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Benzene health questions

Thermal Treatment

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— Satchel Paige

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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

Cures, treatments, solutions—they’re seldom simple. That’s probably because diseases, disasters and problems are usually complex. Even a Band-Aid™ is not necessarily the simple, single option solution it’s cracked up to be—you have lots of choices to make...fabric or plastic, fleshtone or clear...and then there’s all those shapes and sizes. And, by the way, I’d like to know who uses those little tiny ones, and what on earth they use them for. I digress...

The solutions for the thousands of hydrocarbon contaminated sites across this country are no exception. No two sites are the same...no two solutions are the same. Remediating each site becomes a series of choices, depending on many site specific factors. The Location: is it in a heavily populated area, or out in the sticks? What kind of contamination is present? What is the future plan for the site? Playground? Heavy industry? The Contamination: what is it? How much is there? How long has it been there? How deep? How close to water? The Plan: How much time is available? What will the regulations allow? What will the neighbors allow? How much space is available? The Money: How much can we spend? How can we get the most for our dollar? Where can we get financial help?

The point is, with all these options, there’s plenty of opportunity for all the treatment technologies. As this industry develops and as new treatments are invented, it is important that everyone keep in mind that each treatment will have strengths and weaknesses—depending on site conditions. In addition, it is important that service providers and users alike keep in mind the potential for combining technologies as the best approach for some sites.

The industry will only hurt itself if the different technology providers begin to eye each other as a threat and begin swapping and back-stabbing one another. Imagine the result in the medical profession if chemotherapy providers started bad-mouthing radiation treatment for cancer, and vice versa. There is opportunity for both approaches—both can be effective, and both have strengths that lend themselves to application in particular, specific situations, depending on the patient and the problem. And, there are times when both can work together to help an individual patient. It is the same with remediation technologies.

I don’t want people to perceive the soil remediation industry the way I perceive the carpet cleaning industry. The providers of the various methods—dry, wet, steam, chemical, extraction, shampoo dip—whatever—are not content to explain to me the advantages of their system. They have to go on to explain how their competitor’s system will cause rot, fading and brin damage to my fibers. Consequently, I have very little faith in any of it.

The reason I bring all this up is that in putting together this issue, I noticed several examples of competitive jabbing among the providers of various technologies. (Don’t bother looking—I took them all out.) And, in most cases, it was a scuffle between two technologies that theoretically, at some sites, could combine beautifully in a treatment train to produce a more effective, more efficient result than either could accomplish alone.

If the providers of the various technologies downgrade the other technologies to clients, the result will be a decline in the credibility of everyone in the cleanup business. The regulations and the unseen subsurface provide plenty of mystery and uncertainty. Let’s not add the downgrading of other technologies to the mix.

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Benzene mixtures 
raise health questions

A closer look at carcinogenic potential of gasoline and jet fuel

By Carolyn Harper, Ph.D., Obaid Faroon, Ph.D., and Myron Mehlman, Ph.D.

While little is known about the cause-effect relationship between the exposure to benzene-containing mixtures and their carcinogenic potential, the widespread use of gasoline and jet fuels make it imperative to look closely at what we do know. Benzene is classified by the EPA as a human carcinogen.

Gasoline and jet fuels are complex, synthetic mixtures that do not exist naturally in the environment. Processes that modify the character of gasoline include catalytic cracking, coking, alkylation and catalytic reforming. Gasoline, containing more than 1,000 possible substances, (see box, page 7) is one of the more complex chemical mixtures to which humans are exposed.

The composition of gasoline varies by geographic region, season of the year, performance requirements (octane rating), blending of stock and source of the crude oil.

The hydrocarbons in liquid gasoline consist of 60 to 70 percent alkanes (paraffins), 25 to 30 percent aromatic compounds, five to 10 percent alkenes (olefins), octane enhancers and lead scavenger agents. Some of the many chemicals in gasoline and jet fuels are carcinogenic. The concentrations of alkyl benzenes present in gasoline are summarized in figure one, page 32.

Gasoline and jet fuel are composed of several hundred hydrocarbons in the range from C4 to C11.

As a pure chemical, benzene is a colorless, volatile, flammable liquid with an aromatic odor. Benzene recovered from petroleum and coal sources is used primarily as an intermediate in the manufacture of other chemicals and end products. Benzene is used extensively as a solvent in the chemical and drug industries as a starting material, and an intermediate in the synthesis of numerous chemicals, and as an additive in gasoline and jet fuels.

The annual U.S. production of benzene is in excess of one billion gallons, accounting for over 30 percent of the total produced worldwide.

Benzene is obtained almost entirely from petroleum sources and is present in gasoline and jet fuel at concentrations generally between one-half to two percent, in some cases, up to four to six percent.

Exposure to benzene and benzene mixtures by humans most frequently occurs via inhalation and skin contact. Inhalation is the primary exposure route for the general population.

According to the International Agency for Research on Cancer (IARC), Lyon, France, an estimated three million workers may potentially be exposed to benzene annually. Benzene comprises approximately one-half to six percent by volume of the total hydrocarbon emissions from gasoline engines. The magnitude of exposure to benzene mixtures is greatest for refinery workers. However, far greater numbers of people are exposed as a result of benzene release from gasoline filling stations and auto exhaust.

Benzene is everywhere. It has been identified in soils, in freshwater, saltwater, drinking water, groundwater and the air. Increased environmental or occupational levels to the substance may be used to monitor gasoline or jet fuel exposures, known as a biomarker of exposure. Biomarkers of benzene exposure, such as elevated urinary phenol levels, are often used to detect exposure to gasoline or jet fuel.

The average level of urinary phenol excreted by gasoline workers in a test was 40 ng/L (nanograms per liter), considerably higher than the normal amount of less than 20 ng/L.

(Although, the range of benzene content in this test, conducted by K.P. Pandya, and published in the Annual of Occupational Hygiene, 1975, was relatively high—10 to 17 percent, compared with typical American gasoline products at one-half to six
percent typical benzene content.)

Measurable levels of benzene in the air range from less than five to 64.6 ppb. The highest value, 9,900 ppb, was measured near a gasoline bulk loading facility, and the second highest, 9,400 ppb near a similar facility, the loading and discharging of gasoline from road tankers. IARC, however, documents much lower levels of benzene in the air, ranging from nine to 19 ppb.

A correlation has been observed between concentrations in ambient air containing benzene and in alveolar (exhaled) air. Analysis of air samples for benzene at a gasoline refueling station and exhaled breath levels of benzene in the station attendants showed that benzene levels in the breath samples taken during refueling operations were considerably higher than during times when refueling was not occurring. Concentrations of benzene in exhaled air ranged from 210 to 458 ng/L during refueling and from 52 to 191 ng/L when refueling.

Continues on page 324

### Some chemicals in gasoline

<table>
<thead>
<tr>
<th>Benzene</th>
<th>Butanes</th>
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<tr>
<td>1,3-butaediene</td>
<td>Pentanes</td>
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<td>Toluene</td>
<td>2-methyl-2-butene</td>
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<td>Xylenes</td>
<td>2,2-dimethylbutane</td>
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<tr>
<td>Ethylbenzene</td>
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<td>Methylcyclopentanes</td>
<td>C11-alkylbenzene</td>
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<td>Alkenes</td>
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Partial list of some of the key chemicals in gasoline.
Portable unit takes petroleum contaminated sandy soils down to non-detectable levels.

Thermal treatment heats up

Case histories reveal strengths of thermal desorption at various sites

Thermal desorption has progressed to the point where numerous manufacturer's mobile units are busy in the field, remediating sites with a wide variety of contamination problems. These case histories show examples of differing site conditions and performance capabilities of thermal desorption technology.

Unit handles sandy soils

Kalkaska Construction Service (Kal Con), Kalkaska, Mich., ran their mobile soil remediation unit through a pilot study to test its performance on sandy soils. The unit, manufactured by ADM, Inc., Huntertown, Ind., processed approximately 1,400 yards of sandy soil contaminated with weathered crude oil.

Soils at the site were brown medium sand with particle size ranging from .2mm to .6mm. Soil moisture content was elevated, as groundwater was encountered only eight feet below the surface, and because of precipitation that occurred during the project.

Analysis determined that the sand contained 1.7 percent oil and grease, and 10,600 ppm total petroleum hydrocarbons and 15 percent moisture. The oil and grease was extracted and analyzed, revealing that it was composed of 59 percent saturates, 25.6 percent aromatics and 14.6 percent non-hydrocarbon. A true boiling point gas chromatographic test identified the distribution of organics by carbon number. The material was predominantly comprised of carbon chains ranging from 12 to 40 carbon molecules, with an average length of 25. Few light ends of less than 12 carbons were present. Lab tests found total petroleum hydrocarbons ranging from 10,000 to 20,000 ppm.

The lab conducted additional tests on samples of the material which appeared to be weathered crude oil, to determine if it would respond to the remediation unit's temperatures and retention time to meet cleanup standards, considering the presence of long chain hydrocarbon molecules.

A flame ionization detection test was performed on the material three times: as received, after heating at 250°C for ten minutes, and at 300°C for ten minutes. Treatment in a static system at 250°C brought the oil and grease concentration down to 3 mg/g. Treatment of 300°C achieved .2 mg/g. Curve C in figure one, page 9,
demonstrates adequate hydrocarbon removal. The second jump, between 400 and 500°C, evident in all three curves, is generally accepted to be organics inherent in all soils, biological in nature, not contamination.

The ADM unit achieved soil exit temperature in excess of 800°F after a residence time in the drum of approximately seven minutes. The afterburner operated in the 1,600°F range, oxidizing the hydrocarbons driven from the soil, as verified by emissions tests.

Discharged soil samples tested nondetectable (below 10 ppb) for BTEX.

Write in 737

Unit cleans up 50,000 cubic yards at former waste oil lagoon.

Site had 40,000 ppm as contaminant concentration

The rapid and permanent effects of low temperature thermal desorption attracted O’Brien & Gere Engineers, Inc. to remediate a former 1.7 acre waste oil lagoon. The lagoon received waste lubricating oils from a manufacturing process for more than 50 years.

First, free liquids were removed from the lagoon and recycled. Then, the remedial focus turned to excavation, thermal treatment and backfill of over 50,000 cubic yards of soils highly contaminated with petroleum hydrocarbons. O’Brien & Gere worked with the Soil Purification division of Astec Industries, Inc.,

Continues on page 10→

ADM SOIL PLANTS ARE IN A CLASS OF THEIR OWN

Conceived and built to process the highest temperatures around the clock at its actual production rates, ADM remediating soil plants reflect the quality, completeness, and features that only an experienced manufacturer can provide. ADM characteristics such as self erecting, simple hook-ups, and brand name parts are incorporated with counterflow technology, high-temp baghouses and 1 second retention oxidizers. Simply stated. . ADM beats everything in its class.

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Thermal treatment, from page 9

Chattanooga, Tenn., for more than a year to develop a site specific system for the project.

The average contaminant concentration at the site was 40,000 ppm. The Btu value of the contaminant was 23,000 Btu per pound, which is higher than most fuel oils. Since the concentrations of contaminants were expected to be in the 40,000 ppm range, issues of process control and plant safety were the focus of the planning.

Typical alternatives include extensive soil blending with clean soils or very low processing rates combined with very high excess air levels. Both these alternatives are inefficient. But, with the input of combustion, a low temperature thermal desorption system was developed that could process soils at minimum temperature, use heat from the oxidation of the contaminants in soil heating and monitor and control process safety within the system while maintaining the maximum processing rate. The system typically operates 24 hours a day, seven days a week with scheduled shutdown for maintenance.

The procedure to obtain operating permits for the project required the application of BACT (Best Available Control Technology) to each of the air pollution control devices. Astec supplied calculations of the minimum control efficiencies for the air pollution control equipment and stack gas constituents.

As the heat evaporates the contaminants, they are routed to a three part system to remove vaporized oils and particulates. The oils are oxidized, transforming them into carbon dioxide and water. The clean particulate is collected and recombined with the other soil particles, leaving all solids clean, remoisturized and ready for testing and backfill at the site.

The flow diagram of a standard thermal desorption process is similar to incineration, but the process is significantly different. Thermal desorption evaporates the organic compounds at around 500°F to 800°F, where incineration reduces all materials to ash at temperatures up to 1,800°F. Incineration requires a great deal more fuel than thermal desorption. Since low temperature thermal desorption only destroys the organics, the soil is left unchanged and suitable for return to the site.

The system components in a low temperature thermal desorption units can be finely tuned according to specific treatment requirements that vary from site to site. Seven portable components made up the system:
- soil feed system,
- primary treatment unit,
- soil discharge unit,
- secondary treatment unit,
- heat exchanger,
- baghouse,
- control house.

The feed system meters soil into the primary treatment unit. Here, preparation plays a vital role. Debris such as large rocks, roots and trash are screened and aggregated clay materials are mechanically treated to decrease particle size. Materials are also blended to achieve uniformity of contaminant concentration at about four percent and moisture content of 12 to 15 percent.

The primary treatment unit is a rotary chamber where soils are heated by a direct-fired, dual fuel burner (natural gas and No. 2 fuel oil) until contaminants are vaporized and become part of the air stream. Soil retention time in the unit is controlled by a variable-speed rotational drive system. This control allows optimum treatment of both heavy, long-chain hydrocarbons, as well as the lighter, short-chain hydrocarbons. A feed forward signal from the feed system controls an air injection system into the heart of the chamber. The design was based on flame kinetics with consideration of gas segregation within the chamber which can actually use a controlled portion of the contaminants for soil heating. Vaporized hydrocarbons leaving the chamber are continuously measured by a system which can adjust the process if safety parameters are exceeded.

Soils treated at temperatures ranging from 500 to 800°F (typically 650 to 700°F) are discharged from the chamber into the soils handling unit. Larger particulates entrained in the air stream are removed by a multi-tube collector (cyclone separator) and blended with the treated soil. Adding water for cooling and dust control, this unit provides a stockpile of treated soil for use as on site backfill.

After initial particulate removal, exhaust gases are treated by controlled oxidation in the secondary treatment unit. Gases travel through ducts to this unit where a direct-fired
burner provides supplemental energy and oxygen to promote contaminant destruction. Once in the secondary unit, gases are heated to temperatures ranging from 1,400 to 1,800°F (typically 1,500°F), and reduced primarily to carbon dioxide and water.

Secondary treatment unit exit gases are conveyed through the heat exchanger where they are cooled prior to discharge. The heat exchanger also preheats ambient air that is used at several points within the process and is crucial to the success of the system. The unit itself consists of an air-to-heat exchanger, a cooling air fan, and associated ductwork, dampers and controls. The heat exchanger allows the system to use pre-heated combustion air to reduce fuel consumption.

Gases exit the exchanger at approximately 350°F for final particulate filtration in the baghouse. The bags are finely-needled filter media. While particulates collect on the fibers of the filter material and in the particulate cake, exhaust gases and water vapor pass through the cake of collected material as well as through the filter material itself. Resultant particulate is removed from the baghouse and conveyed to the treated soils handling unit for processing, while the filtered exhaust is discharged to the atmosphere through an exhaust stack. To monitor emissions and document compliance with regulatory requirements, CEM (Continuous Emissions Monitoring) equipment is installed on the discharge stack.

The entire thermal desorption process is monitored in the control house. This portable control room is equipped with instruments to allow operators full control of the system. An automatic system of “smart controllers” pinpoints operational problems as they arise.

With the system in operation since July of 1992, the cleanup goal of <100 ppm is being surpassed with most samples testing at less than 50 ppm total petroleum hydrocarbons.

“We took a tough application coupled with complex remediation issues and came up with a site specific solution, a solution that is meeting the client’s objectives cost-effectively and permanently,” says Joseph Sorena, project supervisor for OBG. “This technology also prepares the site for future redevelopment. The ability to process soils at higher contaminant concentrations puts us on the cutting edge of on-site cleanup.”

Navy chooses thermal for cleanup

Over 50 years of firefighter training at a U.S. Navy facility in Norfolk, Va., had left an accumulation of fuel contaminated soils that had to be remediated before construction could begin on a new training facility.

The Navy determined thermal desorption was the most cost effective and certifiable means of treating soils on site. A work plan was implemented to excavate, stockpile and remediate all contaminated soils over 100 ppm total petroleum hydrocarbons. Clean soil was to be backfilled and compacted in the original excavation areas where construction of the new facility would start as soon as remediation was complete.

Continues on page 12→
Navy uses Purgo’s unit to clean soils with contaminants over 100 ppm.

**Thermal treatment, from page 11**

Purgo, Inc., of Richmond, Va., and S.H. Barner, Inc., of Williamsburg, Va., teamed up to do the job for the general contractor, W.M. Jordan Co., Inc., of Newport News, Va. Barner handled the removal and treatment of all contaminated water, while Purgo was responsible for processing of all contaminated soil.

Purgo brought in their portable soil remediation unit, manufactured by ThermoTech Systems Corp., Orlando, Fla. Soil temperatures in the desorber were maintained at 650°F, and afterburner temperatures at 1,400°F throughout the project. As soils were excavated, contamination levels were monitored with a photoionization detector to determine the limits of excavation. Lab analysis confirmed the limits of excavation through soil sample testing.

The project began with a schedule of 20 hours of processing and four hours of maintenance per day. Soil samples were taken a maximum of every 175 tons, as measured by the unit’s weigh bridge scale, and analyzed for total petroleum hydrocarbons by EPA method 8015 and for BTEX (benzene, toluene, ethylbenzene, xylenes) by EPA method 8240.

Required cleanup levels were 50 ppm total petroleum hydrocarbons and 10 ppm BTEX.

Original estimates predicted 14,000 tons of affected soils to be remediated in 60 days, weather permitting. But, contamination was more extensive than anticipated, and ultimately, 25,065 tons were thermally treated in less than 90 days.

Over 145 soil samples were analyzed for total petroleum hydrocarbons and BTEX without a failure. Initial total petroleum hydrocarbon levels ranged as high as 14,365 ppm. The majority of total petroleum hydrocarbon results were less than 2.85 ppm, and all BTEX results were less than 23 ppb.

Soil processing rates varied from 16 to 33 tons per hour, depending on moisture content and weather conditions.

**Thermal makes progress in Canada**

The low temperature thermal desorption industry is less developed in Canada than in the U.S. The primary reasons for this are Canada’s large area and harsh climate.

One company, Canada Soil Exchange, Inc., Nepean, Ontario, has been a pioneer in getting the word out to regulators and clients.

One recent project proved the potential for on-site remediation of hydrocarbon contaminated soils in the Canadian marketplace.

The Canadian Department of National

*Continues on page 14*
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.

SPI plants remediate hazardous and non-hazardous waste either by high temperature incineration or by low temperature thermal desorption. The plants may be either portable or stationary and may include the following components:

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Write in 292
Thermal treatment, from page 12

Defence (DND) identified hydrocarbon contaminated soil while undertaking a tank replacement at Canadian Forces Base Borden, north of Toronto, in the fall of 1992. Contaminated material was excavated and moved to a temporary staging area while a plan was considered. DND asked Canada Soil Exchange, Inc., to use a low temperature thermal desorption unit, a Cedarapids 64LT, to decontaminate the soil. The decision-making process considered:
- cost effectiveness,
- ability to remediate on site,
- time to complete,
- ability to pre-target cleanup levels,
- ability to work in Borden’s severe winter weather.

A Sprung temporary structure was erected to house the unit. The drier, baghouse and oxidizer were set up inside the structure. Contaminated material was loaded into the supply hopper outside the building, and conveyed inside for preparation. Of particular importance on this project was the feed preparation equipment incorporated in the plant. Large frozen clumps of soils were reduced to manageable 50mm minus size prior to delivery to the drier.

Total project duration was less than six weeks from initial grading, though demobilization and site cleanup. Soils contaminated with diesel fuel at levels ranging from 400 to 5,500 ppm total petroleum hydrocarbons were remediated at temperatures up to 600°F to final levels of .2 ppm for an average destruction and removal efficiency of 99.97 percent. The unit processed the soils at a rate of 24 long tons per hour.

Emission monitoring was completed in accordance with the requirements of the Ontario Ministry of Environment and Energy, and the Canadian Ministry of Environment. Since thermal treatment can be implemented year round in cold Canadian winters, it promises to be a popular option for future projects.

**Write in 740**

Thermal tackles UST contamination at tank farm

Hanson Engineers, Inc., Springfield, Ill., took a look at site in Paris, Mo., where a 20-year-old underground storage tank system was believed to be the source of petroleum contamination and recommended on site thermal treatment.

Regulators from the Missouri Department of Natural Resources issued one of its first permits for thermal desorption to Hanson. Soils were identified based on visual observation and screening for volatile organic hydrocarbons with a photoionization detector equipped with a 10.2 eV lamp calibrated to an isobutylene standard. The 2,250 tons of contaminated soil was excavated and stockpiled on industrial grade polyvinyl sheeting to prevent leachate formation or migration.

Working with Midwest Soil Remediation, Inc. of Wheaton, Ill., Hanson collected samples once a day for every 100 cubic yards of treated soil. Samples were analyzed for total petroleum hydrocarbons and for BTEX. Missouri regulators accepted Hanson’s closure report for the tank system only two weeks after it was submitted.

**Write in 741**
Date: ________________________________

To: Cedarapids Inc Soil Remediation

From--
Name: ________________________________

Title: ________________________________

Company: ________________________________

Phone: ________________________________
FAX: ________________________________

Notes:

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What it all means

Handy definitions to various remediation technologies

*Air sparging*
Groundwater and/or liquid contamination in the saturated zone prohibits vacuum induced air flow and eliminates the option of vapor extraction. This can be overcome by sparging. Air is injected into the saturated zone under pressure, creating an oxygen-rich zone in which adsorbed and dissolved phase contamination are volatilized and discharged to the surface or a collection system. Benefits include: volatilization of adsorbed phase contaminants within the oxygen-rich zone; provision of oxygen to enhance biodegradation of contaminants; removal of dissolved phase contamination; and oxidation and precipitation of iron or manganese, which might cause a fouling problem with stripping equipment.

*Air stripping*
This is the most efficient means to remove volatile organic compounds from groundwater. In the air stripper, the surface area of water is dramatically increased by a variety of means (such as having it flow over a packing) while a counterflow of air volatilizes the contaminant. Vapors created by the process are typically treated by catalytic or thermal oxidation, carbon adsorption or, where permissible, released into the atmosphere. The requirement for off-gas treatment increases the cost of air stripping. One way to mitigate this cost is to design a system that removes the highest volume of contaminant with the lowest volume of air flow.

*Bioremediation*
This processes uses the metabolic process of naturally-occurring organisms (bacterial or fungal) to degrade dissolved or adsorbed phase contaminants. Bioremediation is frequently a supplemental technology combined with other processes, such as vapor extraction and sparging. Bioremediation can be used either in situ, or aboveground in engineered treatment cells. The value of bioremediation is its capacity to degrade semi-volatile organic compounds.

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compounds such as diesel fuel and polycyclic aromatic hydrocarbons not readily removed through aeration.

**Heat-enhanced technologies**

Heat increases the speed and thoroughness of other treatment technologies such as vapor extraction, air stripping and air sparging. Heat is most useful on semi-volatile chemicals—chemicals that volatilize easily with a modest temperature increase. The decision to add heat depends on the costs and savings created by shortening the cleanup time. Heating costs can be curtailed by using heat generated by other remediation equipment on site, such as a thermal oxidizer used to treat vapor phase chemicals.

**Pump and treat**

This term refers to several technologies which either recover liquid phase chemicals and/or control groundwater and plume flow. There are several methods to separate and recover both light and dense chemicals in the subsurface and treat contaminated groundwater. These include dual pump recovery systems, air stripping, bioreactors and advanced oxidation systems.

**Steam sparging/steam injection**

Also known as vacuum extraction, and similar to air sparging, steam sparging is the highly-controlled injection of steam into a chemical plume that has reached the capillary fringe or saturated zone. Steam dislodges chemicals at a higher rate than air sparging—especially useful for treating semi-volatile chemicals.

**Thermal desorption**

This is an on-site method to treat heavily contaminated soils or sludges by increasing soil temperature to volatilize the chemicals. Resulting vapors are incinerated or condensed and adsorbed. Thermal desorption is effective on a wide range of organic chemicals, ranging from petroleum hydrocarbons to polycyclic aromatic hydrocarbons. Permitting, monitoring, emissions control equipment and ultimate cost of thermal desorption depend in large part on whether soils contain nonhazardous petroleum hydrocarbons or hazardous constituents such as polychlorinated biphenyls (PCBs), mercury and pesticides. Systems to treat petroleum hydrocarbons usually have stage two thermal oxidizers that destroy organics in the off-gas. If the unit is direct-fired, then it is considered an incinerator and is regulated differently by the EPA. Thermal desorption is especially beneficial when soil types prevent the effective use of other on-site treatment technologies and for larger quantities of soils.

**Vapor extraction**

A vacuum system induces air flow in unsaturated soil to removed adsorbed phase contaminants. At the surface, vapors are collected for further treatment or directly discharged into the atmosphere. Success of the treatment is proportional to the volatility of the contaminant. Air flow, provided by vapor extraction, also enhances biodegradation.

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August September 1993 Soils 17
Progress report for in situ bioremediation

Bioreactors enable treatment of chlorinated hydrocarbons

By Sam Fogel, Ph.D. and Jan Sointio

The next frontier in bioremediation is in situ applications. Significant breakthroughs have been made in enhancing and predicting the ability of in situ bioremediation to biodegrade chemicals and toxins, many of which were difficult to treat in the past—most notably, chlorinated hydrocarbons.

Only a few years ago, chlorinated hydrocarbons, such as perchloroethylene or tetrachloroethylene, dichloroethylene and vinyl chloride were considered non-biodegradable. Chlorinated hydrocarbons resist degradation by conventional biological waste water treatment processes. They also pass through activated sludge or trickling filter plants into groundwater and the air.

The elusiveness of chlorinated hydrocarbons is due to the propensity of the chlorine part of the molecule to shield the carbon atom from enzymatic attack. In addition, some chlorinated hydrocarbons do not dissolve well in water, the environment in which bacteria function most effectively.

Volatile two-carbon compounds constitute 10 of the 14 most common volatile organic compounds detected in drinking water supplies. Because of the suspected carcinogenicity of these compounds, their presence in the drinking water is troublesome. In Massachusetts alone, 27 of the 45 communities that retired water supply wells from service due to contamination did so due to contamination by chlorinated hydrocarbons.

However, in 1986, researchers at ABB Environmental Services (ABB-ES), Wakefield, Mass., reported the complete mineralization (conversion to carbon dioxide) of trichloroethylene in the presence of aerobic, methane-utilizing bacteria—bacteria which obtain carbon from methane and require oxygen. As a result, many chlorinated solvents proved biodegradable, but not all. Highly chlorinated compounds, such as tetrachloroethylene still resisted the bacteria.

But, additional research by ABB-ES and other scientists demonstrated that anaerobic bacteria could transform tetrachloroethylene to trichloroethylene, dichloroethylene, vinyl chloride and ethylene—a process called “reductive dehalogenation.”

Unfortunately, the reductive dechlorination transformation process does not entirely transform tetrachloroethylene to ethylene—a nontoxic gas, but generates significant levels of an even more hazardous intermediary product, vinyl chloride—posing yet another challenging problem for environmental managers.

To meet the challenge, researchers combined two biochemical processes that degrade chlorinated solvents, since neither process achieved complete biodegradation when applied alone. Here’s how the combined processes work.

Anaerobic bacteria (methanogens) existing or introduced into the contaminated environment transform tetrachloroethylene to dichloroethylene, vinyl chloride and ethylene. The introduction of methane-utilizing bacteria (methanotrophs) complete the degradation. The two groups of bacteria must be brought together in the proper transforming sequence to complete the microbial model.

There are two ways to carry out sequential anaerobic...
aerobic treatment. First is the two-zone plume interception treatment, performed completely in situ. The second method uses an in situ first phase and a rotating biological contactor in the ex situ second phase.

The two-zone method first applies the anaerobic reductive dehalogenation process and follows it with the aerobic treatment of the degradation products from the anaerobic treatment. Contaminated groundwater is withdrawn and reinjected via permanent groundwater recovery and injection wells. This process creates the two zones through which the contaminated plume flows.

The first zone, placed immediately downgradient of the plume, withdraws groundwater from the first row of wells, adds nutrients to enhance the breakdown of the contaminants by the methanogens and recirculates the modified groundwater. The process stimulates the in situ growth of indigenous methanogenic bacteria, creating conditions to encourage partial dechlorination of the contaminants through anaerobic biodegradation.

The second zone, immediately downgradient of the first zone, recirculates groundwater from a second row of wells and aerates the groundwater with oxygen and methane before reinjecting it. This step creates an area that promotes the production of methanotrophic bacteria which oxidize the remaining contaminants. (In the case of shallow aquifers, trenches can be substituted for the rows of wells.)

Monitoring wells within both zones provide process control information. The two-zone method permits removal of multiple contaminants in a single in situ system, rather than establishing aboveground physical operations, such as air stripping, that are costly and only transfer the contaminants to another medium.

A new hybrid option uses a bioreactor, such as the ABB-ES air-tight rotating model, that treats multiple contaminants. Designed for ex situ anaerobic treatment of groundwater, the unit uses a consortium of aerobic bacteria to destroy chlorinated organics and enables the matching of specific bacteria to specific contaminants. The system has successfully converted trichloroethylene, dichloroethylene and vinyl chloride in groundwater to benign carbon dioxide, water and chloride ions.

The bioreactor cultivates methanotrophic bacteria which produce an enzyme called MMO. Methane and oxygen added to the system serve as the carbon food source for the microbes. The MMO enzyme breaks down the chlorinated organics by oxidation, leaving carbon dioxide. The MMO enzyme is particularly destructive to vinyl chloride.

Naturally occurring bacteria, bred for their ability to degrade specific chemicals, reside on continuously rotating disks inside the airtight unit. The moving disks assure that the influent, as well as the precise mixture of feed gases—methane and oxygen—are exposed to the bacterial colonies.

The unit and methodology have been successfully tested at three Superfund sites contaminated by trichloroethylene, vinyl chloride, chlorobenzene, methyl methacrylate and coal tar constituents.

Write in 743 for more information
Reports offer a variety of information about the industry

Forecasts and market analysis highlight new studies

The demand for bioremediation services and related biotreatment products is forecast to grow 15 percent per year through 1997, according to an industry study released by The Freedonia Group, Inc., Cleveland, Ohio. Stepped up enforcement, rising costs of other technologies and a shift in government policy to favor innovative treatments are cited as reasons for the predicted growth. According to Freedonia analyst Teresa Hayes, the trend is toward the use of a more service-oriented approach. In 1992, bioremediation services accounted for nearly 65 percent of total demand, and Hayes forecasts services to reach over 68 percent of demand by the turn of the century. Products will also continue to see increases in demand, due to strong growth in equipment revenues and regulatory approval of genetically-engineered microorganisms expected around (the year) 2000.

The greatest growth market for services through the end of the century will be in-process pollution treatment, which allow large industrial manufacturers to further reduce emissions from production facilities while cutting costs of abatement activities. In equipment, bioreactors and biofilters will show the greatest growth.

The complete 212-page study: #488 Bioremediation: Services & Products, is available for $2,600 from The Freedonia Group, Inc., 3570 Warrensville Center Rd., Ste. 201, Cleveland, Ohio 44122. Phone 216-921-6800, Fax 216-921-5459.

The Jennings Group, Inc., Columbia, N.J. and Devo Enterprises, Inc., Washington D.C., announce a comprehensive analysis of the U.S. bioremediation market. This market and business assessment includes historical market size, market forecast, an analysis of market structure, competitive trends, customer requirements and purchasing practices, technology developments and trends, regulations and other government activity, profitability factors, market success factors and recommendations for successful participation in this market. Product and service segments covered in the report include remediation firms, engineering and consulting firms, support firms (labs, microbe suppliers, equipment manufacturers) and research companies. For information, contact Olin Jennings, The Jennings Group 37 Ramseyburg Rd., Columbia, N.J. 07832. Phone 908-475-1100. Fax 908-475-3336.

The global instrument industry is projected to expand an average of 8.5 percent per year through 1997, according to a report published by Strategic Directions International, Inc., Los Angeles, Calif. The report, entitled The SDi Global Assessment Report-3rd Edition: The Analytical Instrument Industry 1992-1997, analyses 86 instrument techniques in six regions of the world. While North America is the largest market, the Pacific Rim and Latin American regions will grow most rapidly, with demand increasing 11 to 15 percent per year over the next five years. Europe and Japan will be among the slowest growing regions. For information, contact David Milligan, Strategic Directions International, Inc., 6242 Westchester Parkway, Ste. 100, Los Angeles, Calif. 90045. Phone 310-641-4982. Fax 310-641-8851.

Environmental liability issues dominate the concerns of U.S. companies in the petrochemical and natural resources industries, according to the sixth annual national survey conducted by Alexander & Alexander Services, Inc., New York, N.Y. The unpredictability of insurance market price swings was the top concern. For more information, contact Alexander & Alexander Services, Inc., 1211 Avenue of the Americas, New York, N.Y. 10036. Phone 212-840-8500. Fax 212-719-5746.

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20 August September 1993 Soils
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Write in 397
Hot probe fires sampling
New steam heated sampling point innovates sampling technique

By Byron Taylor

A new, steam-heated soil vapor sampling point is the latest development in sampling technology. Since the heated point volatilizes most petroleum hydrocarbon contaminants in low temperature subsurface soils, the presence of contamination can be determined faster and cheaper than current techniques. The system can extract and analyze samples on site at continuous depths without the danger of contamination carryover from one sample depth point to the next. This provides a vertical profile of contamination presence and relative strength with one boring.

The well point allows for the introduction of high pressure steam into a sintered, stainless steel diffusing material which provides a heat source within the soil matrix. The steam is used only as a heat transfer medium from the 50 psi boiler to the stainless steel tip. The heat then radiates into the surrounding soils by conductive heat transfer, which is more efficient than injecting steam directly into the soil.

Residual heat in the stainless steel well point acts as a continuous point source of heat, as opposed to rapid dissipation of steam into the soil. Under normal operating conditions, only condensed water is emitted from the microscopic openings in the sintered metal sleeve. Since the steam injection and vacuum are not run simultaneously, there is no change in pressure within the soil structure to affect sampling. The introduction of steam in this manner not only adds heat to the subsurface soil, but also ensures that drying of the soil does not occur during the vacuum extraction process.

Since this probe, known as the Steam-Probe™ tip, developed by TVG Environmental Consultants, Nashville, Tenn., is hydraulically inserted into the soil, the shaft and soil provide a seal against the intrusion of diluting atmospheric gases. As the shaft is inserted under steady, perfectly vertical pressure, the soil expands to allow for passage of the sampling tip, then contracts around the shaft to form an impervious seal.

The steam line passes through the center of the probe shaft to the well point. This shaft functions as the vacuum chamber and causes the vapor sample to rise vertically through the annulus while being continuously, yet indirectly heated until it reaches the gas cleaning and flow measuring devices where it is injected directly into the flame or photo ionization detector with a gas chromatograph. The cross-sectional areas of the annulus and other vacuum lines are balanced to reduce significant pressure or velocity changes. This design prevents condensation of compounds, and insures they will remain in the gaseous phase throughout the process.

The vacuum extraction section of the well point is designed to remain closed during the insertion process, and is heated to drive off residual contaminants from adhering soil particles during withdrawal. Thus, carry-over contamination and blockage of sampling ports are avoided. As the well point is extracted in incremental steps, additional measurements can be made by reheating the well point and extracting volatiles through the cross section of the contaminant plume. Relative contaminant levels are plotted to delineate the borders of the plume.

Percussion or impact inserted soil gas samplers can cause an inadequate seal between the atmosphere and the sampling point. Non-homogenous soil porosity and confining layers or structures between the contaminant source and soil vapor monitoring location can also affect the accuracy of the
Vapor pressures and Henry’s Law constants for volatile organic compounds

<table>
<thead>
<tr>
<th>COMPOUND</th>
<th>VAPOR PRESSURE (mmHg)</th>
<th>HENRY’S LAW CONSTANT (kPa M3/mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>benzene</td>
<td>95</td>
<td>0.6</td>
</tr>
<tr>
<td>carbon tetrachloride</td>
<td>15</td>
<td>0.06</td>
</tr>
<tr>
<td>chlorobenzene</td>
<td>12</td>
<td>0.4</td>
</tr>
<tr>
<td>chloromethane</td>
<td>3750</td>
<td>1.0</td>
</tr>
<tr>
<td>ethylbenzene</td>
<td>9</td>
<td>0.8</td>
</tr>
<tr>
<td>methylene chloride</td>
<td>350</td>
<td>0.3</td>
</tr>
<tr>
<td>tetrachloroethene</td>
<td>15</td>
<td>2.0</td>
</tr>
<tr>
<td>toluene</td>
<td>28</td>
<td>0.7</td>
</tr>
<tr>
<td>trichloroethene</td>
<td>50</td>
<td>0.9</td>
</tr>
<tr>
<td>vinyl chloride</td>
<td>2200</td>
<td>50.0</td>
</tr>
<tr>
<td>o-xylene</td>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>m-xylene</td>
<td>8</td>
<td>0.7</td>
</tr>
<tr>
<td>p-xylene</td>
<td>8</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Figure one: Vapor pressures are approximate.

process. An experienced operator can manipulate the Steam Probe system to avoid situations that create voids around the shaft and result in false negatives or non-representative contaminant concentrations.

Chemical factors affecting the soil vapor assessment process include the variations in vapor pressures and boiling points of the compounds of interest. The relationship among the various soil conditions can be characterized by the following formula:

\[ \frac{C_g}{C_t} = \frac{1}{(P_g K_{oc} f_{oc}/K_h) + (O/K_h + a))} \]

where:
- \( C_g/C_t \) = relative vapor concentration
- \( P_g \) = bulk density (g/cm³)
- \( K_{oc} \) = organic carbon-water
- \( f_{oc} \) = fraction of organic carbon content (g/g)
- \( K_h \) = Henry’s Constant [unitless ratio]
- \( O \) = volumetric moisture content (cm³/cm³)
- \( a \) = volumetric air content (cm³/cm³)

Since there is a virtual absence of advection, minimal thermal gradients and insignificant pressure gradients, the sampling regime influenced by the heated sampling tip and subsequent vapor extraction does not disrupt the equilibrium of the gaseous contaminant balance in the soil. In other words, the sampling zone is in virtual equilibrium with the surrounding soil environment before, during and after the contaminant vapors have been extracted. No concentration gradient is created by this process.

Research into the behavior of wet and dry gaseous compounds and the laws affecting gases has revealed a number of constants and predictable reactions for the contaminant compounds commonly found in soil matrices. Soil vapor contaminant assessment is possible since vapors indicative of contamination resulting from volatile organic

Continues on page 24→
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Figure two

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Continues on page 50→
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26 August September 1993 Soils
industrial wastes. Drums were dumped alongside temporary roads and bulldozed into pits and low mounds. Bulk wastes were deposited into sand pits and other low lying areas of the site. The Sikes Pits have been a source of sand for construction use, a mining process that has created a number of lakes as the shallow groundwater filled the sand pits. The site operator is believed to have occasionally flared the waste, setting it ablaze to burn off the lighter, noxious hydrocarbons in the waste that rose to the surface of the lakes.

Thus, in 1981, the site was placed on the National Priority List of Superfund sites. In 1983, in an emergency action, the EPA removed approximately 400 cubic yards of waste to an offsite disposal facility. EPA also relocated the occupants of the site and erected a security fence around the site. The Texas Water Commission (TWC) retained Lockwood, Andrews and Newnam, Inc., a consulting firm in Houston, subsidiary of Leo A Daly Co., Omaha, Neb., to investigate and produce feasibility studies to remediate the site. Project costs are funded by EPA, 90 percent and TWC, 10 percent. These investigations revealed that the waste in the soils and waste sludges in the bottoms of several lakes were ongoing sources of groundwater contamination under the site. It was also determined that direct contact with the contaminated soils and sludges presented a significant health hazard.

In 1986, the EPA and Texas regulators stipulated that the soil and sludges should be excavated and incinerated on site, with the incinerator ash to be buried on the site. At that time, LAN began design for the remedial action and prepared the remediation contract documents. That design began with another sampling and analysis phase to provide data specific to the selected remediation method. The EPA has

Continues on page 28→

Information provided by Lockwood, Andrews & Newman Inc., Houston, Texas; Tom Davis, project manager. Sikes Disposal Pit, Crosby, Texas, is remediated and funded by the Texas Water Commission and the U.S. EPA.
Sikes Disposal Pits, Crosby, Texas, on EPA’s SuperFund priority sites list since 1981, is being remediated by incineration.

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Write in 296

Here’s what’s hot, from page 27

stated that the additional data contributed to the success at the Sikes project. LAN’s design addressed site security, air monitoring, health and safety, excavation of hazardous material, trial burn and operation of the incinerator along with all other activities that would be necessary to remediate the site.

In October 1990, the joint venture of International Technology Corp., Torrance, Calif., and Davy-McKee Corp., a British firm, began preparations for the project. In conjunction with the joint ventures preparations, LAN assembled the management team to oversee the work on behalf of the TWC. The full service field office is staffed with up to 12 inspectors and managers who oversee the work on behalf of the TWC and EPA around the clock.

They established 24-hour security, and flagged all known contaminated areas to warn workers of areas that required protective gear. They installed the incinerator, a water treatment plant, a laboratory and perimeter air monitoring stations. This step was completed in January 1992, 80 days ahead of
schedule at a cost of $31,405,326.

The next phase was to conduct trial burns of the incinerator. Three test burns of the incinerator demonstrated its readiness, its waste destruction capability and the efficiency of its air pollution controls. Extensive sampling in the investigation phase provided enough information to enable project designers to adequately size the incinerator to be able to efficiently handle the quantity of waste. At this time, installation of a system of wells to remove groundwater for treatment was initiated.

All the drums at the site were damaged and in deteriorated condition. The contents had leaked into the soil. The ones still containing contaminants are punctured in accordance with the site health and safety plan, the contents blended in with the contaminated soil and incinerated. The drum shells are chipped into maximum two-inch size and campaigned through the incinerator. To date, approximately 260,000 tons of waste have been excavated and incinerated on site. The incinerator operates 24 hours a day, seven days a week. The minimum operating temperature of the primary combustion chamber, a rotary kiln, is 1,058°F. The secondary combustion chamber minimum temperature is 1,760°F. Maximum feed capacity is 45.76 tons per hour.

The soil is conveyed into the unit through an adjustable rate mass flow feed device. Residency time in the secondary combustion chamber exceeds two seconds.

Air emissions are controlled by dual hydrosonic scrubbers. The exhaust to the atmosphere was tested during the trial burn for particular constituents which were found to be significantly below regulatory requirements. Continuous emission monitors operate during normal production.

When all the waste is treated, the ash residue will be covered by a minimum of 18 inches of clay fill material. The ash residue consists of the original soil matrix particles, plus primarily carbon left after the incineration of the hydrocarbons, hence a black soil. Samples are taken hourly and composited every 24 hours. Analysis is submitted to LAN within 48 hours, and within 24 hours, LAN authorizes removal of the ash to a stockpile or to be reincrement. The ash is suitable to use as backfill at the site, with the 18 inch clay cap, then to be covered with topsoil and planted with grass to prevent erosion. Then, the incinerator and other facilities will be dismantled.

Since the incinerator can treat waste three times as fast as the minimum of 15 tons per hour required by the contract, the contractors anticipate that the project will be completed in late 1994, not early 1996, as required in the contract.

The bid price for the incineration and site restoration is $59,914,473. This bid was based on the quantity of waste estimated on the basis of limited surveys and sampling of the site. Only a minor amount of additional waste has been encountered that was not anticipated in the investigation phase.

Write in 749 for more information.
Tank upgrade: to be or how to be

By Ted Lewis

There are many decisions to make when planning to upgrade an underground storage tank. The regulations for both underground and aboveground tanks are constantly changing, and are expected to become more restrictive. An experienced consultant, familiar with local regulations and testing requirements can steer owners away from pitfalls and costly mistakes.

Ted Lewis is an environmental consultant for Schnabel Environmental Services, Bethesda, Md.
ABOVEGROUND...

Reduce potential for undetected release, easier access for maintenance, but takes up surface space, regulations still in limbo. No excavation costs, but savings offset by surface modifications such as dikes, pads, landscaping. Easier target for vandalism, easier to relocate.

DEVELOP A WORK PLAN

The work plan provides an overview of what tasks are required, timetables for completion contact people, and contract specifications. It outlines specific information on applicable regulations, how tasks may be performed, documentation of the work and payment terms. The work plan functions as the working document to be given to potential contractors so they can prepare a cost proposal for the project. Since contractors base their cost proposals on this work plan, it is important that the plan be as complete and as clear as possible.

A detailed work plan is more likely to produce more competitive and complete proposals, and is more likely to result in a project with fewer surprises. (All projects have some surprises.)

The work plan should be prepared by a consultant experienced in tank work and who is acting in the owner's best interest. Avoid the common problem of submitting a "rubber-stamp" work plan to contractors. Non site-specific work plans often contain provisions that may not apply to a particular project, and force the contractor to include additional fees. Any contractor invited to submit a proposal should request, and be given a tour of the site.

Typically, the appropriate regulatory agency must be notified of the plans at least 30 days prior to the beginning of any work. One or more permits may be required for the work—construction, air quality, sediment and erosion control are some examples of types of permits required in some jurisdictions.

RETROFIT...

Requires leak detection, overflow spill protection and corrosion protection. Or, for such systems already in place, you must verify they are in accordance with the new standards. Excavation costs may equal those to replace the tank system. On-going monitoring and testing requirements may wind up costing you more than replacing the tank system.

COMPLIANCE

Sorry to mislead you, but you're never "finished" with compliance. It's an ongoing process.

August September 1993 Soils 31
Benzene mixtures, from page 7

was not happening. Corresponding air levels taken in the breathing zone ranged from 63 to 611 ng/L during refueling and from 20 to 77 ng/L between refuelings. These increased levels are believed to reflect the increased benzene absorbed when gasoline vapors are inhaled.

More extensive monitoring surveys that account for other possible sources of the benzene-containing mixtures might be able to determine if benzene concentrations in exhaled breath would be useful as a biomarker to determine exposure levels in humans.

Oral exposure to gasoline or jet fuel is generally by intentional ingestion. Intentional or accidental ingestion of large quantities of gasoline or jet fuel often results in aspiration into the lungs. In several case reports, individuals who were immersed in gasoline or jet fuel for several hours described chemical burns on their skin in the area of contact. Dermal exposure is common during underground storage tank removals, maintenance and installations.

The public is also exposed to benzene through spills and leaks. Fuels that leak into the soils risk contaminating the groundwater as well as the soil. Although the majority of the general population may be exposed to gasoline or jet fuel during refueling, many may also be exposed through the use of contaminated groundwater.

Although benzene is relatively soluble in water (1,000 mg/L at 25°C), there is virtually no data to quantify the magnitude of human exposure through water.

<table>
<thead>
<tr>
<th>Concentrations of alkyl benzenes in gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>% by weight</td>
</tr>
<tr>
<td>toluene</td>
</tr>
<tr>
<td>ethylbenzene</td>
</tr>
<tr>
<td>xylenes</td>
</tr>
<tr>
<td>benzene*</td>
</tr>
<tr>
<td>n-propylbenzene</td>
</tr>
<tr>
<td>1-methyl-3-ethylbenzene</td>
</tr>
<tr>
<td>1,3,5-trimethylbenzene</td>
</tr>
<tr>
<td>1-methyl-2-ethyl-benzene</td>
</tr>
<tr>
<td>1,2,4-trimethylbenzene</td>
</tr>
</tbody>
</table>

* Benzene concentration in gasoline may be as high as 6%, and is higher in Europe and Japan.

Total concentration of alkylbenzenes: 31.86%

Figure one

Measured concentrations of benzene in water vary considerably. Representative samples of benzene concentrations that have been measured in rainwater, surface water, sea water, drinking water and groundwater range from .005 ppb to 330 ppb. Monitoring levels of benzene in surface water or groundwater to determine higher-than-background levels of benzene may be useful to detect unsuspected releases or spills.

The migration of the individual fuel components, including benzene, into groundwater depends on their physical and chemical properties. The volatility and solubility of benzene are properties with the greatest influence on environmental transport of benzene. On the basis of solubility data (1,000 mg/L at 25°C), benzene has a fairly high solubility in water. When released into water, volatilization results in a substantial loss of benzene into the atmosphere. The environmental fate of gasoline or jet fuel benzene released into surface waters and soils is uncertain because of the possible influence of other chemicals within the fuel mixtures. After volatilization, biodegradation and photooxidation are the next most important removal mechanisms for gasoline and jet fuel components released into surface soils. Hydrocarbon removal by these mechanisms is rapid, about one week after a release or spill.

Although methods to detect gasoline and jet fuel hydrocarbon in soil exist, very few studies have been conducted on the concentrations of gasoline or jet fuel benzene in the soil. And, while gasoline and jet fuel hydrocarbons are known to be present in soils where fuels have spilled around leaking underground storage tanks or pipelines, no specific data on levels of benzene from gasoline or jet fuel in soil exist. The only measured values of benzene found in soil appear in a study by A.F. Fentimen, EPA Office of Toxic Substances, Washington D.C. This study recorded levels ranging from less than two to 191 ppb in the soil near five industrial facilities using or producing benzene. Benzene released to soil can be transported to the air through volatilization, to surface water through runoff and to groundwater as a result of leaching. A correlation between benzene soil concentrations and the amount of spilled jet fuel or gasoline is needed to establish the use of benzene as an indicator for gasoline or jet fuel leaking from underground tanks.

Data are also scarce concerning benzene concentrations in media other
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Benzene mixtures, from page 32

than air, water and soil. This is due, at least in part, to the difficulty in tracing the source of hydrocarbon contamination in other environmental media, such as plants and animals, fish and other possible food chain sources. Gasoline and jet fuel as mixtures of hydrocarbons do not bioaccumulate in the food chain. However, benzene as an individual component may bioaccumulate, and has been detected in fruits, nuts, vegetables and dairy products. Gasoline and jet fuel partition to the different environmental areas according the physical and chemical properties of the area, and the most important fate process is volatilization.

Gasoline and jet fuel irritate humans at the point of entry into the body—the lungs after inhalation or the gastrointestinal mucosa after ingestion. One target of gasoline and jet fuel toxicity appears to be the nervous system in both humans and animals. A number of neurological effects follow acute exposure to high levels of gasoline and jet fuel, either by inhalation or ingestion. The toxicity is dose dependent—the higher the dose, the more acute the toxic reaction. Effects of acute inhalation exposure include dizziness, headache, giddiness, euphoria, vertigo, blurred vision, nausea, numbness of limbs, drowsiness, anesthesia and coma. Most of the data on the neurological effects of gasoline and jet fuel come from case reports describing patients who sniff fuel. But in most cases, the exposure concentrations could not be determined and the benzene content was not specified.

Adverse respiratory effects, chemical pneumonitis, pneumonia, pulmonary hemorrhage and edema sometimes appear in humans after ingestion of large amounts of gasoline or jet fuels. Blood dyscrasias have been noted in humans acutely and chronically exposed to gasoline and jet fuel vapors, and these effects are most likely due to the benzene. The incidence of these findings has decreased as the benzene content in gasoline has decreased. Inhalation of gasoline and jet fuel vapors has been shown to induce an increased incidence of hepatocellular tumors in mice.

Figure one: From H. MacFarland, in Toxicity of Petroleum Hydrocarbons, 1982, American Petroleum Institute.

<table>
<thead>
<tr>
<th>Test Group</th>
<th>Animals Exposed</th>
<th>Total Carcinomas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>108</td>
<td>18 (16.6%)</td>
</tr>
<tr>
<td>Low Dose</td>
<td>94</td>
<td>20 (21.2%)</td>
</tr>
<tr>
<td>Mid Dose</td>
<td>101</td>
<td>25 (24.7%)</td>
</tr>
<tr>
<td>High Dose</td>
<td>110</td>
<td>40 (36.4%)</td>
</tr>
</tbody>
</table>

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Write in 405

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exposure and cancer in humans is inhalation. The EPA estimates that three people die annually from cancer caused by exposure to benzene emissions.

Several studies have demonstrated that benzene causes tumors in rodents, including lymphoma, hemolympheoreticular neoplasia, all types of leukemias and cancers of the zymbal gland, oral cavity, lung, skin, nasal cavity, forestomach, hardener gland, mammary gland, ovary and uterus. In the American Journal of Medicine, P. Infante and M. White calculated the increased mortality from leukemia for humans exposed to benzene for an occupational lifetime. The relative risk of death from leukemia is 25 per 1,000 workers, depending on level and duration of exposure.

Back in 1948, the American Petroleum Institute issued a widely circulated document entitled, API Toxicology Review: Benzene, by P. Drinker. This report states, “Inasmuch as the body develops no tolerance to benzene and there is a wide variation in individual susceptibility, it is generally considered that the only absolutely safe concentration for benzene is zero.” In the Journal of Toxicological Environmental Health, B. Goldstein, in a comprehensive review of the literature on benzene, compiled case reports on benzene exposed individuals with hemolympheoreticular cancers. The types of leukemias found in these individuals were acute myelogenous leukemia, erythroleukemia, acute myelomonocytic leukemia, chronic myelogenous leukemia, myelofibrosis and myeloid metaplasia.

A 1989 study, reported in Environmental Health Perspectives, reports significant increases in human cancers resulting from benzene exposure. It caused leukemia and cancers of the lung, liver, lymph, stomach, esophagus, nasopharynx and intestine.

The threshold limit value-time weight average for benzene in 1946 was 100 ppm; in 1947, 50 ppm; during 1948-1956, 35 ppm; during 1957-1962, 25 ppm; during 1977-1987, 10 ppm. Currently, it is one ppm. In July 1990, the American Conference of Governmental Industrial Hygienists recommended that the average for benzene be reduced to one-tenth ppm.

The Committee on the Evaluation of Carcinogenic Substances, Health Council of the Netherlands concluded that chronic exposure to benzene in ambient air should be limited to below 12 µg/m3 or four ppb to limit risk of leukemia.

But, because no safe level above zero is known, it is desirable to avoid any exposure to benzene and benzene-containing products to the greatest extent possible.

Chemical carcinogens are characterized by their interaction with biological macromolecules. Therefore, benzene metabolites account for its carcinogenicity. The primary benzene metabolites detected in the urine of monkeys, chimpanzees, mice and rats were hydroquinone conjugates, phenyl conjugates and muconic acid. During the course of benzene exposure, all cells in the bone marrow of the exposed animals were damaged and gradually disappeared. This and other evidence support the concept that benzene produces its carcinogenic effect by inhibiting cell division. For example, fewer mitotic figures have been observed in the bone marrow of mice exposed to benzene.
Benzene mixtures, from page 35

the bone marrow of benzene-intoxicated animals, and benzene has been shown to cause abnormal mitotic figures. Furthermore, chromosome aberrations have been seen following benzene exposure, and livers of rats that had undergone partial hepatectomies failed to grow back when animals were exposed to benzene.

The potential genotoxicity of gasoline in humans was evaluated by measuring micronuclei induction in the peripheral lymphocytes of male gasoline pump operators in Sweden. In this study, a significant micronuclei induction was observed in the B-lymphocytes of the gasoline exposed group, but no induction of micronuclei was observed in the T-lymphocytes. It has been suggested that benzene may have been responsible for the genotoxic effects.

There is concern about human exposure to gasoline vapors because lab tests have shown that rats and mice develop cancers after exposure to vaporized gasoline. The animals were exposed for two years to wholly vaporized gasoline at 67, 292 and 2,056 ppm. Tumors in the mice increased significantly as in figure two, page 34. Increases in kidney cancers (adenomas and carcinomas) were clearly dose related. Such increases in cancers in rats and mice are important to evaluate human cancer risk.

In 1992, T. Partanen published results of a study in the Journal of Work Environmental Health that measured ppm equivalents of benzene, ranging from one tenth ppm to two ppm, as indicators of exposure to gasoline and showed that humans exposed to gasoline demonstrated a large increase in the incidence of renal cell carcinoma with an odds ratio of 7.39 (95 percent confidence interval of 1.58 to 34.6). The excess risk of human renal cancers was highest at a latency period of approximately 30 years. This study also showed that exposure to nonchlorinated, petroleum-derived solvents resulted in a significant increase in the incidence of renal cell cancer with an odds ratio of 3.46 (95 percent confidence interval of .91 to 13.2).

The results shown in figure three, above, summarize cancers that result from exposure to hydrocarbon vapors. These data show that exposure to petroleum hydrocarbon vapors significantly increases the incidence of leukemia and hematopoietic and lymphatic cancers. They also show an increase in the incidence of other human cancers.

While in some cases, more research is needed to specify the effects, it is clear that benzene is a carcinogen and that humans exposed to petroleum product vapors should understand the risk.
December 1968: the principals of ten major consulting geotechnical engineering firms—all strong competitors and not fully trusting each other—met in a Chicago airport hotel, drawn together by a common problem. All ten firms were being forced to operate without professional liability insurance. From the mid-1960s on, consulting geotechnical engineers had become the most liability prone professionals in the world. The principals put aside their mistrust and established a new organization to identify liability problems and develop programs and materials to help members overcome them. In April 1969, Associated Soil and Foundation Engineers (ASFE) was born. An insurance and loss prevention specialist, Edward Howell, began by establishing a captive insurer that since has become Terra Insurance Co., an organization owned by its insureds, about 80 of the members of ASFE. Although Terra requires insured/owners to be active members of ASFE, there is no business relationship between the two entities. Membership in ASFE does not guarantee insurance to a firm. ASFE membership has grown to about 325 firms operating from 1,500 offices, principally in the United States. Soon after it was established, ASFE adopted the concept of limitation of liability. Long used in the transportation industry, and recognized in British maritime law since the early 17th century, limitation of liability is an agreement between a service provider and client that, should certain problems occur, the service provider’s liability would be limited to a fixed amount. In practice, many ASFE members included in their contracts a provision stating that, in the event of negligence, their liability would be limited to $50,000 or the fee, whichever was higher.

Philip Johns is a freelance writer in Washington, D.C.

Originally, the concept was greeted with howls of derision. Critics labeled it unprofessional, said the courts would never uphold it and owners would never accept it. But ASFE members persevered. Today, most practitioners and clients recognize limitation of liability as a sound business issue. As for the notion that the courts would not accept limitation of liability, every known challenge to it has been turned back by the courts. Although most courts are reluctant to enforce such limitations, the fact is, they are legal and will be enforced when set out in clear terms. Clients readily understood the appropriateness of limitations and today, accept it for virtually all types of design and environmental professional services. ASFE also innovated alternative dispute resolution to the industry. Arbitration, the foundation of alternative dispute resolution, was first used in the construction industry in the 1870s. But ASFE wanted to go a step beyond arbitration. Even though it was faster and cheaper than litigation, it was still costly and slow. Worse, it still contained an adversarial component.

So, in 1973, ASFE introduced a new concept, called mediation/arbitration, that emphasizes the importance of settling amicably to preserve relationships, and resolve problems faster and at less expense.

In 1990, ASFE began work on a new organization whose sole purpose would be to promote alternative dispute resolution in the construction industry. The group is known as DART, Dispute Avoidance and Resolution Task Force, one of the few organizations supported by virtually every segment of the construction industry, including insurers, sureties and attorneys.

Another pioneering concept ASFE brought to the industry was peer review. Through peer review, a team of senior professionals visits a firm, interviews key personnel and reviews operational documents. The impact of this program was so positive that the program is now offered by the American Consulting Engineers, the National Society of Professional Engineers/Professional Engineers in Private Practice, American Institute of Architects and the Association of Consulting Engineers of Canada. The American Society of Civil Engineers also has a peer review program for use by governmental engineering operations.

Other services and materials offered by ASFE include report review, loss prevention seminars, Professional Liability Loss Prevention Education Program and Contract Reference Guide.

The analysis of losses, in the form of actual case histories, was the principal source to determine causes of problems. The case histories revealed that one basic problem was inadequate communication with clients. Consequently, clients were expecting perfect results in circumstances where perfection was not possible. Encouraging clients to accept limitation of liability gave consultants a chance to explain to clients what could go wrong when relying on sampling to create a picture of an underground site. Another problem that emerged was lack of field observation services. For whatever reason, many geotechnical engineers felt it was inappropriate to urge the client to use the firm for construction observation in addition to engineering. Members now recognize that the only way to assure that the intent of a design is realized is to be on site while the design is being implemented.

In the early 1980s, geoenvironmental activities began to predominate for member firms, so ASFE changed its name to ASFE/The Association of Engineering Firms Practicing in the Geosciences. Recently, ASFE opened membership even more. Now known as, ASFE: Professional Firms Practicing in the Geosciences, the association welcomes geologists, engineering geologists, industrial hygienists and others to join the engineering firms.

Write in 751 for more information

August September 1993 Soils 37
Choose the right microbe

By John Opsasnick and Mark Krupka

Selective adaptation targets the best microbe for the job

A successful bioremediation project is actually a series of choices. The correct microbes must be determined, and the optimal application of those microbes to the site depends on the particular site characteristics and the goals of the project. Selective adaptation methodology isolates the microbes best suited to degrade a target contaminant. In selective adaptation, microbes are first removed from a natural environment.
which has been exposed to a particular contaminant. The species which dominate are generally those best able to use the target contaminants as a growth substrate. The dominant species are then isolated under laboratory conditions and subjected to higher concentrations of the target compound. Surviving species have been found to have significantly improved metabolic degradation capabilities, breaking down the target compound at an accelerated rate. These microbes are also more resistant to concentrations of contaminants which would be inhibitory or toxic to naturally occurring organisms.

The key to a successful biodegradation is a function of the bioenzymatic behavior of the microorganism. Microbes can produce enzymes which are proteinaceous compounds and function as catalysts. These enzymes allow for both intracellular and extracellular complex biochemical reactions to occur, and step by step breakdown of the targeted contaminant. This step by step process is typically referred to as the metabolic pathway and often requires 15 to 20 steps to achieve complete mineralization. Each step can require a different enzyme and different microbial strains. Synthesis of the proper enzymes is critical for a successful project. Figure two, above, is an example of the sequence of reactions in the breakdown of cyclohexane.

In one case, after removal of several tanks at an abandoned gasoline station, obvious leakage required further investigation. A Phase II assessment revealed that, due to

Continues on page 40→
Choose the right microbe, from page 39

highly impermeable clay soils surrounding the tank pit, contamination was limited to the backfill, which surrounded the original storage tanks. Backfill soils had total petroleum

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hydrocarbons of 440 ppm.

Because of these site conditions, the remedial plan was a recirculating leach field as in figure one, page 38. Water saturated with oxygen and augmented with ABR® Gasoline Blend from Sybron Chemicals, Inc., Birmingham, N.J., was percolated through the soil. Leachate from this system is collected and processed aboveground in a bioreactor. Processed effluent from the bioreactor is redistributed over the contaminated soil, resulting in a closed loop system. The recirculating leach field allows for total petroleum hydrocarbon degradation in both the soil and water phases, which accelerates the entire process. To prevent rainwater infiltration, the perimeter of the pit was bermed and the pit covered with tarps.

After six months, all 15 sample points had total petroleum hydrocarbon values below regulatory limits. The average total petroleum hydrocarbons reading at the site was 42 ppm, a 90 percent reduction.

After two more quarterly groundwater samplings, regulators closed the site and the property was sold.

In another case, working with Cyto-Culture International, Inc., Point Richmond, Calif., the site contained 2,400 cubic yards of excavated soil which was contaminated with diesel and crude oil. Average total petroleum hydrocarbon levels were 6,700 ppm. Because of limited space and time, landfarming was ruled out. The best option was a vacuum heap system.

Layers of soil, interspersed with slotted piping were configured as in figure three, page 40. ABR® Diesel Blend was added to the soil along with a nutrient amendment. When the pile was completed, it was covered with an impermeable liner to prevent water infiltration.

At startup, 50 percent of the perforated pipe was connected to a vacuum system and the balance of the piping was open to the atmosphere to allow makeup air to be drawn through the piles, thus allowing for oxygen transfer. Leachate was collected and transferred to a bioreactor in which the soluble fraction of total petroleum hydrocarbons was degraded. Effluent from the reactor was distributed back over the pile in order to maintain proper levels. This stream was also used to distribute additional culture and nutrients.

In two months, average total petroleum hydrocarbon concentration was less than 10 ppm, 99.8 percent removal. The site was closed after 70 days of treatment.

Advantages to these approaches include minimum site disruption and elimination of any potential liability associated with transport and off site disposal.

In some cases, bioremediation can be combined with other technologies to provide the most cost effective solution. For example, pump and treat systems can be modified with a biotreatment system and bioaugmentation at minimum cost to accelerate the cleanup of sorbed phase organics.

While bioremediation can take more time than other treatments, at many sites, it may save 30 to 70 percent in project costs.

Write in 752 for more information
Debate continues between biostimulation, bioaugmentation

Consider site specific factors when choosing bioremediation approach

By Pamela Bell, Ph.D. and Sarah Tremaine, Ph.D.

Biostimulation and bioaugmentation are the choices to enhance bioremediation activity at hydrocarbon contaminated sites. It is important to understand the differences and factors to consider when deciding which would be best for a particular site. Biostimulation is any means that encourages the native population of microorganisms already present at the site, and bioaugmentation is the importation of microorganisms that have been cultured to degrade a particular contaminant.

Bacteria have been on the earth for at least 2.5 billion years and have evolved to degrade naturally occurring compounds. Since the chemical revolution, many manufactured chemicals have been introduced into the environment, and bacteria have evolved to degrade nearly all these as well. Bacteria are ubiquitous in soils, air and water.

At sites where a particular compound has been generated over a number of years, or where there has been historical spillage, ample time has passed to evolve a population of bacteria that can degrade those compounds. A list of chemicals known to be degraded by bacteria is shown in figure one, right. The list is not comprehensive and many chemicals not on the list are also degraded by microorganisms.

Three sources of bacteria can be used for biodegradation: bacteria already on site that have been in contact with the pollutant, bacteria from other sites that have been cultured in a lab, and bacteria that have been genetically manipulated in a lab. Processes that stimulate bacteria from these sources are:

- biostimulation, using in situ or native (pre-existing at the site) bacterial communities,
- bioaugmentation, the addition of bacteria isolated from other sites and cultured in a lab, and
- genetically engineered bioaugmentation, where genetically altered bacteria are added to a site or a reactor.

Release of genetically engineered microorganisms is not currently permitted in the U.S. Efforts are underway to allow the use of genetically engineered microorganisms in bioreactors—where the organisms could be kept separate from the environment. The use of such organisms in bioreactors is a potentially powerful technology that could be used to promote biodegradation of recalcitrant...

Some chemicals known to be degraded by bacteria

- acetone
- anthracene
- atrazine
- benz(a)anthracene
- benzene
- benzoate
- benzotheophene
- biphenyl
- chlorobenzene
- chlorophenol
- creosote
- cresol
- dibenzotheophene
- dichlorophenol
- dodocane
- ethylene bromide
- fluoroanthene
- haloaromatics
- hexachlorobenzene
- jet fuels
- linuron
- methanol
- methyl ethyl ketone
- missile fuels
- naphthalene
- naphthol
- nitroglycerin
- PCBs
- phenanthrene
- phenol
- quinoline
- tetrachloroethylene
- toluene
- trichloroethylene
- vinyl chloride
- xylene

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Write in 414 42 August September 1993 Soils
compounds and increase degradation rates.

Experience shows that bacteria able to degrade pollutants are usually already on a site. Soils have huge populations of bacteria, usually in the range of 10^9 bacteria per gram of soil. The organisms contained within soils include bacteria that thrive under aerobic and anaerobic conditions, molds and yeasts. The reason that toxic compounds remain at a site is that the capacity of the native bacteria to degrade hydrocarbon contamination is limited by the absence of other essential nutrients. So, the bacteria remain in a sort of “suspended animation” until they are exposed to the nutrients necessary for them to metabolize the toxic compounds.

For example, bacteria require high water activity, circumneutral pH conditions and appropriate nutrients. Temperature is also an important variable, with reaction rates decreasing during cooler seasons. Because bacteria are so small, about one micrometer, they have a large surface to volume ratio and can catalyze an enormous amount of chemical reactions.

However, because many of the degradative enzymes are attached to the cells, bacteria can only facilitate chemical reactions if they can come in close contact with the target pollutant. Therefore, if the pollutant or soil matrix consists of large size particles, the effective potential of any bioremediation strategy is significantly reduced.

The options of bioaugmentation and biostimulation require site by site analysis. At some sites, indigenous organisms may be able to be pressed into action with appropriate nutrient amendments such as oxygen or nitrogen. At others, bioaugmentation may be a desirable enhancement.

Companies that sell bacteria spend a considerable amount of time and money to isolate bacteria that can degrade compounds and creating mixtures of the various bacteria along with nutrients and a carrier. In some experiments, the unanswered question "What is it, and where did it come from?"

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Often, in the mad rush to satisfy state or federal regulators, characterization and identification analyses are overlooked. After the regulators are gone, questions come up like: “Was it all ours?” or “Just how old was it?”. It is usually too late to ask these questions because all of the evidence needed (oil sheens, contaminated soils) has been removed.

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Debate continues, from page 43

is whether the bacteria that were applied actually catalyzed the degradation, or whether the native bacteria were responsible for the degradation, using the added organisms as an extra nutrient source. Several steps must be taken to adequately bioremediate a site. First, the physical-chemical nature and hydrogeology of a site and the nature and extent of contamination needs to be delineated. Next, the biodegradability of the contaminant should be addressed, including an evaluation of what organisms and conditions would be optimal by referring to the literature and previous experience. At this point, the general conditions suitable for biodegradation of the compound will have been identified. Suitability of the site to biosimulation also needs to be evaluated. And finally, the experimental phase of a project can begin, using bench scale and/or pilot scale tests to refine designs for degradation of the contaminant.

Lab studies should include determination of:
1. biodegradability of compounds, 2. existing nutrient conditions 3. estimate of degradation rate, and 4. optimum nutrient conditions for most effective biodegradation rates.

Companies that specialize in bioremediation usually have standard treatability testing procedures and can also customize the design to suit unique situations. This phased approach provides sufficient information for design and construction of suitable full scale systems. The full scale implementation step includes final design, construction, operation, maintenance and monitoring of the remediation.

Overall, there are many tools available for the application of bio remediation to the environment. For soils, there are two major options, whether the remediation will be done in situ or on site. For in situ bio remediation, aerobic or anaerobic bioventing is possible in the vadose zone, while biosparging is used for contamination across the water table interface zone. On site soil remediation can be achieved with solid phase land treatment with plowing, chemical aeration, windrows or composting. Other strategies for soils include sequence batch reactors, slurry reactors or soil washing followed by biodegradation of the wastewater.

A phased, scientific approach to bio remediation is strongly recommended to achieve best results in the most cost-effective manner. When bioaugmentation is considered, the purchaser might be wise to seek outside quality assurance to ensure that bacteria added to the site will facilitate degradation. Careful testing can direct decision-makers to appropriate choices for the prevention of contamination and remediation of the environment.
CES has ready to go remediation systems
Continental Environmental Services, Gainesville, Fla., offers pre-packaged remediation systems that remove VOCs from groundwater.
Available components include low profile air strippers, carbon and filtration systems, pumps, and remote telemetry and oil/water separators.

Write in 757

Alpha Omega offers mobile lab
Alpha Omega Technologies, Inc., Farmingdale, N.J., offers a mobile laboratory system that allows GC, GC/MS, Purge/Trap and various instrument set-ups to be custom configured, installed and tested.
The AlphaLab is a self contained laboratory system, 31 feet wide and six feet long. The lockable unit holds a variety of full-size instruments, computers and telecommunication systems. The unit also includes three C-size gas cylinders, storage shelves and heavy duty transport wheels.
A ready to operate system arrives at the testing site. The chemist is ready to run samples after 110V electricity from a power source is attached.

Write in 759

Finch ships kiln to oil pit site in Louisiana
Finch Environmental Corp., West Pittston, Pa., ships their rotary kiln, measuring 10 feet in diameter by 40 feet in length, weighing 120,000 pounds, to a site in the New Orleans area.
The kiln is part of a complete system provided by Finch for use in the remediation of oil-contaminated soil at many oil pit sites owned by a number of major oil companies, Finch says.

Finch designs and fabricates specialized incineration equipment such as rotary kilns and stationary thermal oxidation furnaces.

Write in 760

Fort Transfer adds new equipment to its fleet
Fort Transfer, a hazardous waste transportation company based in Morton, Ill., expands its fleet to 220 units, by adding two power units and 17 trailers.
The company’s fleet and equipment includes tractors, tank trailers, aluminum semi-dumps, steel semi-dumps, vacuum trailers, vans, flat beds and portable scales. Fort says they can now handle every element of a remediation project.
Fort Transfer, established in 1926, also transports agricultural chemicals, anhydrous ammonia and propane.

Write in 758

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August September 1993 Sols 45
Fertech now offers bioremediation

In addition to thermal desorption, Fertech Enviro Systems, Inc., Moberly, Mo., now offers bioremediation services with a new division, Bio-Tech. Fertech says they have all products necessary to implement a full scale bioremediation project, including acclimated microbes, bio-nutrients, bio-enhancer, bio-activator oxygen supplement, soil conditioners and pH adjustment chemicals.\[Write in 746\]

Foxboro’s analyzer has dual detectors, easy portability

The Foxboro Co., East Bridgewater, Mass., introduces the first vapor analyzer featuring simultaneous dual detectors and over-the-shoulder portability, the company says. Using both photoionization and flame ionization technologies, the new TVA 1000 features on-board datalogging and allows users to monitor a wide range of organic and inorganic vapors in the range of 0.1 to 50,000 ppm.\[Write in 745\]

West coast firm donates to wetlands

EnviroSupply & Service, Inc., Fountain Valley, Calif., donates a Hydac pH conductivity and temperature meter to the Bolsa Chica Ecological Reserve, located along Southern California’s Pacific Coast Highway. The Hydac meter, used for water analysis, will help volunteer scientists and researchers measure changes in the pH, temperature and salinity of the wetland’s water.\[Write in 762\]

Patterson’s filter has many uses

Patterson Resources, Industry, Calif., offers the VF-500LP vapor filter, which is designed for installations where pressure drop is the critical design factor influencing GAC absorber selection. Common uses are air stripper retrofits, plant fume exhausting, aerator exhaust treatment and odor control degassing projects. The filters are stackable and bandable together.\[Write in 762\]

Double-wall UST has strength of steel

Total Containment, Exton, Pa., offers a secondary containment system that consists of a UL 58 steel tank with a high density polyethylene outer wall. The outer wall material is dielectric, non-corrosive and compatible with all petroleum products and most chemicals, the company says.\[Write in 747\]

BioCAT™ absorbs hydrocarbons 60 -1

Spill Containment Inc., Houston, Texas, says their BioCAT™ particulate cleaned aged and heavy petroleum contaminated sites from 30,000 ppm of total petroleum hydrocarbons to less than 30 ppm in less than six weeks. The product absorbs at a rate of 60 to 1, the company says.\[Write in 761\]

Test shows if bioremediation is right for a site

Microbe Inotech Laboratories, Inc., St. Louis, Mo., offers the End-point Assay test that demonstrates in 24 hours the ability of individual bacterial strains to break down specific hydrocarbons. This knowledge allows companies to evaluate the potential for bioremediation, the company says. Up to eight bacterial strains are isolated from soil or water samples and placed in a microtiter plate containing the free-phase contaminant from the site. After 24 hours of incubation, the plate is read by an automated, optical plate reader, which determines the degree of growth on the contaminant by each strain or combination of strains.\[Write in 744\]
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• Association for the Environmental Health of Soils
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  Detroit, MI 48243
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• Steel Tank Institute
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  708-438-8265

If your association is not listed here, fax details to the editor, Soils magazine, 816-254-2128.
Mixer allows batch control for solidification of wastes

Solidwaste Technologies, L.P., Beaumont, Texas remediates contaminated sites with solidification treatment. They use a chemical fixation technology to characterize the contamination. The design is laboratory tested for proven fixing results to comply with regulatory standards. The company uses the Maxcrete, manufactured by Maxon Industries, Milwaukee, Wis., to assure proper integration of the materials in the mix and duplicate the lab results in the field.

“According to the EPA, one of the biggest problems with traditional solidification technology to date has been inadequate mixing and blending. My Maxon equipment has eradicated that problem,” Robin Somerville, managing partner of Solidwaste, says.

At a Superfund site contaminated with acidic oily waste sludge and filtercake resulting from the reprocessing of waste lubrication oils, the company used Univichem™, a fixation reagent to solidify the wastes. The portable Maxcrete unit’s eight paddles provide the proper mixing, thorough integration and residency time while allowing precision batching.

Write in 763 for more information

At an EPA Superfund site demonstration at Imperial Oil Co. in Marlboro Township, N.J., soil contaminated with oil, heavy metals, oil sludge and PCBs was treated and mixed with Univichem reagent specifications in a Maxcrete 10 yard mixer. Leachate tests on the solid product passed regulatory limits.

“Remediation Equipment & Service to Support It”

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Write in 408

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of various organic compounds, it is clear that not all contaminants can be
detected with soil vapor assessment
techniques. The compounds of interest
must be sufficiently volatile to enter
the vapor phase in sufficiently high
concentrations to be extracted and
detected, and must have low enough
aqueous solubility so they do not
remain in aqueous solution. Currently,
soil vapor analysis is limited by the
vapor pressure and Henry’s Law
constant (vapor pressure and aqueous
solubility) for the compounds of
interest. Generally, for the process to
be considered reliable, the contaminant
compounds should have a vapor
pressure of at least 1.5 mmHg at 25°C
and a Henry’s Law constant of at least
1 kPa m3 per mole. Figure one, page
23, is a partial list of compounds that
are amenable for soil vapor
assessments. Figure two, page 24,
illustrates the relationships for a
variety of organic compounds.

Since temperatures of subsurface soils
below one meter reflect the mean
groundwater temperature of 65°F or
less, normal low vacuum gas extraction
is generally limited to those
compounds that have standard
condition boiling points of less than
150°F and vapor pressures greater than
0.002 atmospheres.

The capacity to detect organic
compounds by soil vapor techniques
also depends on contaminant volatility.
Soil vapor concentrations are related to
two governing systems: water phase
and non-aqueous product phase.
Raoult’s and Henry’s laws are
commonly used to understand
equilibrium vapor concentrations
governing the volatilization from
liquids. Therefore, the ability to change
the variables in these equations allows
for expansion of the range of
compounds detectable by soil vapor
extraction. The theory of the
interaction between soil temperature
and the role of pressure has not been
fully developed. However, research
and experience have established
without question that elevating
subsurface soil temperature and
reducing local atmospheric pressures
results in a broadened spectrum of
extractable compounds. It has also
been established that the release of
volatile gases from a soil matrix is
influenced by the moisture content of
the soil. Gases adsorb more strongly to
dry soil particles, and conversely,
desorb to a greater extent from moist
particle surfaces.

Experience with in situ vacuum
extraction shows that moist soils are
dried by the vacuum extraction
process. Some decrease in the release
of volatile organic compounds results
due to enhanced adsorption on soil
particle surfaces due to drying as
extraction progresses. This restriction
can be reversed or avoided by
maintaining adequate soil moisture
during the process. By applying heat to
the subsoil conditions, ensuring that
drying of the soil matrices does not
occur, and reducing the ambient
pressure in the zone of extraction,
compounds with boiling points of up to
400°F and 0.007 atmospheres vapor
pressure may be suitable for soil vapor
analysis.

Lowering the interstitial soil vapor
pressure can be effective to induce
volatilization. By extraction with
induced vacuum, the partial pressure of
most heavier, non-volatile
hydrocarbons at standard temperature
and pressure conditions increases to
facilitate volatilization.

The concept of inserting probes into
the soil to extract and analyze earth
gases was first reported as early as
1853. In the early 1900s, it was used to
explore for natural gas and crude oil. It
was not until 1975 that the technique
was first applied as a means to detect
and trace contaminants.

The problem with augering a
borehole is that the augering process
alters soil gas composition and causes
loss of many gases of interest. The
procedure requires several days for the
disturbance to equilibrate, which raises
questions about the variability of
gaseous movements through the
undisturbed soil. Also, due to the
absence of a reliable seal between the
sampling point or probe shaft and the
atmosphere, the dilution of the gaseous
samples causes false negatives and
unreliable relative concentration
results.

To correct these deficiencies,
mechanically inserted probes with
sacrificial penetration tips or perforated
well points to the desired depth were
developed. The principal limitation of
the perforated well point method is the
blinding of the sample ports with soil
during the insertion process. This led
to the development of closed well
points which were opened
mechanically by extracting the
insertion casing after reaching their
desired depth. However, it is not
uncommon for compression pressures
of the insertion process to make the
well point difficult or impossible to
open.

The principal limitation of this
process is the relatively high volume of
gas inside the probe that needs to be
extracted to get a representative
sample. Also, dilution of the sample
becomes a problem when the volume
of gas within the probe is relatively
large. The rigors of the insertion
process requires probe shafts to be
relatively heavy, which limits the
freedom to physically downsize the
casing shafts. So, well points were
revised to allow for the attachment of
laboratory tubing between the well
point and the surface where the sample
is withdrawn. The benefit of this
development is that a smaller sample
volume is necessary to purge the
system, and consequently a sample
more representative of the interstitial
gases is obtained at the surface.

One method to vertically profile a
contamination plume is to drive
multiple probes at various depths for
sampling and analysis. This process is
economical, and can be cumbersome in
some field operations. The most
practical application of this technique
is the stepped insertion or withdrawal
of the well point sampler, and
sampling, extracting and analyzing the
soil vapors at predetermined intervals.
The Steam Probe system overcomes
many limitations of previous soil vapor
assessment techniques. It broadens the
range of detectable compounds and
allows for economical and rapid
assessment and plotting of the
contaminant plume.

Write in 748 for more information
Oxidizers destroy VOCs and off gases


Designed to achieve destruction efficiencies of at least 99 percent, Remedial Systems' catalytic and thermal incinerators are supplied skid-mounted or trailer mounted for ease of installation and startup, the company says.

Rental and lease programs are available.

write in 765

9th IEA show to be held in San Diego

The 9th Annual IEA Industrial Environmental Conference & Exposition will be held at the San Diego Convention Center on September 27-29, 1993.

Call Jack Flynn, conference coordinator at 619-295-3461 for more information on attending, speaking or exhibiting.

write in 766

Jordan announces upgrade to software

Jordan Systems, Cedar Rapids, Iowa, offers an upgrade to Hazardous Material Manager™, a PC-based environmental data management software system.

Introduced to the industry in 1987, the system tracks hazmat usage and waste, reports spills, records employee training and community right-to-know efforts and creates annual SARA Title III and state-specific reports.

Write in 766

Rugged computer retrieves data

Isco, Lincoln, Neb., introduces the handheld 583 Field Computer designed to retrieve data from Isco 3700 Series Samplers, 3200 Series Flow Meters and PAL 1110 Parameter Actuator/Logger in harsh environments. Data can be transferred to a PC for analysis.

Write in 767

Software directory is central source of useful information

Donley Technology, Garrisonville, Virg., offers the Environmental Software Directory, designed to help professionals find software packages, databases and online systems to meet their needs.

The directory is the only comprehensive reference book on government and commercial software for environmental professionals, Donley says.

The 1992/93 edition was recently released, featuring descriptions of nearly 1,000 systems. Information in the directory is current up to January 1, 1993. The number of systems listed has nearly doubled since the 1990/91 edition was published two years ago.

The new directory has 446 pages and is organized into chapters. The cost is $75 with a $15 shipping cost outside the U.S. For further information contact, Donley Technology, Box 335, Garrisonville, VA 22463. 703-659-1954.

Write in 764

Liner system protects bulk storage facility

One of the largest petroleum storage and handling facilities in Michigan installed secondary containment barriers, manufactured by MPC Containment Systems, Ltd., Chicago, Ill. Because of the size of the installation, as well as its proximity to a major river, Lake Michigan and several housing developments, facility managers called on MPC because they needed an installation that would not interfere with ongoing operations.

MPC uses PetroGard®, a flexible geomembrane liner originally developed to U.S. military specifications for pillow tanks. The liner was placed on the floor of the complex and offered secondary containment, improved corrosion protection and leak detection for the aboveground tanks, plus more efficient spill containment at berms and dikes.

Extensive pre-planning with computer drawings enabled MPC to cut and roll each section for shipment. “The pre-engineered sections reduce the number of welds we have to make in the field,” Ron MacKenzie, project manager, says.

Write in 764

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New AMS Equipment Catalog

The complete line of AMS soil and groundwater sampling equipment is showcased in the company's new 28 page catalog. The catalog includes AMS's latest innovative entries into the sampling technology field and includes some recently patented items for both soil and groundwater sampling. Designed to be your primary source for sampling equipment for the coming years, the AMS catalog will in itself become a valuable tool in your business. To order your FREE copy, call TOLL FREE, 1-800-635-7330

Write in 400

Clements Associates, Inc.

Clements Associates Inc. manufactures a complete line of hand-operated soil sampling equipment. Their free, full color, 24 page catalog describes several probe handles, bucket augers, and sampling tubes with removable liners. It spotlights a probe that uses a sliding drop-hammer to drive a 36 inch long sampling tube into the ground and a foot-operated jack to retrieve it. With their equipment, samples as small as 0.0 inches in diameter up to 3 inches in diameter from 10 feet or more below ground level may be obtained. Equipment is sold as complete kits or individual parts. Clements Associates Inc., R.R. #1 Box 186, Newton, Iowa 50208, Phone: 515-792-8285 or 800-247-6630.

Write in 376

Here's how an Arizona community comports tons of trash and sludge daily

After months of investigating costly alternatives to disposal of trash and wastewater sludge disposal, this community used available technology and simple economics to develop its own revolutionary method, a sludge and solid waste co-composting facility. Forty-seven minute video.

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Treat hydrocarbon contaminated soil by incorporating it in cold mix and hot mix asphalt...it works!

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