, boron, iron, sulfur and many others. The micronutrients assist in the microbial use of the macronutrients. Normally, there are enough micronutrients in a healthy soil, but in contaminated environments,
the micronutrients may be entrapped in the contaminating compounds.

When a large quantity of fertilizer is added to the soil, it becomes tied up in the soil within a very short time. As a result, the microbes cannot use the nutrients. To prevent such waste of nutrients, the microbes can be spoon fed with small applications of the nutrients over a calculated period of time. The microbes are fed only what they need in each dose. The nutrients themselves are chelated with complex organic compounds to prevent their tie up within the soil. The chelated nutrients are more readily used by microorganisms because they are attached to favorable microbial compounds.

In a bioremediation project performed near Vanderbilt, Texas, at a large oil field, TPH levels were radically reduced in approximately 2,800 cubic yards of tank bottom materials. TPH levels were decreased from 75,000 ppm to less than 10,000 ppm in six weeks. This was accomplished with only two inoculations of probiological agents and several mechanical aeration procedures. The most notable change in the tank bottom materials was in the color and odor of the soils over the six week period. The materials changed from a black oozing soil with hard crust layers of calcified materials to a fluffy, healthy looking soil. This transformation is noticeable in most projects in which probiological agents are used.

Probiological compounds work with natural microbial forces by providing protection and proper nutrients to the microorganisms working to degrade the organic compounds. This assists the hydrocarbon degrading microorganisms by making the contaminant more available for microbial assimilation and by detoxifying the microbes’ environment. Nutrients are added to fuel the degradation process, and often, non-indigenous microorganisms are added to the environment to ensure sufficient levels of hydrocarbon degrading organisms.

Increasingly, bioremediation is becoming the remediation method of choice for the cleanup of petroleum hydrocarbon contaminated soils and those that are polluted with pesticides, insecticides, herbicides, PCBs (polychlorinated biphenyls), PCPs (pentachlorophenyls) and others. Bioremediation may not be practical in all applications, but is becoming more applicable in more cases as research and trial and error further define process performance. Probiological remediation is redefining the bioremediation process, and is being selected because of its favorable treatment of the environment. The effectiveness of the microbial factors involved in bioremediation can be drastically improved using probiological compounds. Understanding both the biotic and abiotic processes of bioremediation can help establish standards to achieve successful results.

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Write in 393

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With so much attention focused on the cleanup of contaminated soil, it is refreshing to hear about clean soils' ability to clean up the air. Soil beds can eliminate volatile organic compounds, odors and inorganic gases from the air. Here's how this works:

Polluted and odorous air from an enclosed environment is pumped into a network of perforated pipes buried in a porous soil bed. The waste air flows uniformly throughout the bed and upward through the soil. Billions of naturally occurring bacteria and fungi degrade and oxidize the pollutants to CO₂. Oxidation is supplied in excess, as part of the contaminated air stream, and continuously renews the soil bed's adsorption capacity. A typical soil bed is 20,000 square feet, or about half an acre, and two to three feet deep.

Or, a mobile biofilter system with a low flow pump can treat hydrocarbon emissions from soil vapor extraction systems. One company, Bohn Biofilter Corp., of Tucson, Ariz., makes a portable, enclosed unit eight feet wide, 27 feet long that adsorbs and degrades hydrocarbons to efficiencies as high as 99 percent.

Contaminated air from soil vapor extraction wells is pumped into a network of perforated pipes buried in a soil and compost mixture in the unit. The waste air flows uniformly throughout the bed and upwards through the soil. "No pollutant residue remains in the biofilter bed. The bed is as free of petroleum hydrocarbons at the end of the job as it was when cleanup was begun," says Hinrich Bohn, president of the company.

Many states prohibit the air from vapor extraction systems from being vented directly into the atmosphere. So, treating the extracted air can be a costly step in vapor extraction systems. Some systems use a high flow pump to extract the hydrocarbon vapors from the soil and pump them into catalytic incinerators, carbon beds or other oxidizing or combustion chambers.

Soil bed technology is relatively inexpensive, due to both low installation expense and low maintenance cost. According to Bohn, installation costs range from $5 to $20 per cfm of waste gas. The beds are self-maintaining. The pipes are non-corrosive and there are no added costs for catalysts, chemicals or fuel. Soil beds that treat moist air streams require no added moisture. However, if the bed is small relative to the waste gas flow rate, it may need to be watered occasionally.

Soil beds remove 99.9 percent of easily oxidizable gases, such as aldehydes, ketones, organic acids, amines and organic sulfur compounds. They also remove 99 percent of inorganic gases, such as NH₃, NOx and H₂S. They remove 90 percent of relatively nonbiodegradable gases such as methane, propane and carbon monoxide. Soil beds are not effective for nonbiodegradable gases such as halogenated hydrocarbons, which degrade too slowly for soil bed treatment.

Soil beds are nontoxic, nonflammable and create no secondary pollution, according to Bohn's research. There is no danger of groundwater contamination, since the volatile pollutants are converted to CO₂. They also remove all liquids and particulates from the gas flow.

"In Europe and Japan, biofiltration is now considered to be a standard method for the odor abatement of exit gases," says Bohn. "While large areas are required, they can be used—as long as the surface remains unsealed. A soil bed installed in a Coronado, Calif., sewage facility is the center of a group of boutique shops and outdoor restaurants," he says.

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</tr>
</thead>
<tbody>
<tr>
<td>PCBs</td>
<td>1-50 ppm</td>
</tr>
<tr>
<td>Total Petroleum Hydrocarbons</td>
<td>10-1000 ppm</td>
</tr>
<tr>
<td>PCP</td>
<td>5 ppb-50 ppm</td>
</tr>
<tr>
<td>PAHs†</td>
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June July 1993 Soils 71
Invincible AirFlow Systems offers compact blowers with increased power

Invincible AirFlow Systems, Baltic, Ohio, introduces a line of TurboFlow blowers and exhausters designed with a compact profile that provides more power in less space, which makes them more efficient than conventional multi-stage machines.
The backward-curve, single-stage, gear-driven exhausters develop up to 12,500 ICFM and 11" HG. The blowers deliver up to 12,000 SCFM and 8.3 PSIG, the manufacturer says. Built for continuous operation, these blowers and exhausters are available in models with five to 200 h.p. motors.

Containers sample gas range organics

Environmental Sampling Supply, Oakland, Calif., offers sample containers and equipment for gas range organics and diesel range organics. Available components include 60ml wide mouth vials for soil samples, premeasured vials of Purge & Trap grade methanol, sterile syringes (cut for soil core sampling), soil scoops, labels and custody seals.

Paragon Environmental thermal oxidizers can be field retrofit for catalytic operation

Paragon Environmental Systems, Escondido, Calif., says their thermal oxidizers can be field retrofit for catalytic operation, which provides savings in fuel costs when soil vapor concentrations are low.
The conversion takes a few hours to complete. For customer convenience, field service technicians are available to perform the modification. All Paragon thermal oxidizers are complete, preassembled systems with full automated controls. All instrumentation and safety equipment required for permitting is included. The units are either side or trailer mounted.

Portable workstation tests PAH on site

Quantix Systems, Cinnaminson, N.J., says their portable workstation can now detect polynuclear aromatic hydrocarbon (PAH) contamination at sub-ppm sensitivities on site.
PAH compounds are found in diesel fuel, kerosene, motor oil and jet fuel. The workstation also detects BTEX at sensitivities of 3.5 ppm for soil and 250 ppb for water.
Ohmicron debuts RaPID Assay® for PCP detection

Ohmicron Corp., Newtown, Pa., introduces the RaPID Assay® kit that tests pentachlorophenol (PCP), widely used as an insecticide and fungicide by the wood treatment industry to control fungal rot and wood boring insects. The kit applies the principle of enzyme-linked immunosorbent assays to the determination of pesticides and environmental contaminants. The kit contains all reagents, tubes and calibration materials required to perform the test.

HNU offers software for GC

HNU Systems, Inc., Newton, Mass., introduces PeakWorks™, a user-friendly software program that enables PC control of the Model 311D portable gas chromatograph. This software enables users with real-time dual chromatogram acquisition, which includes integration parameters, display and editing, conventional storage that does not require inflexible cards; identification libraries (cf unlimited size); customized reports; and single-and multi-level calibrations for individual compounds.

New tool available for product recovery

The Pro Bailer, from Universal Environmental Technologies, Nashua, N.H., is a new tool for product recovery that is 16.5" long, 1.75" in diameter and weighs 3.5 lbs. This unit is housed in a stainless steel casing and can recover product from wells with diameters of 2" or more and depths to 200'.

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ConSolve has 1.2 version of SitePlanner™ software

ConSolve, Inc., releases Version 1.2 of SitePlanner™, a computer-aided engineering data analysis and visualization tool for hazardous waste site assessment and remediation.

The new version offers improvements, including enhanced 3D modeling, stratigraphic modeling and volumetric calculations. It also can generate production-quality engineering maps and drawings quickly and can be used on PCs running X terminal software, which allows a single UNIX server to provide office wide access to SitePlanner™ over a PC network.

Columbus offers air drier for labs

To prevent evaporation of water from laboratory samples, Columbus Instruments International Corp., Columbus, Ohio, developed the condensing air drier that restores moisture to its source, drying air, but keeping the sample wet. This drier allows laboratories to replace refrigeration or water cooling methods.

BioSolve™ agent passes soil, water cleanup test

Western States Biosolve, Huntington Beach, Calif., says their hydrocarbon mitigation agent, BioSolve™, a biodegradable surfactant based concentrate, has been tested by universities and laboratories and is found to be effective in dealing with hydrocarbon related problems.

BioSolve™ can be used in degassing underground pipelines, UST washouts, vapor suppression, spill cleanup, remediation of soil and water, sludge reduction and recovery enhancement, the company says.

The agent does not contain enzymes or bacteria cultures.

Ensys offers test kit for groundwater

Ensys Environmental Products, Inc., Research Triangle Park, N.C., introduces the Petro Rxc® water test that can be used to identify the direction of contaminant plumes, the correct placement of monitoring wells, and for random sampling.

The test utilized immunoassay technology to test samples for petroleum hydrocarbons at 165 and 1650 ppb.

Pugmill Systems acquires Davis

Pugmill Systems, Inc., Columbia, Tenn., announces the purchase of manufacturing facilities and product lines of Davis Pugmill, Inc.

Pugmill can now offer customers a complete line of stationary and portable pugmill mixers for stabilized road base, sludge and waste remediation/stabilization, roller compacted concrete, cold mix asphalt, lime additive and control systems.
SPI thermal remediation plants get stamps of approval

The plants pictured here get high approval ratings from their owners. All were built by SPI, a company operated by people with years of experience in building this type of equipment. Moreover, SPI builds it all at one facility. Thus, the components are designed to work together as a complete system, unlike some that are pieced together from various sources.

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  Once the tank has been cleaned, a safe entry permit allows personnel to enter the tank. All dried solids are removed and containerized. They are tested prior to disposal by recycling to asphalt plant or cement kiln. Hydrocarbons in the temporary storage tank can be mixed with existing product for reuse. Water that is drawn off the bottom of the temporary storage tank is filtered again down to one micron to remove any suspended solids. The company says typical costs, based on 4,000 gallons of sludge average about $13,000, depending on hazardous constituents and transportation costs. Terminal Technologies also handles all EPA paperwork, lab analysis, discharge analysis and permitting.

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The base of the 16 foot long steel container contains a series of well screens packed in pea gravel and protected by steel tracks. The tracks allow a loader to drive into the unit to load and unload soils. Soil is loaded into the vacuum chamber to a depth of 18 inches and 3,000 cfm of air is drawn through the soil, creating a stripping effect and a vacuum gradient. Then, the infrared carriage is rolled into position over the container. This produces hot air and radiant heat which heats the soil to the desired temperature—300° to 900°F. The infrared heat raises the temperature of the top few inches of soil, which then becomes a convection emitter of heat. An extraction fan pulls air downward through the soil increasing the temperatures of the lower layers of soil. The downward air flow and temperature differential between the soil surfaces determines the rate of radiant energy transfer and creates reduced pressure in the extraction chamber. Volatilized gases are swept from the chamber into an emissions control system, which is a cooling loop, followed by a carbon filtration system. Once the carbon has been saturated, hot air from the I.R.V. unit can be used to heat the carbon and desorb the contaminants which are recondensed and drummed as a liquid. Petroleum products are recycled as off-spec fuel.

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